ATACAMA LARGE MILLIMETER ARRAY

BIANNUAL PROGRESS REPORT

31 March 2003

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EXECUTIVE SUMMARY

General

The Bilateral Agreement between ESO and the US National Science Foundation for the construction and operation of ALMA was signed in February 2003. The first formal meeting of the ALMA Board took place at the same time. The ALMA Board offered the position of ALMA Director to Massimo Tarenghi. Massimo accepted and becomes ALMA Director as of April 2003.

Significant Activities of the Project, by Integrated Product Teams (IPT)

- The Management IPT received approval of the Project Plan by the ALMA Board
  - completed a preferred production antenna procurement strategy
  - constructed a schedule of tasks required to obtain site access by May 03
  - finished a draft ALMA Safety Plan
  - drafted a Site Use Agreement that would govern the conditions under which other projects could be located on the ALMA site
  - continued to support the ALMA Board Japan Negotiating Team with a technical and cost evaluation of the Japanese proposal to join ALMA
- The Site IPT completed the definition of the site requirements and placed the first contracts for design of site facilities
- The Site, Antenna, and System Engineering IPTs jointly constructed an interface control document for a universal antenna pad
- The VertexRSI prototype antenna is close to acceptance from the contractor, and parts for the AEC prototype antenna have arrived at the Antenna Test Facility
- The Front End IPT made significant progress on defining ICDs, the Front End production plan, and the plan for the Front End Integration Centers
- Two important specifications for the Cryostat were achieved, and progress was made on the development of other key Front End components
- Definition of the Local Oscillator was organized as a joint group between the Front End and Back End IPTs
- The Correlator IPT made good progress on the two-antenna prototype Correlator and studied the options for enhancing the baseline correlator
- The Computing IPT held a successful Preliminary Design Review
- The System Engineering and Integration IPT made progress defining and organizing their activity, and updated the overall system diagram
- The Science IPT reported completion of all but the most extended ALMA array configurations and made a major effort in the area of calibration

1. INTRODUCTION

The Atacama Large Millimeter Array (ALMA) is a revolutionary instrument in its scientific concept, in its engineering design, and in its organization as a global scientific endeavor. ALMA will provide scientists with precise images of galaxies in formation, seen as they were twelve billion years ago; it will reveal the chemical composition of heretofore unknown stars and planets still in their formative process; and it will provide an accurate census of the size and motion of the icy fragments left over from the formation of our own solar system that are now orbiting beyond the planet Neptune. These science objectives, and many more, are made possible owing to the design concept of ALMA that combines the clarity of detail in images provided by a 64-antenna interferometric array together with the brightness sensitivity of a fully filled aperture.

The challenges of engineering the unique ALMA telescope begin with the need for the telescope to operate in the thin, dry air found only at elevations high in the Earth's atmosphere where the radiation at millimeter and submillimeter wavelengths from cosmic sources penetrates to the ground. ALMA will be sited in the Altiplano of northern Chile at an elevation of 5000 meters (16,500 feet) above sea level. The ALMA site is the highest, permanent, astronomical observing site in the world. On this remote site superconducting receivers, cryogenically cooled to less than 4 degrees above absolute zero, will operate on each of the 64 12-meter diameter ALMA antennas. The signals from these receivers will be digitized and transmitted to a central processing facility where they will be combined and processed at a sustained rate greater than 10^{16} operations per second. As an engineering project, ALMA is a collection of 64 precisely-tuned mechanical structures each weighing more than 80 tons, cryogenically cooled superconducting electronics, and optical transmission of data at terabit rates - all operating together, continuously, on a site very high in the Andes mountains.

A tabular summary of the technical description of ALMA as derived from the ALMA scientific requirements is presented in the Table 1-1.

Table 1-1. ALMA Technical Summary

Array	
Number of Antennas (N)	64
Total Collecting Area ($\pi/4$ ND^2)	7238 m^2
Total Collecting Length (ND)	768 m
Angular Resolution	0".2 lambda (mm)/baseline (km)
Array Configurations	*{dimension of filled area}*
Compact: Filled	150 m
Continuous Zoom	200-5000 m
Highest Resolution	14 km
Total Number of Antenna Stations	250
Antennas	
Diameter (D)	12 m
Surface Accuracy	25 micrometers rms
Pointing	0".6 RSS in 9 m/s wind

Path Length Error	< 15 microns during sidereal track
Fast Switch	1.5 degrees in 1.5 seconds
Total Power	Instrumented and gain stabilized
Transportable	By vehicle with rubber tires

Front Ends	*{All frequency bands}*
84 - 116 GHz SIS	*-Dual polarization*
211 - 275 GHz SIS	*-Noise performance limited*
275 - 370 GHz SIS	*by atmosphere*
602 - 720 GHz SIS	
Water Vapor Radiometer	183 GHz
Intermediate Frequency (IF)	
Bandwidth	8 GHz, each polarization
IF Transmission	Digital
Correlator	
Correlated baselines	2016 (=64x63/2)
Bandwidth	16 GHz per antenna
Spectral Channels	4096 per IF
Data Rate	
Data Transmission from Antennas	120 Gb/s per antenna, continuous
Signal Processing at the Correlator	1.6 x 10^{16} multiply/add persecond

1.1 Financial Status

The following chart and figure, taken from the ALMA Project Plan, show the total projected European construction expenditures for 2002-2012.

European 2002 Contributions

The European ALMA Project expenditures for calendar year 2002 are given in Table 1-2, broken down according to level one of the ALMA WBS. The expenditures have been converted to Year 2000 US$ for comparison with the ALMA Project Plan.

Table 1-2. European ALMA Expenditures in 2002 (all values in 2000 US$)

WBS	2002 Expenditures
1 Management	616,385
2 Site Development	629,146
3 Antenna Subsystem	2,730,067
4 Front End Subsystem	2,431,739
5 Back End Subsystem	817,152
6 Correlator	348,601
7 Computing Subsystem	1,649,444
8 System Eng. & Integration	692,828
9 Science	388,127
Total	10,303,489

These expenditures include the in-kind contributions (see Table 1-3) from organizations other than ESO.

2002 was the final year of ALMA Phase 1 work in Europe. One element of the 2002 expenditures was clearly Phase 2 work - the European contribution to the Joint ALMA Office (JAO). European expenditures for the JAO in June - December 2002, included the compensation of the Interim ALMA Project Manager and Project Scientist, plus secretarial support. The total cost, included in WBS 1 in Table 1-2, is $ 258,939. Credit as Phase 2 value has been requested for this 2002 contribution to the JAO.

The balance of European 2002 expenditures after subtraction of the JAO contribution is 10,044,550 in 2000 US$, or 10,703,332 in 2002 €. When combined with the European Phase 1 contribution for 1999 - 2001, this brings the total European Phase 1 contribution to € 32,966,534. This matches the North American Phase 1 contribution of $ 32,000,000 over the period of 1998 - 2001.

Table 1-3 shows the breakdown of the European Phase 1 contribution for 2002 by organization and by in-kind and in-cash portions. This is essentially equal to the preliminary projection of 45.2 staff-yr + 198 k€ in-kind plus 6,257 k€ in-cash contained in Annex 6 of the Memorandum of Understanding between the NSF and European Organizations.

Table 1-3. European Phase 1 Contribution in 2002 (all values in 2002 k€)

	Actual In-kind Contribution	Actual In-cash Contribution
ESO	19.3 staff-yr	5,703 k€
PPARC	78 k€	
CNRS	8.2 staff-yr	
MPG	5.3 staff-yr + 60 k€	
NOVA/NFRA	6.5 staff-yr + 60 k€	

VR	3.8 staff-yr	
MCyT/IGN	1.4 staff-yr	582 k€
Total	45.3 staff-yr + 198 k€	6,285 k€

Status of the Phase 1 Common Fund

The European MoU governing Phase 1 of ALMA states that the in-cash resources contributed by the signatories in Phase 1 shall be administered by ESO. ESO established within its financial structure a "Common Fund" to consist of the Phase 1 in-cash resources. The total in-cash contributions for Phase 1, when the 2002 contributions shown in Table 1-3 are taken into account, are given in Table 1-4. All of these in-cash contributions have been received.

Table 1-4. Phase 1 In-cash Contributions (Common Fund)

Organization	In-cash Contribution (€)
ESO	9,743,000
PPARC (UK)	300,000
CNRS (F)	871,000
MPG (D)	1,023,000
VR (S)	511,000
MCyT/IGN (E)	1,302,000
Total	13,750,000

Of this total, € 13,688,225 has been committed and € 8,620,289 has been expended. The balance of about € 5 million consists of commitments for the European prototype antenna that have yet to be paid.

European 2003 Budget

Table 1-5 gives the 2003 European budget in terms of the ALMA level one WBS elements and the ESO Work Packages.

Table 1-5. European ALMA Budget for 2003

ALMA WBS	2003 kŪ
1. Management	
Joint ALMA Office	270
European Project Office	250
Chile Office	308
2. Site Development	2,125
3. Antenna	3,415
Transporter	68
4. Front End	2,034
5. Back End	1,540
6. Correlator	
7. Computing	2,190
8. Sys Engr & Intg	395
Antenna Evaluation	723
9. Science	433
Site Characterization	182
Total	13,933

1.2 Schedule

Level 1 milestones, which are controlled by the ALMA Board, are shown in Table 1-6. Schedule status with respect to lower level milestones is discussed in each of the technical Integrated Product Team (IPT) reports in Section 2.

Table 1-6. ALMA Project Level 1 Milestones

Milestone	Date
Start Antenna Evaluation at ALMA Test Facility	Q4 2002
Begin Initial Phase of Civil Works in Chile	Q4 2003
Central Back End Subsystem Ready to Install at Array Site	Q1 2005
Initial Phase of Civil Works in Chile Complete	Q2 2005
1st Antenna-based Back End Subsystem Ready at OSF	Q2 2005
1st Production Antenna Available in Chile at OSF	Q4 2005
Initial Front End Subsystem Available at OSF	Q4 2005
Start Early Science Operations	Q3 2007
Completion of Construction Project	Q4 2011
Start Full Science Operations	Q1 2012

2. STATUS OF THE ALMA PROJECT

2.1 Management

2.1.1 Joint ALMA Office (JAO)

Project Management and Organization

The Management IPT continued to hold weekly teleconferences during this period, with all IPT Leads and Deputy Leads joining the Management IPT in a separate teleconference every other week. Planning has begun for "ALMA Week", scheduled for early June in Victoria, Canada. This is a meeting where key personnel from the entire Project meet face to face to review the status of the project.

The Project Plan was approved by the ALMA Board at their February 24-25, 2003 meeting in Washington DC. It has been labeled Version 1, posted to the ALMA Electronic Document Manager (ALMAEDM), and is under configuration control.

The Joint ALMA Safety Committee developed a draft ALMA Safety Plan to be presented to the ALMA Management Advisory Committee in March. Following any further development which may be required, the Plan will be sent by the JAO to the ALMA Board for approval.

A joint public relations team consisting of R. West and C. Madsen from ESO, and L. Shapiro, C. Blue, and D. Finley from NRAO has met regularly by teleconference to construct an ALMA Public Relations Plan. The National Radio Astronomy Observatory (NRAO) is the lead for a new ALMA brochure and drafting the plan for the ALMA web site, and the European Southern Observatory (ESO) is the lead for a new ALMA video and drafting the overall Public Relations Plan. Both teams are working to generate candidates for an ALMA logo. The group is chaired by C. Madsen.

Chile Issues

Agreement has been reached on the funds expected annually for the total of the rent for the land, the development of astronomy in Chile (Comision Nacional de Investigacion Cientifica Y Tecnologica - CONICYT), and support of cultural/educational activities in the local communities (Region II). The procedure whereby ESO obtains permission to open another observing site remains to be concluded. A schedule of activities which are required to be completed if the Project is to have access to the site by 1 May 2003 was constructed. At the time this report was written, all activities were on schedule. The Environmental Impact Statement was approved on 13 March 2003.

Two offers of land for the ALMA Central Offices have been made, orally, at the last meeting of the ALMA Coordinating Committee. The first was made by L. Bronfman, U. Chile, who offered land on Cerro Calan at no charge for a period of fifty years. The second was made by C. Cesarsky, Director General of ESO, who offered land at the site of ESO – Vitacura. The JAO reported to the ALMA Board at their February 24-25 meeting in Washington DC on the options for locating the ALMA Central Offices: accept one of the above offers, buy land elsewhere and build, buy or lease space elsewhere in an already developed office building/complex. Comparative costs were presented.

When the Executives obtained exploratory mining rights for the land needed for the access road, it was discovered that a mining firm had underlying claims for a portion of the route. Geological surface studies done by the firm at ALMA's expense demonstrate that it is highly unlikely economically recoverable copper lies under the surface. The mining firm would like to make test soil borings before giving up their claims in favor of ALMA, these borings to be ALMA's expense. We have refused, based the opinion of our geologist, one of the most distinguished in Chile, that there is little or no likelihood that copper is present. We expect the mining company may make a boring or two on its own in the near future and abandon the claims rather than continue the expense of maintaining them.

There have been no further developments on this matter during this period.

Interactions with the National Astronomical Observatory of Japan (NAOJ)

The ALMA Board met with representatives of the NAOJ, via video link, at their meeting of February 24-25 in Washington DC. It was decided that the JAO would continue to support the Board Japan Negotiating Team in technical and programmatic areas prior to meetings between the Negotiating Team and its Japanese counterpart. One of these preparatory meetings between the JAO and NAOJ is scheduled for late March.

2.1.2 European Project Office

The ALMA Division was formally established at ESO at the beginning of 2003. The division personnel include the European Project Manager, European Project Scientist, European Project Engineer, the European Subsystem Managers at ESO (site development, antenna, front end, computing, and system engineering), plus eight other ESO personnel working exclusively on ALMA. The balance of the total of 30 full time equivalents (FTEs) working on ALMA at ESO is drawn from the Technical and the Data Management Divisions. Tony Neves accepted the position of future European Project Manager and started at ESO on 3 February. Tony will become European Project Manager in mid-2003 with the retirement of R. Kurz. Recruitment of the permanent European Project Scientist should also be completed by mid-2003. The deadline for applications was 1 March and selection will proceed straightaway.

Negotiations with the European organizations that proposed to perform Phase 2 work packages were not completed by 1 March as planned and continued throughout the reporting period. The scope of work for most of the development work packages has been expanded beyond a single prototype unit to include delivery of the items required for eight pre-production units. The goal is now to complete these negotiations in time for approval by the ESO Finance Committee at their next meeting in May 2003. Contracts should be awarded immediately following Finance Committee approval.

The European ALMA Board (EAB) met in Garching on 20 February in advance of the ALMA Board meeting at NSF on 24-25 February. EAB membership for 2003 was finalized and members of the European Scientific Advisory Committee (ESAC) designated. As shown below all ESO member states plus Spain are represented. The members of the EAB and ESAC are:

EAB		ESAC
• C. Waelkens	Belgium	C. Waelkens
• H. Jorgensen	Denmark	P. Naselsky
• L. Vigroux	France	P. Cox
• T. Henning	Germany	P. Schilke
• G. Tofani	Italy	L. Testi
• E. van Dishoeck	Netherlands	E. van Dishoeck, Chair
• T. Lago	Portugal	J. Yun
• R. Booth	Sweden	S. Aalto-Bergman
• S. Lilly	Switzerland	A. Benz
• R. Wade, Chair	United Kingdom	J. Richer
• J.Cernicharo	Spain	R. Bachiller
• P. van der Kruit - President of Council		R. Hills – ESO Science &
• C. Cesarsky - Director General		Technology Committee -
• M. Steinacher - Finance Committee Chair		STC Liaison

The ESAC will select five of its members as the European members of the ALMA Science Advisory Committee (ASAC).

The production antenna procurement strategy proposed by the JAO - a competitive process in late 2003, with evaluation early in 2004 and contracts placed later in 2004 for a single design - was strongly supported by the EAB.

2.1.3 North American Project Office

Development activities for the Local Oscillator (LO) system have been reorganized. Portions of the LO system are the responsibility of both the Front End and Back End IPTs. In order to facilitate close interaction during the critical design and prototyping phase, LO development activities from both IPTs have been combined and will be coordinated by John Payne from the Systems Engineering and Integration (SE&I) IPT. Following development and prototyping, production of the resulting LO subsystems will revert to the existing IPT structure.

To facilitate the management of contracts and other business activities in Chile that are the responsibility of North America, NRAO is recruiting a Business Manager for Santiago. He will report to Bill Porter, the ALMA Business Manager.

The NRAO and NAOJ have signed an agreement to support the testing of the Mitsubishi prototype 12m antenna at the Antenna Test Facility (ATF) at the site of the Very Large Array. The agreement provides the legal framework for the antenna to be erected at the NRAO facility and for reimbursement of expenses incurred by NRAO for this activity. All work in support of the testing program of the Japanese prototype antenna is on a best effort basis and will be scheduled to not interfere with erection and evaluation of the two baseline ALMA prototype antennas.

The president signed the FY2003 budget passed by Congress. Based on that budget, ALMA will receive a total of $29.805M for the fiscal year. This is $195k less than the expected $30M. ALMA project planning can incorporate this change without impact providing the appropriately inflation adjusted amount is added to the budget allocation in FY2004 or FY2005. This assumes that the base allocations, before the addition of these funds, match the expected ALMA funding profile for those fiscal years. Current NRAO staffing for the ALMA project is 91.5 FTE, distributed as follows:

IPT	FTEs
1 Man/Admin	5.5
2 Site	0.4
3 Antenna	5.7
4 Front End	33.2
5 Back End	10.5
6 Correlator	5.1
7 Computing	12.1
8 System	16.1
9 Science	2.9

2.2 Site IPT

2.2.1 Main Activities

An analysis of approximately 1,100 individual replies to site requirements questionnaires together with the presentations of the various IPTs at the Design and Engineering Requirement Review was completed in December 2002, and the complete documentation including questionnaires, replies, and presentations of the individual IPT's has been placed in the ALMAEDM system on 4 January 2003. Some safety related comments were received later and shall be incorporated into the document soon.

The final Level-2 Milestones were established on 24 January 2003 (70 milestones).

M3 Engineering was contracted to provide architectural programming services for the Array Operations Site (AOS) buildings, an overall master plan, a study of options for cooling the correlator, and a preliminary antenna station interconnections and road layout. Contract extension for the preparation of schematic design and design development documentation is in progress.

A total of five architectural program versions for the technical building and the hangar at the AOS have been presented by M3 and have been reviewed by the site IPT team in consultation with the other IPT's involved. Version 5 (E) was approved by the JAO on 3 March 2003. The technical buildings at the AOS have changed size from a net constructed surface of 1,062 m² (version 1) to 600 m² (version 5). The initial drafts of the master plan, of the AOS road layout, and of the correlator cooling study have also been presented by M3.

Milestone 8208 Final Approval of architectural program for all AOS Buildings (1 February 2003): The program was approved by the JAO on 3 March 2003. M3 Engineering are now producing schematic (conceptual) design and design development documentation. The Critical Design Review (CDR) is scheduled to be on 1 April 2003. Because of the delay in the approval of the above referenced programming this date may be slightly delayed.

Milestone 8213 Freeze Joint Antenna Station interface (15 February 2003): The first submittal of this interface was on 7 March 2003. The CDR for the antenna stations, scheduled for 1 March 2003 will therefore no longer be possible. Site Development will prepare a plan that constructs antenna pads on a schedule that meets the milestone for First Science.

Milestone 8216 Freeze Center Cluster Configuration (1 March 2003): The configuration specification prepared by the Science IPT (ALMA-90.20.00.00-001-D-SPE) awaits approval by management and systems. Milestone 8224, Construction/tender documents for the foundations central cluster, may therefore be delayed. The tender documents for the geotechnical studies for the center cluster of antenna foundations (down and cross-hole investigations) are being prepared by M3.

Milestone 8300 Contract for the Design/Engineering of the Access Road to the OSF and AOS: The tender documents for the design, Engineering and preparation of construction documentation for the ALMA access road from the intersection of the road from San Pedro de Atacama to Toconao (C23) to the Operation Support Facility (OSF) and from the OSF to the to the AOS were sent out by ESO (Santiago) to local Chilean contractors on 4 December 2002 Tender closing was on 23 January 2003. This contract is in the process of award.

Milestone 8290 Tender/Construction documents complete for the establishment of a construction access to the OSF and the AOS: The tender/construction documents were completed on 26 February 2003. Scheduled completion was on 15 February 2003. Release to the bidders is in process. The contract is scheduled to be signed on 1 April 2003. This date will be slightly delayed, but will not impact on the Work completion scheduled to be on 30 September 2003. The work can only be started if the land is available on time. A start later than 1 May 2003 will most likely have an impact on the completion date.

The OSF area has been defined: The facilities will include the Technical Area with the Antenna Assembly Hall, the Technical Building laboratories, operations and software), the Warehouse and Workshop Building, the Administration-Logistics-Operations-Management Building, the Gate House, Open Storage Facilities, and the site preparation; The Residence Area with the Residence Building, recreational and logistical facilities, and the Visitors Center; the temporary ALMA Camp (for ALMA staff); and the Contractor's Camp and working areas.

The tender documents for the Design/Engineering of the Technical Area Facilities have been completed on 17 February 2003. The tender action for this Work is now in progress. Contract award is scheduled to be on 10 May 2003.

The design/engineering of the temporary ALMA Camp and the Contractor's Camp has been contracted to Puebla Architects and the completion of the construction drawings is in process. The tender documents for construction of the Camps are currently being prepared. Contract signature is scheduled to occur on 1 May 2003.

The extended power study including aspects pertaining to the entire project and particular the feasibility of the connection of the power station to the local gas pipe line in San Pedro de Atacama is under way. Scheduled submittal of the study by Fichtner Engineers is 31 March 2003.

Construction of the benchmarks and reference points at the AOS has been completed.

2.2.2 Concerns

- Acquiring access to the site on 1 April 2003.
- Time required to incorporate Japanese requirements into the current design/engineering process, should Japan join the Project.
- Approval of the final Central Configuration (was scheduled to be on 1 March 2003).

2.2.3 Milestones for Next Period

8213 Freeze Joint Antenna Station Interface.
8216 Freeze Center Cluster configuration.
8222 CDR for the Central Cluster antenna stations.
8250 CDR for the building foundations and envelope at the AOS .
8224 Tender/construction documents complete for Central Cluster; geotechnical studies complete for the Central Cluster antenna stations.
8306 Completion of the tender/construction documents for the access road.
8292 Award contract for the establishment of a construction traffic road; construction traffic road open to OSF.
8293 Construction traffic road open to AOS;
Tender opening for the design/engineering of the OSF Technical Facilities.
8340 Award contract for the design/engineering of the OSF Technical Facilities.
8324 Award contract for the construction of the ALMA Camp and the Contractor's Camp; tendering, contracting, and implementation of the ALMA permanent power supply.

Intermediate Design Reviews.

Completion and approval of the document "Conditions, Rules and Regulations applicable to Contractors executing ALMA Contracts on the ALMA Observatory located near the villages of San Pedro de Atacama and Toconao, II Region, Chile, South America".

2.3 Antenna IPT

The Antenna IPT continues to be focused on working with the Contractors to deliver the antennas as soon as possible to minimize delays to the project. This continues to be a significant challenge since the current antenna schedules have very little margin and have already been delayed for several reasons. Other significant, time-critical tasks, as described below, are being pursued in parallel, but at a lower priority. Progress is being made in all areas.

2.3.1 Alcatel/EIE (AEC) Prototype Antenna

The antenna mount was shipped from Genoa shortly before Christmas and arrived on site the 12th of February. No delay was encountered in customs, even though duty-free import status has not yet been granted by the US Customs. (ESO and Associated Universities, Inc. are working on the matter).

In Italy work continued at the Oggiono factory on the carbon fiber reinforced plastic (CFRP) backup structure (BUS) and on the cabin. A setback was encountered at the beginning of the year when the last two slices of the BUS to be delivered were found damaged, due to a road accident, and an handling accident with the cabin caused minor damage to the cabin and severe damage to a third BUS slice. These two events generated around three weeks delay in the manufacturing of both subsystems, which are now close to completion.

At the beginning of February, the Metrology final design review was held. The antenna is well within specifications with proposed metrology system. The metrology system is now in production and in procurement (lasers, inclinometer, etc.). As part of the metrology analysis, the AEC consortium contracted for new wind analyses by an external research institute. Their analysis leads to lower pressure fields than previously anticipated. This issue is under review because it may lead to a simplification of the metrology system.

A review to examine aspects of the Rhodium coating was held at the panel manufacturer in February. No technical issue remains open and the coating is in process. Thermal tests are also being performed to validate the combined thermal behavior of BUS, panel adjusters, and panels.

The start of the work on site has suffered considerable delay (6 weeks) due to the inability of the AEC consortium to provide a temporary shelter for the assembly. This issue seems now to have been solved and work is starting (week 12) to erect the shelter and assembly of the base and yoke, just prior to the AMAC meeting.

The schedule has slipped due to the completion of the CFRP BUS and Cabin and the start of the assembly on site.

Mount steel structure: The antenna steel structure boxes are being opened this week in order to have the base and the yoke mounted on the 24th of March. The assembly includes the base, the azimuth bearing, the yoke, and the yoke arms up to the elevation axis boxes. In addition, various parts and subsystems, like azimuth cables wrap, azimuth direct drive (magnets), azimuth brake rings are already mounted and aligned in the system. The issue of the azimuth bearing stiffness, still inferior to the design despite the past intervention of the manufacturer to exchange the rollers, is being tackled by AEC, who is planning to manufacture at least one additional set of rollers to be exchanged on site (without dismounting the bearing). The azimuth axis boxes are still in Europe where they will be fully integrated with bearings, trunnions, etc. before shipment.

Cabin: The cabin suffered delay due to the accident and due to the slow pace of machining. In particular, it was found that the machining of the various steel appurtenances (flanges to the BUS, elevation motor support flanges, etc.) needed to be performed at lower speed than anticipated in order to keep the temperature safely low with respect to the glue used in the system. Now the cabin (see Figure 1) is undergoing painting, internal furnishing, mounting, and alignment with the elevation axis system.

Figure 1. The cabin during painting (primer)

BUS: The BUS assembly is approaching completion. There are now 15 out of 16 sectors glued and the closure of the BUS is expected to occur this week. This represents approximately 5 weeks delay with respect to what was anticipated in December, and is due to the above mentioned accident and to the fact that the work of joining the segments had to be done fully sequentially, not in parllel as originally envisaged. A one-day thermal curing of the glued joints is planned immediately after assembly, with a subsequent laser tracker check. Afterwards the lower flanges, which attach to the cabin, will be mounted on the same tool aligned and used for the corresponding flanges of the cabin. The next activity will be the preparation of the interfaces to the panels, painting, disassembly, and the packing in two halves. Shipment is planned for end of April.

The BUS, shown below in Figure 2, remains on the critical path. Most operations coupled with schedule uncertainty are basically finished. The only remaining “delicate” activity is linked to the handling of the BUS as a single entity and to the preparation for shipment, which demands special turning jigs. The jigs are being made at the Galbiati factory (owner of the assembly hall).

Figure 2. Status of the BUS as per 15.03.03. One slice (15) to be inserted

Panels and adjusters: All panels are now produced and dimensionally controlled. The decision by AEC to coat the panel with Rhodium has been successfully reviewed by ESO. The coating process has been finalised, including the sealing of the honeycomb structure. The tooling and the Rhodium solution for the deposition were procured in January, and Rhodium coating is now performed routinely. All panels, including spares will have been coated by the end of this quarter.   Panels are illustrated in Figure 3.

The panel packing is now been decided. The panels will be shipped in various batchs for integration on site. Provisions were made for safe air transport by including a degassing valve at the back of the panel.

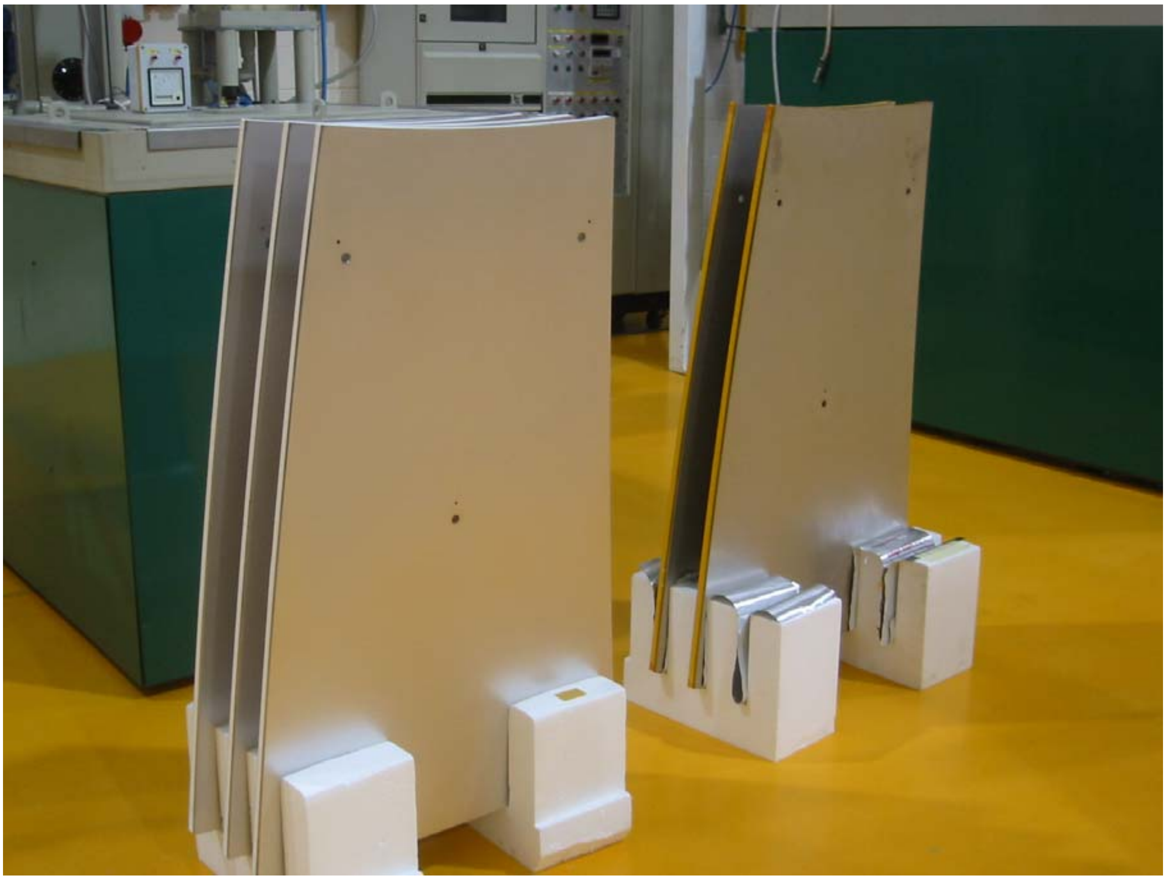

Figure 3. The difference appearance of Nickel panel prior (right) and after Rhodium coating (left).

A review of updates to the panel adjuster design was conducted without any major finding. The production is ongoing. Individual qualification tests are being completed in parallel. In additions thermal tests in a climatic chamber with a BUS sector (one of the three damaged), final panel adjusters, and one panel is being performed to validate individual elements of the error budget.

Antenna Control Unit (ACU) and Software: This area is making good progress. Coding is nearly completed and a preliminary test is now planned to take place with ESO before the end of the month. Immediately after that, the coding of the metrology software will start. The ACU is expected to be ready for shipment in mid-May.

Other assemblies: Most equipment is ready to be shipped or in the process of being accepted for shipment. The remaining items are, however, considered sub-critical, namely, the subreflector mechanism being presently assembled, the apex legs (in manufacturing) and the apex itself whose manufacturing just started, and which is planned to be accepted at end of April. It is important to note that most equipment which is needed for the short term activity on site is either ready, or shipped, or ready to be shipped.

The overall schedule of the antenna has seriously shifted. The antenna is now expected to be fully assembled with panels on the 24 June 2003, preliminary acceptance on the 9 July 2003, and the provisional acceptance on the 28 July 2003. This is largely due to the delays in Europe, but certainly the late start at the ATF (the missing shelter, now being resolved) does not reduce the schedule risk for the coming activities. AEC has been asked for a recovery plan, but it remains to be seen how much they will be able to improve the schedule compared to the dates above. The consortium has been informed in writing of the consequences of such delay including their reduced chances to participate in the next phase of the project.

The as-built documentation is due for delivery on the 18 April 2003. It is not clear at this poiint when and how the documentation will be delivered, as AEC is busy with the the assembly and manufacturing activities. Steps have been undertaken to force AEC to put the necessary resources on this matter.

2.3.2 VertexRSI Antenna

The VertexRSI prototype antenna will be delivered to the ALMA project on 20 March 2003 with only a minor punch list of remaining items to resolve. The antenna is in a very useable condition for the testing activity planned by the Antenna Evaluation Group (AEG). In early April the contractor will return to complete the punch list items.

The main punch list item is drive motor ripple, causing the servo system to perform slightly out of specification. VertexRSI, the motor manufacture, and the amplifier manufacture have investigated this problem and have tracked it down to the amplifier current sensing circuit. Large amplifiers had to be used for the fast switching modes. During sidereal tracking at low velocities the amplifiers are not always able to correctly sense the current fluctuations and un-sensed current pulses are the cause of the motor ripple. In early April, the amplifiers will be replaced and the servo acceptance testing will be repeated to verify the antenna performance.

In late March the Contractor control systems group visited the site for ten days to resolve several punch list items and conduct acceptance testing of the pointing computer and ALMA Bus Master (ABM). The main major outstanding issue is the 150-μsec response time of the ACU. The Contractor is working to resolve this issue by the end of April. This will not limit the activity of the AEG in this time period. A host of small problems have been identified and are being resolved during the routine weekly testing program. This is the ongoing process of early testing of the interface and operation of the system with the intent to minimize problems during acceptance testing by both parties.

Minor problem have occurred on the heat/ventilation/air-conditioning system related to the controls. The Contractor has resolved these problems. This system is currently running and operational.

The assembled Vertex antenna is shown in Figure 4 on the following page.

Figure 4. The assembled VertexRSI antenna.

2.3.4 Antenna Transporter

The requirements document for the transporter is now ready in draft form. Progress is being made on the transporter external study. Interaction with the Site IPT on access road and configuration issues continues.

2.3.5 Optical Pointing Telescope

The optical pointing telescope for the VertexRSI antenna is completed, installed on the antenna and being used for antenna acceptance testing. The interface for the AEC optical pointing telescope was confirmed in March and fabrication has begun on the system. Parts have been order for the second optical pointing telescope that will be used on the AEC antenna. The completion date for that is early July 2003.

2.3.6 Nutating Subreflector

The nutating subreflector (see Figure 5) was installed and tested on the VertexRSI antenna on February 10-12. Interfaces and functionality of the system in conjunction with the antenna was the primary purpose of this testing. The system was tested via the ALMA ABM. This test was considered a success but several other items still remain to be completed. Final tuning of the servo in order to meet the most demanding switching rates is nearing completion, along with the finishing the weather seals on the system. The CFRP subreflector mirror will also require an additional coating before installation on the antenna. The nutator system will be completed by the end on April and ready to install on the antenna. A quote was provided to ESO by NRAO in March for the AEC nutator.

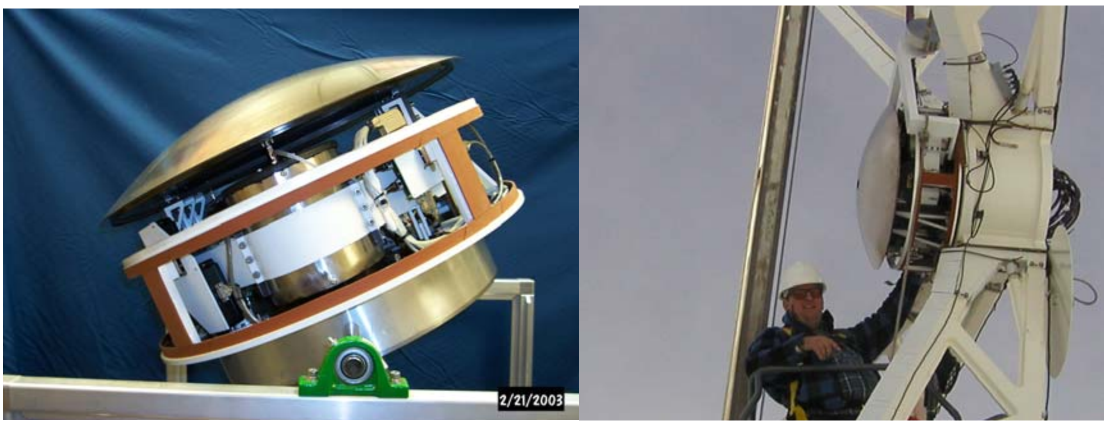

Figure 5. Nutating subreflector in lab and mounted on the VertexRSI antenna.

2.3.7 Antenna Foundations

The AEC and NAOJ foundation were completed and accepted in early January 2003. A picture of the site and completed foundation is shown in Figure 6.

Figure 6: Completed antenna foundations at ATF site as of March 12, 2003.

An antenna foundation ICD was issued as a first draft at the beginning of March containing the loads derived for the Vertex antenna, sensibly heavier than the AEC loads. The document is judged appropriate for the intended purpose. Discussions were held with the Site IPT and JAO on further steps and responsibilities related to the foundation. Engineering comments were received from the various parties, including some from M3 Engineering. An update to the ICD is in process. This common foundation design is required, if the site group is to start pouring foundations in 2003 before the production antenna design has been selected.

2.4 Front End (FE) IPT

2.4.1 General

Consultation has taken place with the bidders for all the European work packages to the Phase 2 Call for Proposals issued last year. In all of these discussions the issue of pre-production of 8 units has been addressed. Bidders are preparing or have prepared revised proposals taking this into account. The European FE IPT management at ESO has completed extensive documentation for all of these work packages that will be included in the contracts. Priority has been given to those work packages which deliver core components - cryostat and RF windows/IR filters/common optics.

Together with the representatives of the Joint ALMA Office, a visit to Spanish institutions and industry was made 5 - 7 March 2003. In the agreement between ESO and the Spanish government for their participation in the ALMA project it was agreed that Spain will have some ALMA Work Packages as an in-kind contribution. Since most of these in-kind contributions are to the Front End sub-system, the focus of this visit was to assess which institutes and industry are able to deliver. In general, it was clear that the necessary technical capability for the requested in-kind contributions is available in Spain. Additional information is necessary in the areas of schedule, resources, and costs. Requests to provide concrete information in these areas have been made. Certain work packages mentioned in the ESO-Spain agreement are originally tasks allocated to North America. This has been brought to the attention of the JAO as an issue to be resolved on the short term.

Considerable attention has been given to the Front End Integration Centers. A major event to address this task was a meeting held on 11th February 2003 at ESO in Garching. All European institutes interested in setting up and operating the EU FE Integration Center (FEIC) were present. In addition, representatives from the Band 7 and 9 cartridge groups and the Systems Engineering & Integration IPT, together with the FE IPT management, were present. Based on an earlier proposal jointly prepared by the Institut Radio Astronomie Millimetrique (IRAM) and the Rutherford Appleton Laboratory (RAL), a first draft for this infrastructure was assessed. Main topics were organization of the FEIC as well as the necessary activities for integration and testing. Consensus was reached between the participants of this meeting how to proceed with the organization of the FEIC and establishing a final test and integration plan. The outcome of this meeting was a substantial contribution to the joint Europe-North America meeting on the FEIC held 17 March 2003 at NRAO in Tucson.

Work on the external and internal Interface Control Documents (ICDs) continues. At an IPT meeting in January the external ICD work was assigned to various members of the IPT and on the 18th and 19th of March the IPT will meet again to review progress. It is unlikely that we will be able to have the large number of internal ICD's ready for the completion deadline of 15th April. In February a request was made to the JAO to extend this deadline or allocate more resources. The relocation of the Tucson group and its consolidation with the front-end group at Charlottesville has required a great deal of planning and its impact on the schedule remains a concern.

On 27-29 January 2003 the FE IPT management and sub-systems engineers had a very productive meeting at NRAO in Tucson where FE specifications, design and both internal as well as external ICDs were discussed. At this meeting progress was made on the FE sub-system specification & requirements document. Work on the external interfaces for the FE sub-system was also done. We have completely identified all items that should go in to the four external FE ICDs to other sub-systems, including Antenna, Back End, Computing, and Site. Various discussions with involved IPTs have been held in Tucson and the week before in Socorro to obtain the necessary information. In the next period all this information will be described in final draft versions of these ICDs.

Given the complexity of the FE sub-system the list of internal ICDs has grown to nearly 140 documents. For most of these internal ICDs first drafts were received in December and January. It has become clear that it will be impossible to complete all these ICDs, given their complexity and with the manpower available, within the FE IPT before the deadline of 15 April 2003 (a Level 2 Milestone). Progress will also be limited by any further calls on Bob Freund's time to assist in the servo tests of the VertexRSI antenna. Given the availability of these sub-systems resources to the FE IPT our objective is to complete: 1. all external ICDs, and 2. the most urgent internal ICDs linked to those parts of the FE covered by formal contracts for the pre-production phase (Band 3, 7, and 9 cartridges, cryostat and warm optics/IR filters/windows) by April 2003.

In the course of January 2003, Mark Harman of RAL started to contribute to the FE sub-systems engineering activities. Harman has been assigned half-time to the FE sub-system group in 2003. With his background in mechanical engineering and familiarity with the ALMA front end, Harman is an important complement to the two other FE sub-system engineers, who both have an electrical engineering background.

On-going work	Due date	Progress	Comments
Revised front-end specifications and	1 Jan 2003	On going	Draft available,

requirements			awaiting input from the systems IPT
Front-end internal ICD's	15 April 2003	On going	Draft only, much work remains
Cryogenic performance of dewar determined	1 Jan 2003	On going	Awaiting tests with windows
Prototype cartridge bodies delivered	1 Jan 2003	Complete	
DC bias and monitor and control circuits (for lab tests) delivered	1 Jan 2003	On going	Likely delayed until May due to ATF work
Local oscillator chains for all four bands delivered	1 Jan 2003	Band 3&6 complete	Band 7 and 9 final multiplier delayed by commercial supplier
Cold multiplier performance verified	16 Dec 2002	Complete	Band 6 only
First local oscillator – internal review	19 Nov 2002	Complete	Minutes available
Specifications and requirements workshop	21 Nov 2002	Complete	Minutes available
Band 3,6,7, and 9 cartridge and test sets design		On going	Level Three Milestone(s)
Optics and calibration design frozen	2nd Quarter 2003	On going	
Integration center design meeting	Jan 2003	Pending	March 17
Front-end design (conceptual)	13 Dec 2002	On going	Conceptual design available
ATF – Deliver first evaluation receiver	Jan 2003	Complete; requires chopper	Second receiver to be completed by mid-April

2.4.2 Herzberg Institute of Astrophysics (HIA)

The Band 3 elemental mixer has been tested at the HIA using a revised experimental setup that allows the use of a cooled feed-horn and a 4-12 GHz IF amplifier supplied by the NRAO. These tests were restricted to a bandwidth of 4-8 GHz, determined by the cooled isolator inserted between the mixer and the amplifier. The results are very encouraging, coming close to meeting ALMA specifications in a bandwidth that is adequate for the preferred double sideband (DSB) mixer configuration that is currently proposed by the HIA group. Similar results from independent tests at the NRAO using a mixer block and Superconducting-Insulator-superconducting (SIS) devices supplied by the HIA, an integrated amplifier and the full 4-12 GHz IF bandwidth are shown in Figure 7 below. The increased noise-temperatures at higher IF frequencies are due to impedance matching between the mixer and amplifier. A simple modification is expected to flatten the response.

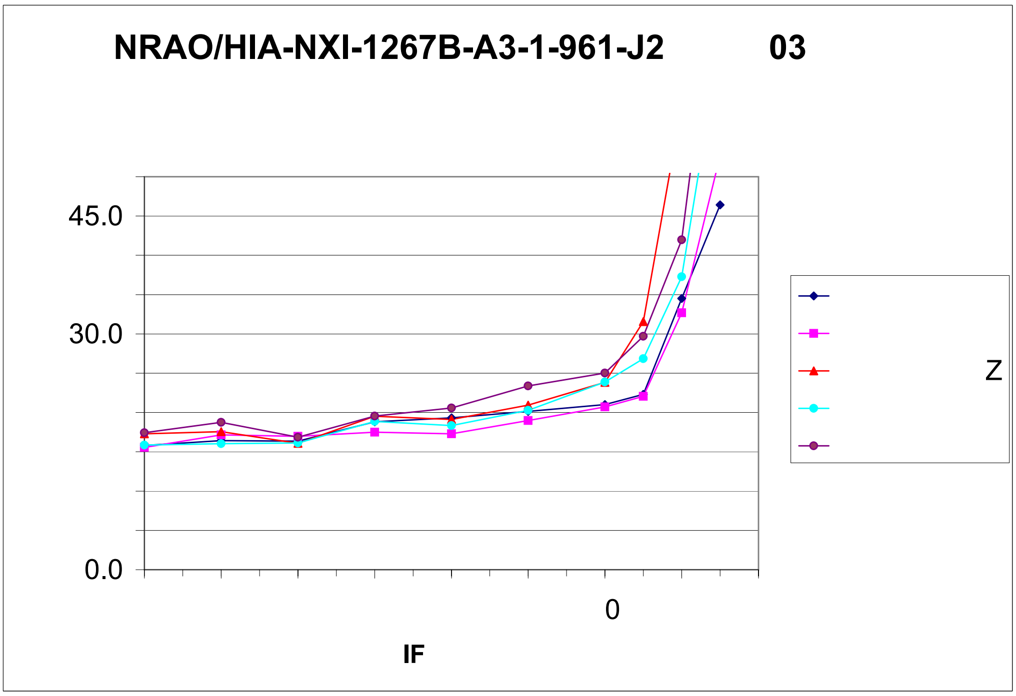

Figure 7. Band 3 DSB receiver noise temperature (courtesy S. K. Pan)
ALMA spec = 17K

A waveguide quadrature-hybrid (see Figure 8) has been completed and tests (in collaboration with the group in Tucson) indicate that it works well. It will be used to convert two of the elemental mixers described above into a sideband separating mixer.

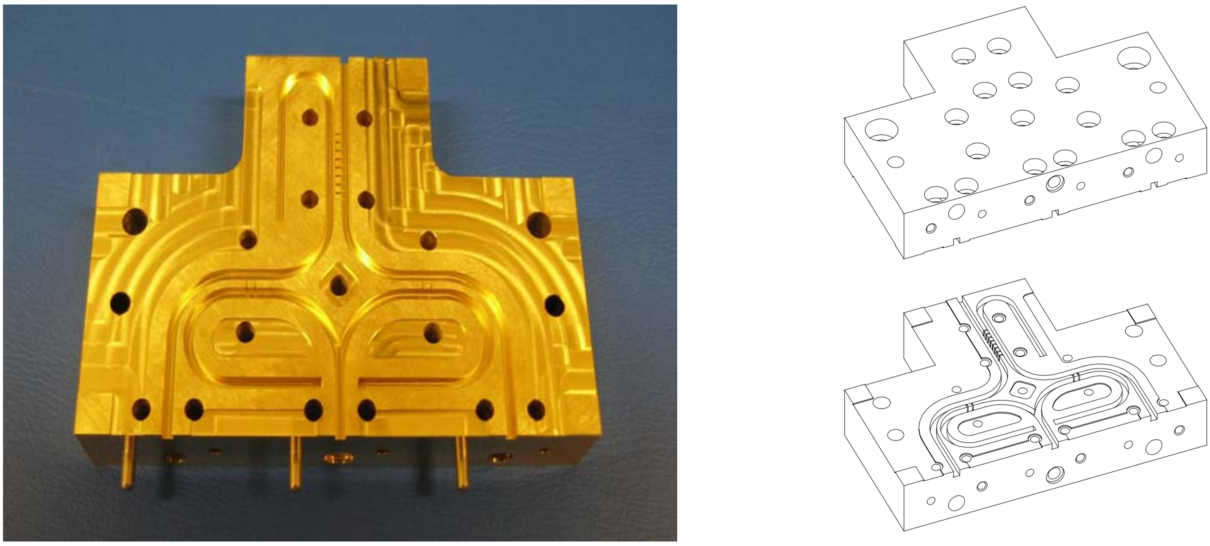

Figure 8. Band 3 Quadrature hybrid

Work on designing test and measurement equipment continues with the emphasis on finding commercial products that can replace custom-built apparatus and software. A mixer test cryostat that allows simultaneous testing of four devices is under development. Infrastructure changes are being made to allow the use of the Japanese cartridge test cryostat that is due to arrive on the 20th of March.

2.4.3 NRAO Central Development Laboratory

Sideband-separating mixer blocks based on the wave-guide approach have been delayed by about eight weeks due to machining difficulties in the NRAO shop. These difficulties have been resolved and the mixer blocks delivered. A photograph of the finished block, fully assembled with two integrated 4-12 GHz IF amplifiers and ready for testing, is shown in Figure 9 below.

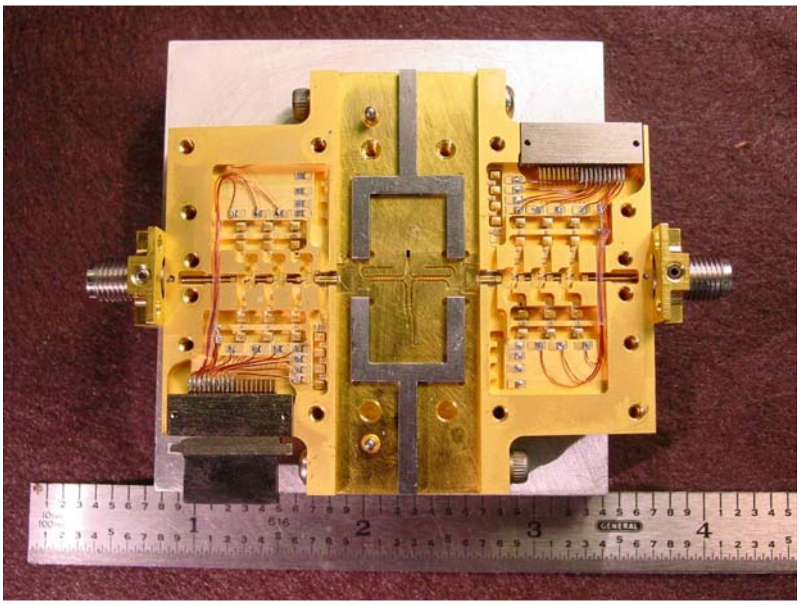

Figure 9. Sideband-separating mixer block with integrated IF amplifers.

The testing of DSB elemental mixers continues as a backup solution. The latest results are shown in Figure 10 below and indicate that the ALMA specifications can be met with this technology.

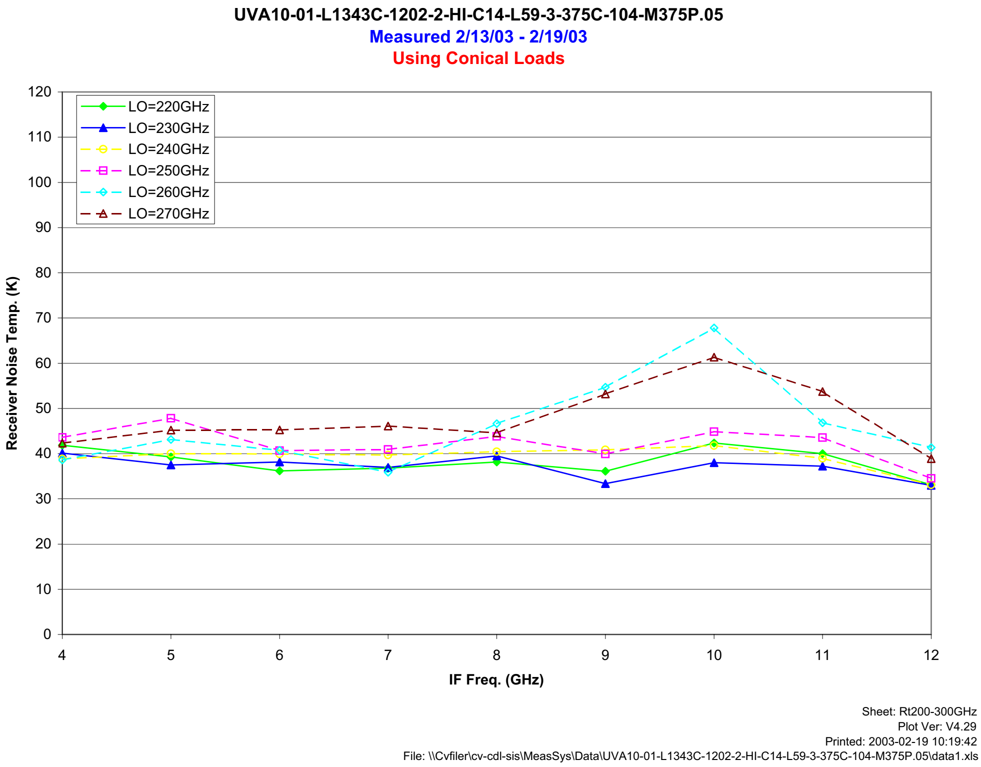

Figure 10. Band 6 receiver performance; ALMA spec 39K

Pre-prototype local oscillator chains that will assist the various cartridge groups in their radio frequency (RF) tests have been delivered. Final frequency multipliers for bands seven and nine are due for delivery this month by the commercial supplier. Work continues laying out the cartridge-specific LO components. It is not clear that we have enough space for our original design in which these components are located on the bottom of the individual cartridges and the design is under review. The technical direction of the local oscillator work up to the prototype demonstration phase has been transferred to J. Payne (a member of the systems IPT). The front-end IPT is collaborating closely with J. Payne.

The layout and internal details of the Band 6 cartridge such as the wiring heat sinks and the overall layout are being worked on in close collaboration with other parts of the front-end IPT. The current layout is shown in Figure 11 below.

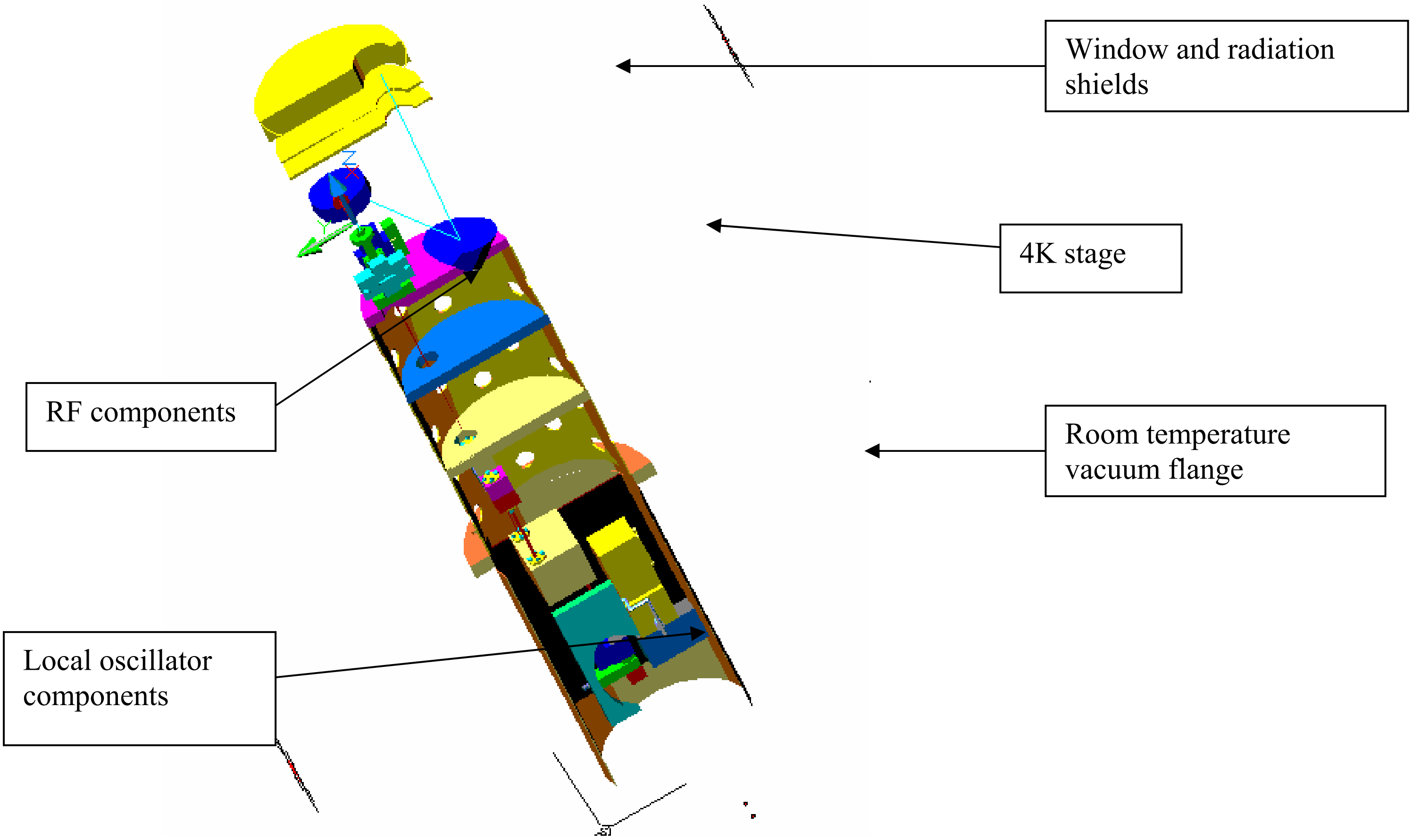

Figure 11. Band 6 cartridge layout

2.4.4 NRAO Tucson

The holography transmitter and receiver have been delivered and are working well. One evaluation receiver, and its associated compressor, has been completed and trial-installed on the VertexRSI prototype antenna. See Figure 12a, 12b below for a view of the receiver as installed and first data received, respectively. The second evaluation receiver is close to completion. Both receivers require the design and building of a simple calibration chopper arrangement.

Figure 12a. Evaluation receiver #1 installed in antenna cabin

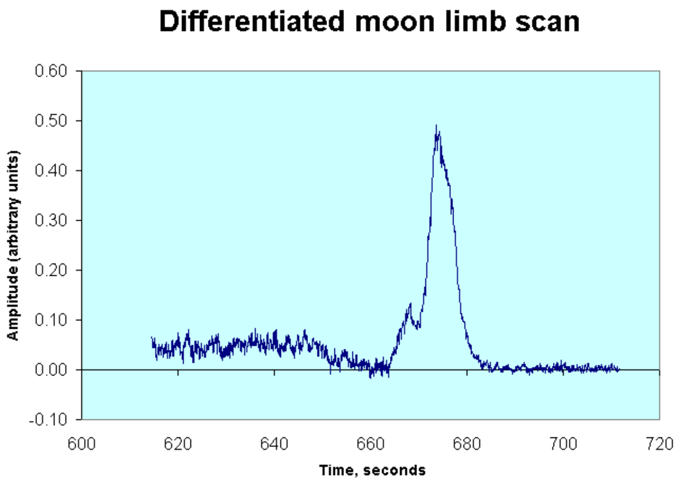

Figure 12b. Data from evaluation receiver #1 at 100 GHz

The Band six ortho-mode transducer design has been tested at room temperature and works very well. Four devices were tested and all gave similar results, this is excellent news as this is a critical component of the Band 6 cartridge design. In the future, testing of these devices will be aided by a recently delivered vector network analyzer (50 to 270 GHz) and by a cryostat that will allow cooled measurements. See Figure 13.

Figure 13. Band 3 orthomode transducers

Work has started on the detailed design of the receiver, concentrating on the block diagram (see Figure 14 below), overall layout, and critical monitor/control and DC bias issues. Good progress is being made in designing the DC support electronics. An extensive list of internal front-end interface control documents are being worked on. Work on the integration centers has started, initially defining exactly what activities should go on at an FEIC, the scope and nature of the tests that need to be performed and what infrastructure, equipment, and staffing is required. A joint meeting to discuss these issues with our European colleagues is scheduled for the 17th of March. The continued ATF workload remains a serious concern as it impacts the capacity for receiver and integration-center design work.

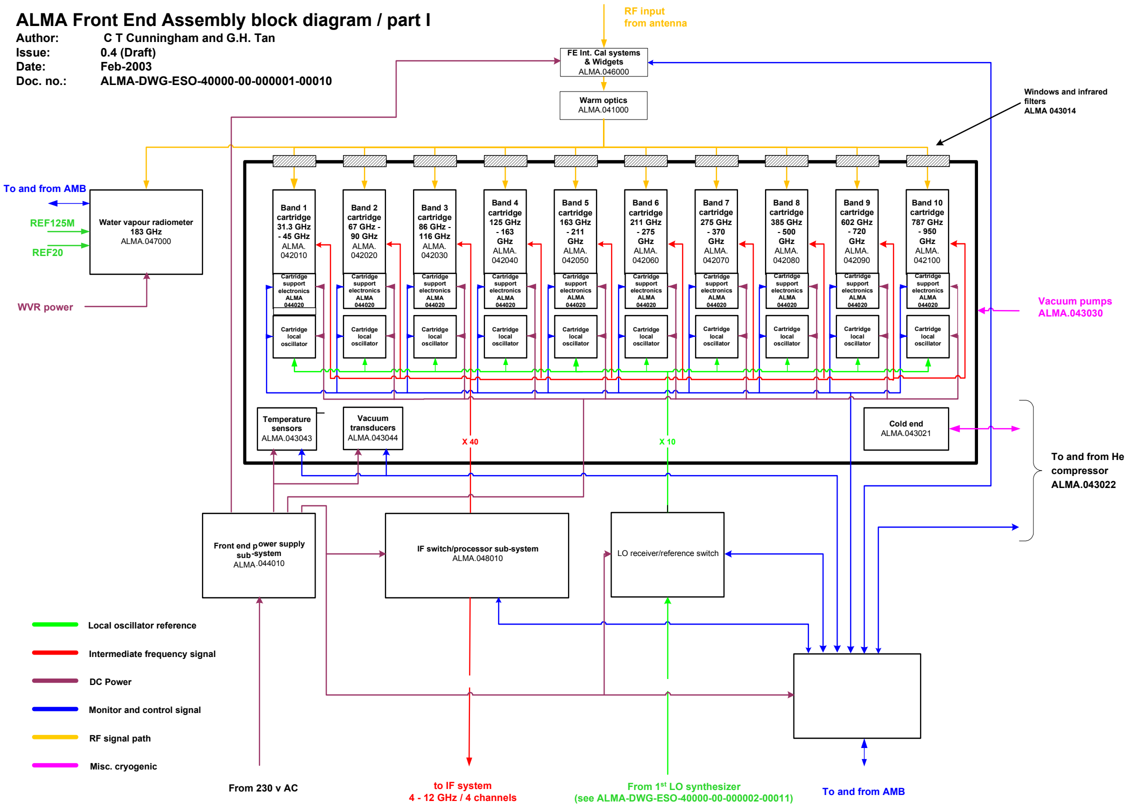

Figure 14. Receiver block diagram

2.4.5 Cryostat design/Prototype

Further detailed testing of the prototype cryostat has confirmed that it will meet the necessary key requirements. It was especially noteworthy that the temperature stability of the 4 K stage is within spec; 1.5 mK over a 1 minute time interval has been achieved, while 2 mK is the requirement.

The cryostat (see Figure 15) was fitted with sample plastic RF windows from IRAM in January and has been cold ever since. Shortly these plastic RF windows will be replaced by quartz windows to measure leakage and heat load, as was done for the plastic windows. The plastic used is high density polyethylene.

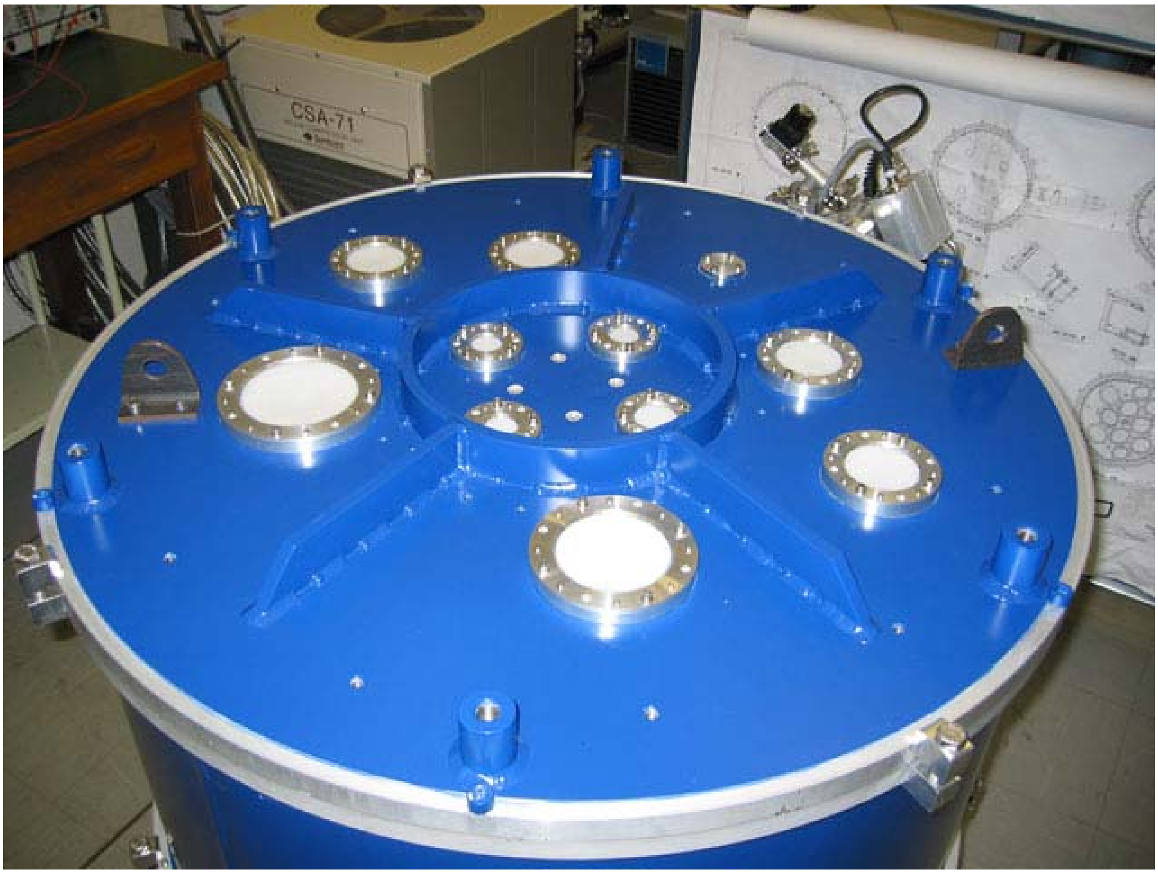

Figure 15. ALMA prototype cryostat fitted with plastic RF windows under test at Rutherford Appleton Laboratory

RAL has submitted costs figures to ESO and schedule for the pre-production series. Both costs and time schedule match the overall project plan.

On the 3rd of March a meeting was held with ESO and RAL representatives and a major supplier of cryo coolers to negotiate the delivery of these key components. Our aim for this meeting was to not only secure the delivery and pricing for the 8 cryo coolers needed for pre-production but also for the remaining 56 units.

2.4.6 Windows/IR/Common optics Design/Prototype

Windows:
Both plastic and quartz windows for testing with the prototype cryostat have been delivered for integration to RAL
RF Windows for the test cryostat have been made and tested. Instead of delivery to NAOJ for the integration with the test cryostats they have been directly send to the various institutes that will use the test cryostats.

Infra Red Filters:
The filters for the prototype and test cryostats have been made and shipped to the cartridge design groups.

Common Optics:

The cryostat front plate that was delivered by RAL was mounted in the anechoic chamber at IRAM and is ready for tests.
Various optical components for the different ALMA frequency bands are being integrated with this cryostat front plate.
Recent research on the calibration of ALMA by the calibration working group made them conclude that additional calibration devices, hot and cold loads, are advisable. However this change will have a major impact on both common optics design and the cryostat design. Limited analysis of this impact has been made, but more work on this assessment will only be done when a formal Change Request has been submitted by the Science IPT.

2.4.7 (Focal Plane) Calibration System Development

The semi-transparent vane calibration unit has been put into the 30m IRAM telescope at Pico Valeta and has undergone tests within the cabin. These tests are yet not good enough to make a final confirmation of the calibration scheme and more tests are planned in April/May of this year. Due to bad weather very limited telescopes measurements were possible. The results are being processed by members of the Science IPT.

2.4.8 Band 7 cartridge Design / Development

Work at Chalmers University towards Band 7 development consisted of the following activities:

- Made the first cooling of the prototype DSB mixer with measurements of the noise temperature. Analysis of the results with the first mixer measurements; we tediously investigated possible reasons of asymmetry in the junction pumping levels; this work is still continued however our preliminary conclusion is that we mostly blame the fabrication peculiarities on the substrate (it was some suspected over etching during the fabrication of that particular substrate))rather than the mixer structure itself. The latter is under further investigation too. The SIS production process has been adjusted based on these first results. It is expected that the second batch is ready by 26th February.
- We are preparing the second mixer block identical to the first one which should make testing and development process easier.
- The work on scaling to Band 7 progresses well and we expect to finish the design by middle-end Spring and begin manufacturing. With respect to that we are working on a new technology for corrugated horn manufacturing allowing for mass production; some more simulations are still necessary for that new technology.
- We finally finished the multi-channel computerized direct current (DC) test setup for characterization of big substrates. This will improve our ability to identify substrate problems early and make mixer chip selection faster.

At IRAM the following activities towards Band 7 were pursued:

- SIS junction production
  A third batch of junctions has been processed and characterized. The problems encountered with the two first batches have been solved. The global yield is 55%. The normal resistance, which is still 2 times too high, will require an adjustment of the barrier oxidation time, in the next (fourth) batch, which is in progress.
- Cartridge:
  A thermal budget for the cartridge has been completed.
  The issue of mode conversion in wave guide bends used for the LO injection to the Band 7 mixers has been analyzed.

2.4.9 Band 9 cartridge Design / Development

The main activities for the Band 9 Cartridge by the Netherlands Research School for Astronomy (NOVA) – Space Research Organization Netherlands (SRON) Band 9 group were the following:

- Prepared for the contract negotiation meeting with ESO representatives in Leiden (14th January 2003). Participated in the same meeting.
- Finalized the ALMA main horn design details for Band 9. The design data was sent to IRAM and Mullard Radio Astronomy Observatory for a physical optics propagation analysis of the Band 9 optics.
- Production drawings of ALMA Band 9 horn/mixer are being prepared in Solid-Works. A few major horn producers will be asked for quotations.
- Ten industrially produced mixer blocks, including 10 back pieces and 10 diagonal horns are partly delivered. There was a problem dissolving the glue that temporarily holds together the two halves of the diagonal horn split-block. The problem is being addressed. We received a few back pieces. The quality is acceptable.
- Background measurements on the spectrum content of our Gunn multiplier chain were performed. The intention was to provide background information for comparison with a future pre-prototype lab LO source to be delivered by NRAO.
- A set of measurements on the SIS mixer temperature was performed. The physical temperature of SIS mixer was varied from 2.5 to 6 K with steps of 0.1 K. This allows an accurate evaluation of derivatives required to connect the receiver stability requirement with the stability requirements for the mixer environment.
- Measurements of the NRAO IF amplifier temperature stability were also performed. The general conclusion is that temperature variations of the IF amplifier have relatively little effect on receiver noise and gain. The automatic measurement system was used for the two mentioned above experiments.
- Two batches (SIS-15) were received from U. Delft. Both contained a new technology Nb-AlN-NbTiN SIS junctions. These junctions have a gap voltage of 3.6 mV instead of 3 mV for standard all Nb junctions. It allows to increase the mixer gain and potentially improve the noise temperatures. The DC evaluation has shown at least 60% yield (very high for an experimental technology run). Enough junctions for future heterodyne tests can be selected.
- A first contact was placed with a Russian company "Ferrite Domen". This company is an alternative source for cryogenic isolators in the range of 4-8

GHz. The request was made about the price and duration of development for two prototype 4-12 GHz isolators as needed for the Band 9 cartridge design.

- A person to fulfill the role of management assistant was found. The contract negotiations are underway.
- A lab pre-prototype LO system (see Figure 16) has been delivered to NOVA/SRON by NRAO. Preliminary tests using Fourier Transform Spectrometer (FTS) and a Rohde & Schwartz Synthesizer instead of the supplied (YIG) oscillator demonstrated the operation of high frequency part. The spectral purity (absence of spurious signals in this case) looks to be acceptable. The band coverage is consistent with measurements at NRAO. The control board is still to be delivered. Preparations are underway for switching power to the oscillator and phase-locking it, as well as preparations for noise/ output power measurements .

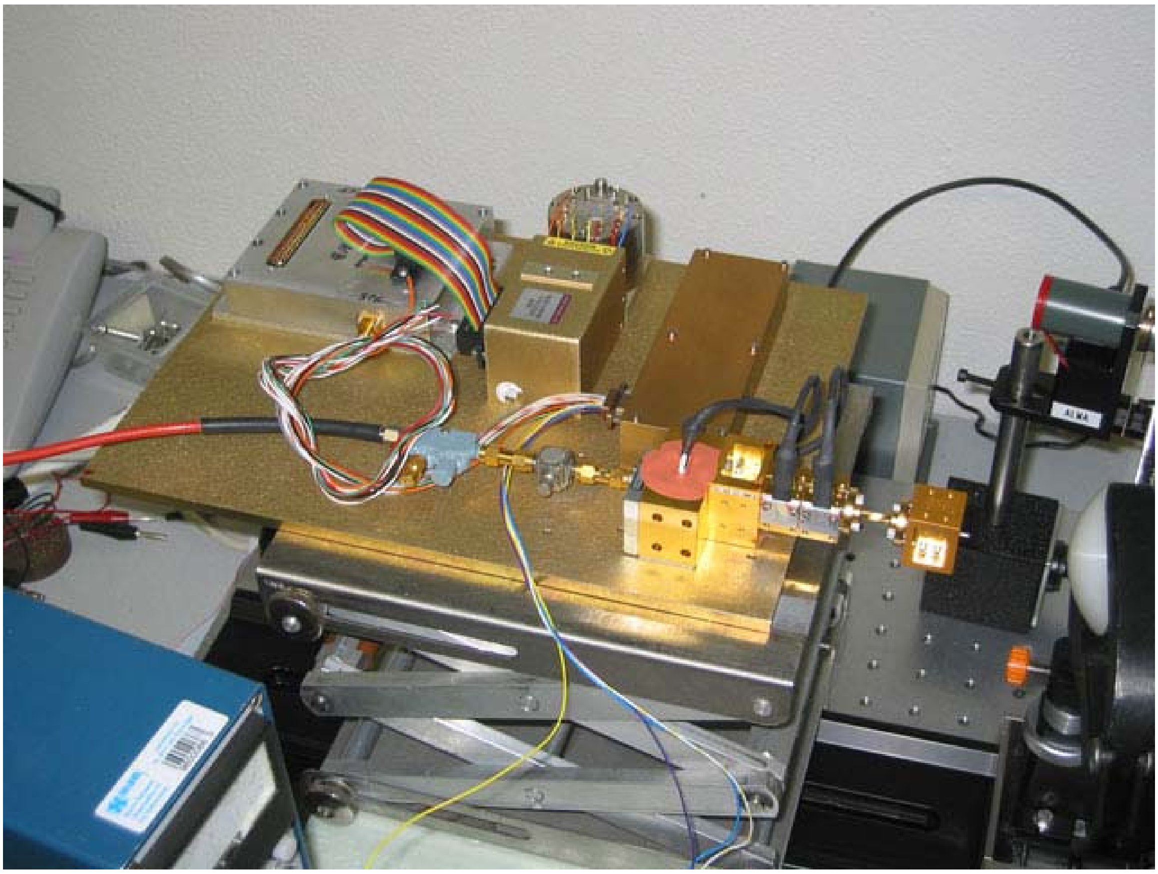

Figure 16. ALMA pre-prototype Band 9 local oscillator mounted at FTS test bench at SRON

- A super-lattice solid state device was mounted in one of the Band 9 back-piece. This device is equivalent to Schottky diode but it has higher efficiency. The performance of this device was verified by using it as comb generator (with the base frequency of up to 20 GHz). Harmonics up to 1.5 THz were detected by means of FTS and bolometer. Band 9 is also fully covered. This device can be also used as harmonic mixer in phase and amplitude beam pattern measurements. This enables us in principle to verify experimentally Band 9 optical design and test Band 9 horn patterns at room temperature.

- The cartridge test cryostat was received from Japan, with compressor and accessories. Final installation in the lab and is underway.
- The draft ICDs for Band 9 were communicated to the FE IPT.
- A meeting on IF amplifiers together with IRAM, YO, and with participation of NRAO, was prepared and held on 24-25 of January at SRON. The goal was to unify the European IF amplifier design and formulate clear requirements for a prototype.
- Work started towards selecting a mechanical design company for making the detailed opto-mechanical cartridge design and possibly a hardware prototype.
- A discussion of formally finalizing the Band 9 ALMA Phase 2 contract with ESO took place with general agreement on both sides.

2.5 Back End (BE) IPT

2.5.1 Data Transmission System

Successful tests of the 10 Gbps "daughter card" reported last quarter led to a design update of the Digital Formatter card. The circuit cards for the new design have been fabricated and populated. Final checkout of the Field Programmable Gate Array (FPGA) code to synchronize samples between channels is nearly complete. Once the code is proved, the formatter card will undergo a trial on the 10 Gbps test link as described last quarter. Then samples of the card are planned for shipment to JBO by the end of this quarter for use in further developing the Fiber Optics (FO) transmitter cards.

The update of the formatter card design is being carried over to the design of the digital deformatter card; a new layout for the circuit card is partially complete.

JBO has fabricated and is populating prototype FO transmitter cards in preparation for testing with the formatter card. One FO transmitter card will be constructed at NRAO - Socorro following the JBO design to assist in further formatter card system checkout.

A delayed funding start at JBO is expected to delay delivery of fiber optic Data Transmission System (DTS) components by 9 weeks, which could impact the plan to deliver the completed DTS system prototype for system integration tests by January 2004, but otherwise the design development is on schedule.

2.5.2 Total Power Backend for radiometer tests of the VertexRSI prototype antenna

All modules necessary for the radiometer, to be used in evaluating the VertexRSI prototype antenna surface, have been constructed, checked, and installed in an equipment rack for connection to the evaluation front end receiver. The system includes an IF downconverter, a total power processor, and a monitor and control board (Figure 17). Timing and frequency reference modules, completed last quarter, are also part of the rack. The Computing IPT has developed the control software for the entire total power backend evaluation system. The radiometer tests can proceed after systems tests of the total power backend with the evaluation receiver.

Construction of modules to configure a second total power backend system and other modules for the AEC prototype antenna is scheduled for completion next quarter.

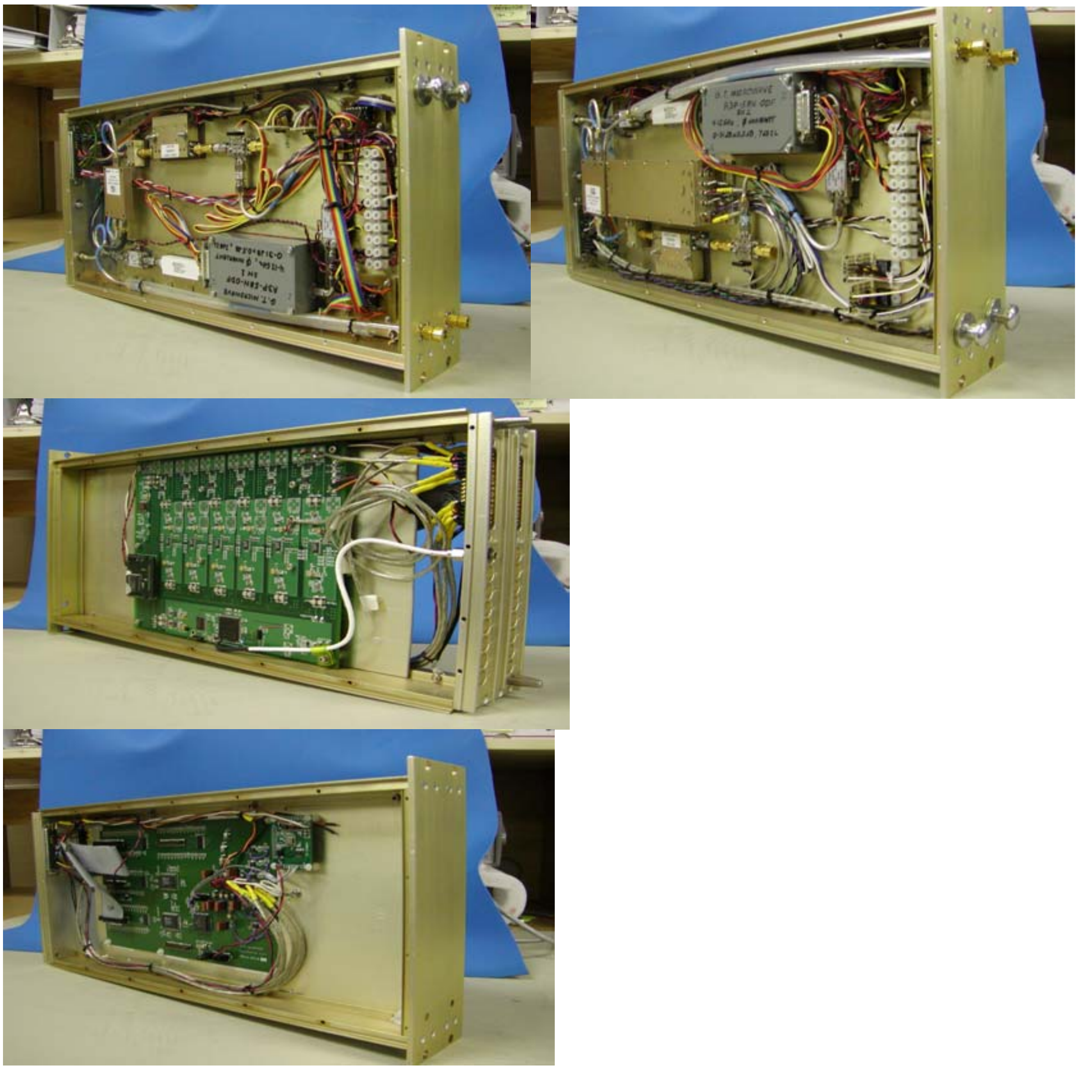

Figure 17. Components of Total Power Back End for evaluation program of ATF.

2.5.3 LO Distribution

An engineer was hired this quarter to develop the 2nd LO synthesizer. The LO development has been assigned to a separate task group. As a result, progress on the LO system is now covered in a separate report.

2.5.4 IF Downconverter

A proposal has been prepared to have the 4–12 GHz downconverter or the baseband processor or both designed by an external vendor using integrated components. An integrated version, that is, a version with no RF connectors on board, is expected to save up to 50% of the cost of the "coax-connector" version in production quantities. If the proposal is approved, quotations for the design(s) will be solicited from external vendors next quarter.

Work will proceed in-house to complete the design and prototype of the coax version so that prototype downconverter modules can be delivered on time for the system integration starting January 2004. The plan is to have integrated versions of the downconverter available for testing and comparison with the coax versions for the system integration tests.

It has not been possible to identify diodes for the total power detector with sufficient linearity. During the next quarter, the plan is to develop a total power processor for the downconverter that incorporates linearizing lookup tables.

2.5.5 Digitizer Sampler and Demux

The most important goal during this period was to meet the first Level-3 Milestones of CY 2003: 1) submit version 2 of our 3-bit SiGe sampler design, and 2) submit the first 1-bit SiGe 1/16 demux design to the STMicroelectronics foundry. Following internal reviews held in December 2002 and January 2003, these two milestones were reached on 30 January 2003. We have verified that our final layout and gerber files have been received by ST.

We have continued our lab tests with the first packaged (VFQFPN44) 3-bit sampler mounted on a special 4-layer PCB (Figure 18). Several measured characteristics of the first 3-bit design have been summarized in the ALMAEDM BackEnd Web page; the maximum sampling frequency is 5.5 GHz The new sampler has low power consumption (1.5 W) and better decoupling of low frequency noise; it includes a low frequency clock for future life tests to be performed by ST.

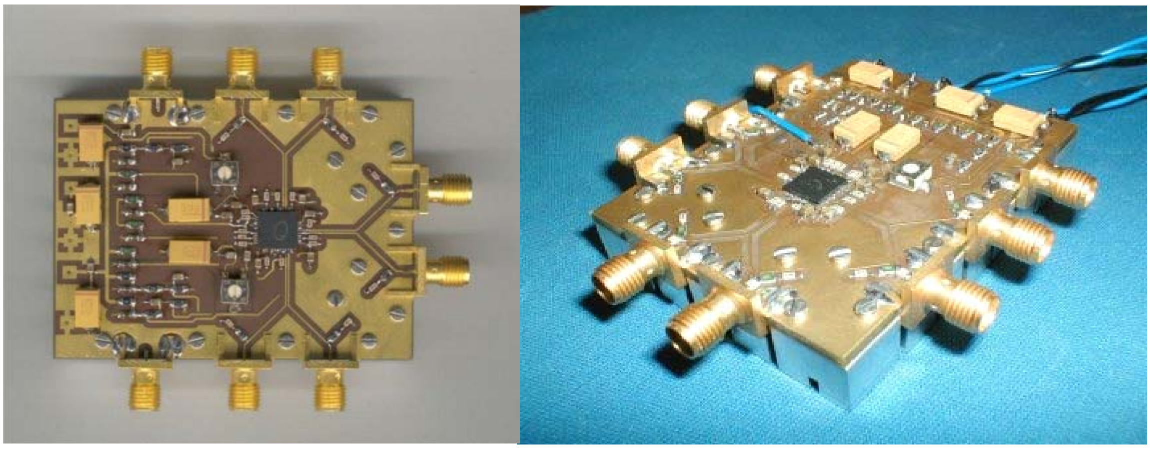

Figure 18. 3-bit Sampler

.
Among the seven packaged chips delivered to us, preliminary static measurements and X-ray images have shown that the packaging was not successful in three cases. This unexpected poor packaging yield will be compensated for by a new trial using extra naked chips delivered to us. These naked chips are now in the hands of ST.

The demux chips (one for each bit of the sampler Application Specific Integrated Circuits) will deliver Low Voltage Digital Signal (LVDS) levels at 250 MHz as required by the project. The consumption is around 2W (and will later be optimized). The 58-pin chip will be mounted naked on a special Printed Circuit Board (PCB).

The layout for a full prototype digitizer with one packaged sampler chip, 3 demux chips, clock distribution, and alignment is progressing with technological support from Solectron R&D. (The final layout and output connector will be for 2 samplers to cover 2 polarizations.) The design reports (Rapports de Conception) for these Sampler and Demux circuits will be completed by the end of March.

Negotiations and technical discussions continue with ST in order to define all phases necessary for entering ALMA sampler production. Before entering production, we must conclude the prototyping phase with a robust design including electrostatic discharge protection, specifications defined jointly with ST, and reliability tests prepared using special reliability boards and our test bench for dynamic qualification tests. We expect to clarify all steps before June 2003.

2.5.6 Digitizer Clock

Following regional meetings, IRAM has proposed a scheme to deliver the clock signals required by the Digitizer in a manner that will compensate for the drifting sampler clock resulting from fine delay adjustment.

Two meetings have been organized jointly with the System Engineering IPT to investigate more completely this question. Among a number of proposals, it has been decided that the 4 GHz clock would be multiplied up from the 250 MHz signal to avoid any phase ambiguity. A general block diagram for the new scheme has been approved. A sampler clock module prototype will be prepared according to IRAM's detailed design which will start in March.

An ICD is to be written with the digital transmitter module builders in April, 2003.

2.5.7 Other Matters

Interface Control Documents are being written, both externally (with other IPTs) and internally, for approval during the next quarter. The ICDs will be accompanied by Hardware Definition Documents, one for each BE module. A top level description and requirements document for the BE IPT equipment is due by the end of this quarter. A few questions about science requirements remain to be resolved.

2.5.8 Local Oscillator and Timing

2nd LO Synthesizer

Quotations have been requested for the filters in the 2nd LO. The lowpass filter in the Intermediate Frequency (IF) portion of the phase locked loop may be changed to a highpass/lowpass diplexer to avoid reflections back to the mixer.

A second source for the relatively high power (P1dB=27 dBm) amplifiers needed to obtain the required 2nd LO power levels has been identified. The amplifier required in the Local Oscillator Reference Receiver (LORR) for comb generator amplification doesn't have to be high power which will save half the cost.

The Coupled Power Divider for the through and coupled ports was designed in-house because of the $7k cost of a commercial unit.

An internal ICD between 2nd LO synthesizer and the downconverter was developed which, among other things, limits the amount of Radio Frequency (RF) that the downconverter can leak back into the 2nd LO. A study is taking place to see if two AMBSI2 Monitor and Control bus connections are necessary or if just one will suffice . In short, nearly all parts have been procured or designed for a first prototype.

First-LO Synthesizer and Microwave Synthesizer

The front end LO group delivered lab prototypes for Bands 3 and 9. The Band 9 lab prototype has been tested with a SIS receiver and shows equivalent noise to a Gunn Oscillator at 654 GHz [Eric W. Bryerton, Andrey Baryshev, and Dorsey L. Thacker, "A 660 GHz Electronically Tunable Local Oscillator", Submitted to European Microwave Conference, October 2003]. We have received the Band 7 multipliers from Virginia Diodes. The final version of the Band 9 quintupler, using a Millimeter Integrated Circuit (MMIC), is presently scheduled for delivery in the first part of April. The wafer has been received from the foundry and is presently undergoing tests. The InP wafer run at HRL (formerly Hughes Research Laboratories) is in process with delivery expected in June. Designs for interstage filters for the warm multiplier assembly are completed and filters are being fabricated by an outside vendor. We are re-estimating production costs of the FE LO components, and assuming success with the wafer runs we expect this MMIC approach to reduce the production costs significantly. Mechanical design is in process. Draft ICDs were written.

Priority tasks:

- Integrate the total LO effort under the leadership of John Payne;
- Investigate developing a second source for multipliers;
- Final mechanical design and integration of MMIC chips into system;
- End to End test of LO in December 2003

LO Photonics

In December, a major milestone test took place with the ALMA line length correction system. A joint test between the NRAO, Tucson photonics group, and the NAOJ, documented in ALMA memo #445, measured long term phase down to about 100 femto-seconds, which is much lower than was previously measurable. The system appears to work at this level. Future tests are planned to further prove the system to the lower levels required by ALMA by using even more highly stabilized lasers. To this end, a contract was let in February, 2003, for the construction of a master laser to ALMA specifications. A laboratory prototype model will be delivered in six months.

The optical comb generator construction is at the University of Kent, Canterbury. The design is complete, parts have been ordered, and final delivery of all parts is expected by 31 March 2003. Assembly and testing will take place in the next quarter.

Tests of the NTT photomixer have taken place with good results. The photomixer appears to meet ALMA specifications for output power and frequency range up to at least 110 GHz. Previous work on the Rutherford Appleton Laboratory (RAL) photomixer also had good results. Further work involves finalizing ALMA specifications for device polarization sensitivity and responsivity, evaluating the devices in the 120-142 GHz range, and determining which available devices best meet the project's needs in the various bands.

The photonics rack, consisting of a master laser, laser synthesizer, wavemeter, fiber distribution, and an optical amplifier was delivered to the ATF testing site in February, 2003. The first operational use of the instrument will take place in April, 2003 for holography testing. A photonic holography transmitter with an RAL photomixer was constructed and mounted atop the 50-m holography tower at the Very Large Array site.

Certain polarization tests have been taking place during the reporting quarter. The test results will be used to determine what type of photonics distribution will be needed to support delivery of two polarization aligned signals for the photonic reference. The variability of the polarization vs. time and wavelength is still under investigation.

Selection of a suitable slave laser for the ALMA laser synthesizer has been unsuccessful. So far no laser has met our requirements. Further work in this area and investigation of a fallback "comb generator" alternative are being actively pursued. Final proof of concept for the line length correction system is a highest priority, as there is no obvious backup plan.

Low Frequency LO and timing

Prototypes of the central reference generator, central reference distributor, and the LO reference receiver were installed for the VertexRSI prototype antenna; and, at last report, were working correctly.

Other LO Matters

Consolidation of the photonics effort has taken place under a newly formed ALMA LO group. The major effort of the group in the next quarter will be to finalize the design, make critical test of the line length correction and comb generator, and complete ICDs and specifications for the system.

2.6 Correlator IPT

2.6.1 Prototype Two-Antenna Correlator

Good progress was made on the prototype two-antenna correlator. A draft ICD was written on the interface details for the optical receiver/demultiplexer card which plugs into the correlator station bin (see Figure 19), which is the same for the prototype and the full correlator. For the 73 active boards plus 16 spares which are needed for the prototype, the status is as follows:

Assembled and tested:

Station Control Cards	3	
Station Bin Motherboard	2	(+1 spare)
Correlator Bin Motherboard	1	(+1 spare)
FIR Filter Card	18	
Station Card	10	
6U Bin Power	5	

Assembled and in test phase:

Station Interface Card	5	
Correlator Interface Card	10	
Power Control Card	1	(+1 spare)
Front Panel Data Port	1	(+1 spare)
9U Bin Power	3	

Being assembled:

Correlator Mezzanine Card	11
LTA Card	3

Ready for PCB fabrication:

Correlator Card (11 required)

In layout phase:

Quadrant Control Card (2 required)

Hardware design complete:

Optical Receiver Simulator used for testing only

Wiring work continued on the prototype correlator rack (see Figure 20).

Firmware development for advanced operation modes continued. Most of this is required in the LTA card, including:

(1) Special adder tree modes required by the two-antenna prototype system;
(2) Support of the operational environment of the two-antenna prototype system.

Figure 19. Fully populated prototype correlator station bin (no optical receiver cards).

Figure 20. Front (left) and rear of prototype 2-antenna correlator rack showing
card cages, cards, backplanes, fans, and power supplies mounted.

2.6.2 Enhanced filter card

Further study of a possible enhancement of the baseline correlator performance has been done. By substituting an advanced filter card with multiple simultaneous output bands for the single-band output present filter design, it is possible to achieve much greater frequency resolution in the widest bandwidths, or to analyze several narrow bands simultaneously with even higher frequency resolution. A preliminary design for a filter card capable of providing up to 32 separate bands has shown that the use of a polyphase filter algorithm makes such a card achievable with the current generation of FPGA chips. However, the costs would be higher than the present single-band filter card unless the FPGA program is converted to a custom chip; this appears to be practical once the algorithm performance is confirmed. We have investigated two companies which are capable of making the conversion from FPGA to custom chip. It appears that the development and production cycle may be too long to allow implementation of the enhanced filter card for the first quadrant of the correlator without delaying the delivery schedule for that quadrant. We will continue the concept development and try to provide a definitive assessment of the cost and schedule implications over the next 3 months.

2.6.3 Schedule

The goals for December 2002-February 2003 were:

(1) complete assembly of all printed circuit boards for the prototype correlator;
(2) begin integrated testing of cards in the rack;
(3) achieve 90% completion of integrated testing of at least 50% of the cards in the rack.

It became apparent in January that the layout of the final version of the correlator board would take longer than anticipated, and that this would delay the completion of the layout of the Quadrant Control Card. We therefore generated a Level 3 milestone to have assembly of all except the Quadrant Control Card completed by March 15, 2003. There is no change to delivery.

Integrated testing began, and both control and data signal integrity between boards in one Station Bin were successfully demonstrated.

The goals for March-May 2003 are:

(1) Complete assembly and individual test of all prototype correlator circuit boards;
(2) Perform the first end-to-end testing of the entire prototype correlator;
(3) Complete the design study for the enhanced filter card and recommend a course of action for implementation;
(4) Based on experience with building the prototype correlator, re-estimate the schedule and cost of the complete 64-antenna baseline correlator.

2.6.4 ALMA Second Generation Correlator (2GC)

Our main goals in the last two months of 2002 were: "freeze" in a synthetic document the specifications of the 2GC; define and share tasks among the European Institutes involved in the 2GC concept and prototyping; consolidate the FIR filter bank system design. Definition of tasks, share of responsibilities and organization in Europe have been presented to ESO.

Our 2GC specifications and general block diagrams were sent to NAOJ for comparison with their correlator and for evaluation by two Japanese companies. We answered in December and January several technical questions asked by Japan about our design.

In advance of a planned Correlator IPT/Japan meeting on the 2GC, NAOJ, Fujitsu, and Nippon Electric Company have sent back two documents showing their understanding of the 2GC. These documents are under investigation by our IPT.

In January 2003 an "ALMA 2GC System Requirements" document has been issued and awaits approval by the Correlator IPT. This document and other memos explaining the choice for a 2-stage Finite Impluse Resonse (FIR) filter architecture form the basis for a review meeting on 2GC requirements.

Several tasks are ongoing and we expect to release 2GC documents before the end of June 2003. They include: a description of FIR filters in (Very High Speed Integrated Circuit) Hardware Description Language (VHDL) and practical implementation in existing FPGAs, interconnect technology study, 3-bit multiplication scheme and optimum implementation.

2.7 Computing IPT

2.7.1 General

The Computing Preliminary Design Review (PDR) is to be held in this quarter. All IDR documents were revised and distributed to the PDR panel after internal discussion. Most major IDR issues were resolved or at least have default assumptions that allow work to proceed.

A meeting of post-processing subsystems was held in January. At it a proposal emerged for Astronomical Information Processing System (AIPS++) to adopt certain ALMA technology and designs (e.g., Common Object Request Broker Architecture - CORBA, ALMA Common Software - ACS, Python, Container/Component). This would have the effect of making it much more straightforward for AIPS++ and ALMA to interoperate, and is considered a major advance for the Offline, Pipeline, and Data Reduction User Interface (UI) subsystems. This proposal needs to be confirmed by the AIPS++ Consortium, as it would be a major change for that project.

The AIPS++/IRAM Phase 1 test concluded, and Phase 2 (repeat with different data sets and testers) and Phase 3 (benchmark with ALMA sized data) are expected to finish this quarter. The Phase 1 technical results were essentially identical between

AIPS++ and the IRAM software, however the schedule was delayed by approximately one year over that originally envisaged.

The software group provided considerable support for antenna commissioning, relieving Vertex of effort required to write one-time test routines.

2.7.2 Milestones

The Computing IPT Level 2 Milestones for previous, current, and next quarter are as follows.

Milestone	Original	Current	Actual
Internal Design Review (IDR)	2002-12-09	2002-12-09	2002-12-09
Preliminary Software System Design Review	2003-03-15	2003-04-04[1]	
Subsystem Software Release R0	2003-05-01	2003-05-01	

2.7.3 Significant Issues

There is considerable concern in the ALMA community about the status and capabilities of AIPS++. These are being investigated in ALMA through the published[2] audit of capabilities, the AIPS++/IRAM Phase 1-3 tests, and additional benchmarking that will be carried out by the Science Software Requirements Group (SSR). In addition, an independent technical review of AIPS++ has been arranged by the NRAO Director and will be carried out March 5-7 in Socorro. The results of this review will be of great interest to ALMA.

Progress in filling vacant positions, particularly at NRAO, has been made, but we are still below plan.

The control software subsystem is presently under great pressure to carry out long term development activities as well as provide support for the ATF. This problem has been exacerbated by the departure of a senior staff member in January.

There are still operational issues that have to be resolved. For example the proposal preparation tools will be affected by how the proposal refereeing process is carried out, and the Archive subsystem will be affected by data distribution relationship between the OSF, Santiago Central Office, and Regional Support Centers. Computing will be represented on a committee that is being formed to answer such questions.

2.7.4 Work Element Reports

All work elements (excepting 2660 – hardware) prepared for PDR. This work is generally not discussed below.

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[1] The PDR date has not actually changed. It was originally intended as the date of the meeting. In the current formulation it is the delivery date of the PDR panel report to the JAO.

[2] http://www.alma.aoc.nrao.edu/development/computing/docs/joint/0019/ALMAoffline_audit.pdf

Management (2640)

Progress: The overall computing management plan was submitted to the document approval process for approval. Comments were received from the Project Manager and Scientist and have been reincorporated into a subsequent draft. Level 2 and 3 milestones were updated and submitted to the JAO. L. Cryer started work in Socorro offering administrative support to B. Glendenning at 50%. Invited PDR panel and organized logistics and document distribution.

Science Software Requirements (2680)

Progress: Data Reduction UI requirements underwent a second iteration. Result is nearly final. Requirements for a lightweight Java-only simulator ("SimLite") for the observing tool are under discussion but have not yet converged. A discussion and request for input about data rates in light of the proposed Baseline correlator upgrade was sent to the Science IPT. A first detailed listing of metadata contents was drafted.

Issues: SimLite features need to be finalized.

Analysis and Design (2700)

Progress: The overall architecture document was completely revised for PDR, most notably adding a section on the physical architecture and adding a description of subsystem data volumes. Evaluated commercial software for automatically creating C++ entity objects from Extensible Markup Language (XML). The software in question had some problems.

Issues: Are XML binding class frameworks required for C++, or is the XML needed by C++ sufficiently simple that this is not required. Some subsystems require assistance in determining appropriate use of some technical architecture features, e.g., events.

Software Engineering (2720)

Progress: Configuration Module Manager to Concurrent Version System (CVS) transition, including rehearsal, documentation, and support Makefile enhancements for XmlIDL compilation and Component Helpers (new ACS Java Component/Container support). Improvement of daily code quality reports with migration to own web server. Experimentation and in some cases set-up of various QC/CASE tools (valgrind, ccache, JTest, Purify, Rose).

Common Software (2740)

Progress: ACS 2.0.1 containing support for the Java Container/Component design was released. New versions of underlying support libraries and facilities have been tested for Linux. We intend to use them generally, but this will require an as yet untested upgrade in our version of VxWorks. A binary-only installation procedure was developed. Transition to a new Object Request Broker (from Orbacus to the JacORB) was started. Orbacus is no longer freely distributable.

Issues: The conversion to CVS took much more effort than anticipated. The current version of VxWorks has limited support for modern C++ which is a constant drag on the project. It is hoped that the VxWorks upgrade will cure this.

Executive Software (2750)

Progress: The Java message system and STScI OPUS system were investigated for possible ALMA use.

Control Software (2760)

Progress: Vertex antenna commissioning support. Implemented software to support the Central Reference Distributor/Central Reference Generator/LORR at the ATF. Debugged various problems, most notably a memory leak in the ABM required the system to be rebooted, sometimes several times a night. Finishing the final pieces of software required to support holography.

Issues: Two vacant positions in Socorro (one departure, one ATF support position that was recently approved).

Correlator Software (2780)

Progress: Resolved issues related to ACS installations under Solaris. Hired a new developer for a vacant position, completing the staffing for the group. Intel/VME hardware was purchased in furtherance of real-time Linux evaluation. Similarly, prototype hardware for the correlator data processing (CDP) computer was purchased.

Pipeline Software (2800)

Progress: Began a demonstration project to develop a prototype automated pipeline for reducing repeated VLA snapshot images in the current AIPS++ environment.

Archiving Software (2820)

Progress: A “micro” archive covering the XMLStore interfaces was released. Tests were made of the Apple “Darwin” streaming server/client. This is a possible solution to transmitting bulk data within the system.

Scheduling Software (2840)

Progress: Filled vacant staff position at NRAO.

Observing Preparation and Support (2860)

Progress: The prototype was restructured to allow for use of ACS and micro Archive integration. Import/export of ObsProjects was implemented in the prototype, as was a tree view of observing tool items (e.g., scheduling blocks), as well as a first prototype “expert” class (for Receiver setup). Evaluation of the JskyCat Java display package was started.

Issues: Although the development is entirely in Java, integration with ACS requires C++ libraries and binaries be available. This has complicated development, but the recent progress in binary ACS releases should be a big help.

Off-line Data Reduction (2880)

Progress: Benchmarking and providing support for the AIPS++/IRAM tests. The design of the Simulator was agreed to in a meeting in Socorro.

Issues: Requirements for the lightweight Java-only Simulator ("SimLite") are still under discussion in the SSR.

Data Reduction User Interface (2890)

Progress: Work towards a prototype: test of a Python server calling methods provided by the Telescope Calibration subsystem.

Issues: Requirements still being finalized by SSR.

Telescope Calibration (2900)

Progress: A first working prototype has been implemented. It now needs to be updated for the new version of ACS.

Issues: Work on the third-party library ATM, although well advanced, is stalled due to personnel availability. This is expected to be resolved in March.

Integration, Test, and Support (2920)

Progress: Two vacancies (one at NRAO, one at ESO) were filled. A first monthly integration was held. An Integration Guidelines document for subsystems document was written.

Issues: The first monthly integration revealed, as expected, various issues (e.g., missing makefiles, incomplete release tagging) to be resolved for subsequent months.

2.8 System Engineering and Integration IPT

Work in the first quarter 2003 was dominated by setting up and organizing the ALMA SE&I IPT. The main task was the preparation of the top level documents indicated in the previous quarterly report. On both the NA side and the EU most of the IPT members were newly appointed. In January a meeting of the entire IPT was held in Socorro to work on requirements documents and to define the structure and priorities. It was agreed that the SE&I IPT is responsible for the following tasks:

- ALMA Technical Management
- Engineering

- Integration
- Product and Quality Assurance

It is understood that the ALMA Safety Committee, which reports directly to the JAO, will write the ALMA Safety Plan plus safety procedures and policies for construction and interim operations. Also, standards related to the safety aspects of engineering will be established by the ALMA Safety Committee. Therefore safety issues at this level will not be among the SE&I tasks.

2.8.1 Management

Progress was made in setting up the SE&I IPT structure. A System Engineering Management Plan is in preparation and available as first draft. The level two and three milestones were revised and updated. Weekly progress meetings of the IPT are held and an Action Item list is maintained. Communication with the other IPTs is done by regular working meetings on the North American and European sides and jointly.

2.8.2 Engineering

The engineering activities can be divided into the following main subjects:

- System Performance Requirements

Work started on the preparation of an ALMA system requirements document. This work is done together with the Science IPT and shall specify and summarize the ALMA top level performance requirements. This will be based upon the existing text in the ALMA Project Book.
It was decided last year to also establish sub-system and lower tier requirements documents as defining documents for the project. This approach enables the SE&I to track requirements and the compliance statements more easily. These several documents will replace the ALMA Project Book as the location of the detailed requirements of the project.

- System Design and Analysis

The system top level design is almost finalized. However detailed system design activities are ongoing. The emphasis was on the error budget allocation between the antenna, back-end and front end sub-systems for phase and amplitude stability. In addition the ALMA system block diagrams were updated and refined and a system design description is in preparation, which also includes the top-level sub-system design and the corresponding design justification.

- Interface Control

For the definition of establishing and controlling the interface requirements and design a interface control document management plan was prepared, which also included updated interface design template tables. That document will enter the approval process soon. The sub-system to sub-system interface status table was updated and some work was done on preparing and reviewing ICDs. Priority was given to ICDs needed for the tendering process like the antenna to antenna station ICD.

- Engineering Specifications/Standards and Environment

The needed engineering specifications/standards were identified and the preparation started. Focus was on the electrical engineering standards and the environmental specification. The standard for power plugs and sockets, and the power quality specification were submitted for approval. The remaining electrical standards like electromagnetic compatibility, radio frequency interference, electrical design specification, and the environmental specification will be submitted for approval soon.

2.8.3 Product Assurance

An early draft Product Assurance Plan was prepared, but is still in discussion within the SE&I IPT. The web based ALMAEDM wide document management system is now fully operational and in use. However some aspects of that system need to be improved. There is some imbalance between the IPTs and to which level the ALMAEDM system is used.
Another topic which needs to be improved is the speed of the document approval and change control process. SE&I is working on these issues and will improve the current situation.

The main purpose of the product tree is to describe the hardware breakdown of the ALMA system. It also provides a numbering system for ALMA documents. The Product Tree is under revision and will be updated based on input from the different IPTs. The product tree will need to be adapted to the production phase by making provision for parts lists and item serial numbers.

2.8.4 Integration

The main forthcoming integration activity of SE&I will be the lab system integration of ALMA prototypes hardware and software scheduled to begin 1-January-2004. Planning will be a growing task in Q2 2003.

2.8.5 On-Going Work

On-going work	Due date	Progress	Comments
SE Management Plan submitted	1-May-2003	on-going	draft 28-Feb-2003
Product Assurance Plan submitted	1-May-2003	on-going	draft 12-Feb-2003
System Block Diagram distributed	4-Apr-2003	on-going	version F ready for distribution
ICD Management Plan submitted	1-May-2003	on-going	draft 12-Feb-2003
Electronics Design Specification and Guidelines submitted	1-Jul-2003	on-going	outline available

2.8.6 Significant Issues

The document approval and change control process for ALMA needs to be reactivated. SE will actively address this need in Q2 2003 and will reduce the large queue that is awaiting action.

A complete list of necessary project requirements documents needs to be agreed upon and maintained. These documents shall be submitted for review by the end of Q3 2003.

2.8.7 ATF Antenna Evaluation Group (AEG)

Prototype Antenna Evaluation Planning

Staffing:

1. A technician has been hired to provide support for the AEG and other staff working at the ATF. Greg Chavez started work for the ATF in January.

2. Jeff Mangum has recruited a new member of the Antenna Evaluation Working Group (AEWG). Henry Matthews of the James Clerk Maxwell Telescope has agreed to participate in the prototype antenna evaluation tasks. The AEWG is a group of scientists and engineers who have expressed an interest in assisting the AEG with the evaluation of the ALMA prototype antennas. The continuing members of the AEWG are Michael Bremer (IRAM), Bryan Butler (NRAO), Jose Cernicharo (CSIC), Kristy Dyer (NRAO), Steve Myers (NRAO), Angel Otarola (ESO/NRAO), Jose Antonio Lopez Perez (OAN), Eva Schinnerer (NRAO), Pat Wallace (MRAO), and Fabian Walter (NRAO).

Communications:

The Antenna Evaluation Group (AEG) continues to hold bi-weekly teleconferences. During these teleconferences the detailed planning associated with the evaluation of the VertexRSI Prototype and AEC Prototype is discussed. Most recently, this planning has taken the form of:

1. The production of reports describing the installation and use of measurement systems to be used to characterize the prototype antennas;

2. Further definition and planning associated with the major antenna evaluation tasks, which are pointing, surface, radiometric, and monitoring and diagnostics evaluation;

3. Organization of the manpower necessary to execute the major antenna evaluation tasks;

4. Updates to the antenna evaluation task planning resulting from changes in the prototype antenna delivery dates.

Note that these teleconferences include the participation of representatives from the Computing (Ralph Marson, Kevin Long), Front End (Antonio Perfetto), and System Engineering (Dick Sramek) IPTs. The participation of the AEG members from Japan is limited to only every other teleconference, during which discussion is limited to the evaluation planning for the prototype antennas.

Documentation: The AEG and AEWG continue to develop the ATF workspace within ALMAEDM as an information storage and distribution system for ATF activities.

Organization: The AEG has installed two new reporting systems to serve two functions: aid in the solution of hardware and software problems and allow for easy production of ATF site activity reports:

1. ATF Site Reports. This web-based form is accessed from the ATF web page (http://www.tuc.nrao.edu/~jmangum/alma/atf). ATF staff are expected to use this form to report general ATF activity on a weekly basis.

2. ATF Problem Reports. Based on the popular "wreq" system used to track computing problems at the NRAO Socorro and Tucson sites, this system will allow ATF support staff to track and solve hardware and software problems at this facility. This system is also accessible from the ATF web page.

ATF Site Development

The AEG has nearly completed the installation of the testing infrastructure at the ATF site:

1. The ATF Control Room has been made into a functional telescope control center.

2. Real time measurements from the weather station instrumentation is now fed into the ATF monitor data archive once per second.

3. Living accommodations at the ATF have been improved by upgrading the VLA visitor apartments and dining area. New furniture and appliances have been installed in these areas.

Current AEG Evaluation Task Timetable

The current major evaluation task schedule completion dates, based on a 2003-03-19 delivery date, are listed in the table below:

VertexRSI Holography	2003-07-03
VertexRSI Optical Pointing	2003-08-25
VertexRSI Radiometric Evaluation	2003-12-26
AEC Holography	2003-10-10
AEC Optical Pointing	2003-11-17
AEC Radiometric Evaluation	2003-12-29

Problems and Concerns

1. The continuing delays in the delivery of VertexRSI prototype have significantly increased the risk associated with the evaluation of the prototype antennas. It is becoming increasingly difficult to maintain a

schedule which completes evaluation of both prototype antennas by 2004-01-01.

2. The AEG has obtained little information regarding the basic antenna systems which comprise the VertexRSI prototype. For example, an accurate description of the antenna metrology system, requested several times, has yet to be delivered. This information is essential to the evaluation program.

2.9 Science IPT

2.9.1 Progress and Goals

During December - February, a significant part of the Science IPT activity continued to focus on the ALMA array configuration. Revised ICDs (versions C and D) for the inner 172 antenna pads of the ALMA Configuration were submitted (see 1.9.3 for details), meeting a Level 2 Milestone. Work continued on the design of a long baseline part of the plan compatible with this new inner portion.

The other main activity of the Science IPT concerned the production of the calibration plan for ALMA. A Level 3 Milestone for December 2002 was met with the production of a draft calibration requirements document, ready for further review. This document updates Project Book Chapter 3.1 and a review finished at the end of February, 2003, (Level 2 Milestone). The Calibration Group discussed new reports for the two amplitude calibration devices being considered for ALMA: the subreflector dual load device, being tested by the Berkeley Illinois Maryland Association (BIMA), and the semi-transparent vane, to be tested at the IRAM 30m.

The Science IPT arranged the agenda, minutes, and telecon for the monthly ASAC telecons. Science IPT members from Europe, together with B. Butler representing the NA Science IPT, gathered in Leiden 18-20 December to discuss various issues, focusing on the calibration plan. Joint NA/EU Science IPT staff and Calibration Group telecons were held monthly, and the weekly NA Science IPT telecons were continued.

Anticipated activity in the next quarter: Level 3 Milestones and above; with some modifications made as a result of the Leiden meeting.

Milestone	Level	Scheduled Completion
9.380.98151 Configuration antenna motion logic	3	31 March 2003
9.380.98152 Revise configuration	3	31 March 2003
9.380.9805 Calibration requirements Review	2	28 February 2003

9.380.98121 Atmospheric modeling software available	3	31 March 2003
9.380.98122 Draft specifications for calibration devices	3	31 March 2003
9.380.9835 Draft WVR technical aspects (with FE IPT)	3	31 March 2003

The draft calibration requirements document (Level 3 Milestone) was produced in December for reviews. The Project Scientist issued a call to the ASAC during November to provide some examples for this exercise; they were collected, discussed, and disseminated. The calibration requirements document with science examples constitutes a Level 2 Milestone met 28 February 2003. A related Level 3 Milestone due in March 2003 will deliver draft specifications for calibration devices for reviews.

One Level 3 Milestone to be achieved in March will deliver to the project the atmospheric modeling software being developed by Pardo. This activity is in its final stages; ATM has been delivered to the European ALMA Data Analysis Center software project. This and other Level 3 and 4 Milestones lead toward the completion of the calibration strategy for ALMA, a Level 2 Milestone scheduled for September 2003.

In March 2003, there are many Level 3 Milestones concerning various aspects of calibration. A draft of the bandpass calibration plan will be presented, following publication and review of an ALMA Memo describing limitations of bandpass calibration using astronomical sources. Also, a draft of the phase and amplitude calibration plans will be produced, including total power calibration of ALMA. A further Level 3 Milestone will review the SSR plan for all phase calibration techniques. Other items scheduled for March include a draft of the antenna location determination plan, a draft of the delay calibration plan, a draft of global antenna pointing plans, reference pointing plans, focus calibration plans, and a draft of an operational model for calibration, including ideas on sequence of moves and calibrations, dynamic scheduling, and number of antennas needed in calibration subarrays.

Leading to the September 2004 report on water vapor radiometer strategies (Level 2), a March 2003 Level 3 Milestone will present a draft document on technical aspects of the WVR, written in consultation with the Front End IPT.

By March 2003, the Science IPT will prepare a draft plan on how to achieve the Atacama Compact Array (ACA) goal, that is, flux-recovered imaging in all ALMA bands.

2.9.2 ASAC

The Science IPT facilitated the ASAC Telecons held on 4 December 2002, 8 January 2003 and 5 February 2003. It also supported discussions of the calibration examples, many contributed by ASAC members. In anticipation of ASAC discussions on the topic, the Science IPT gathered arguments to provide scientific reasons for favoring an array consisting of antennas of like design.

2.9.3 Configuration

Conway finalized the ALMA configuration specifications document for the inner 172 pads covering 4.5 km. A Version-C was submitted in early January, reflecting the pad positions staked out at the site (see Figure 21 above) in late November 2002. Joint Site - Antenna - Science IPT discussions concerning transporter access in January made it clear that the error budget for the specified nominal minimum pad-to-pad distance was ill defined, and that this value should be increased to 15.15m. Given this new specification a revised configuration plan (Version-D) was submitted in early February for the inner 72 pads by scaling the distance of these pads from the center by 0.6% and moving a few pads a few centimeters. The new version also gave a proposed breakdown of the pad position error budget to be considered and accepted by the involved IPTs as part of the review process, as well as a expanded scientific justification for the array plan. An example reconfiguration plan was also produced to aid the site IPT in the design of road topology, although the final reconfiguration plan will be part of a future document.

Conway also did significant work in two areas of algorithm development. The first is the application of a new algorithm for optimum uv weighting to be applied to ALMA data. This "beam forcing algorithm" selects a weighting scheme to force a particular main lobe shape while minimizing sensitivity losses. The increase in noise to produce perfectly Gaussian beams by weighting was found to be between 0.5% and 1% for the intermediate ALMA configurations. In addition sensitivity losses found when re-weighting data to obtain circular beams at extreme declinations such as +30 and +40 degrees were found to be only 5% to 10%. An important consequence is that it is not worth designing specific NS extended arrays for long or intermediate configurations. Specific NS optimized arrays are required however for the compact arrays where shadowing losses become significant. Second, software for optimizing the reconfiguration sequence has been developed. Using such algorithms significant improvements in an (unweighted) main lobe shape can be achieved for intermediate configurations. Software to optimize the reconfiguration for far North or South sources minimizing shadowing losses has also been partially developed.

Holdaway continued designing the interface from the largest Conway array to the more extended Y+ configurations. Two options are still under consideration. The first option considers the largest Y+ configuration as being separately optimized, with the intermediate steps offering somewhat poorer performance. Since the goal of this configuration is high resolution, this is the favored option at this time. A second option considers a series of semi-continuous moves (4 or 6 antennas at a time), with optimization of each step as a "stand-alone configuration." The two approaches have been debated at the last ASAC telecon, and further work by Holdaway has quantified the expected differences. Operational considerations are also being taken into account. Together with Conway, the impact of optimized weighting on the sensitivity versus sidelobe tradeoff has been analyzed. Simulations in which the largest configuration is complemented by short observations from the 4.5 km array (or a more compact one) may still be useful to define the optimal shape of the largest Y+ configuration.

2.9.4 Calibration

Butler organized and moderated a ALMA Calibration Group telecon 16 December. Action items included review of calibration examples, semi-transparent vane test plan, and work on polarization requirements. Examples were presented by Guilloteau at the Leiden meeting, as was a report on the test plan. Minutes were published both of this meeting, and of the Leiden meeting, for general information. A second telecon on 7 February concentrated on progress toward Milestones, ALMA Memo reviews, calibration device performance tests, including a first report from the BIMA dual load tests, and proposals for absolute calibration introduced by Welch and Guilloteau.

In ALMA Memo No. 402, Holdaway showed that offsets in the illumination of the dishes by the feeds would result in a phase gradient in voltage patterns, a serious problem for high dynamic range mosaicing. In a followup to that memo, Holdaway proposes a simple correction algorithm which can remove essentially the entire effect of the voltage pattern phase gradient. In the report, he explores how to measure the offsets and to apply corrections to the (u,v) coordinates.

Bacmann and Guilloteau studied the standing waves that can arise between the feed horn and the secondary mirror in the ALMA antenna. They considered several configurations: a normal subreflector, a subreflector with a scattering cone to reduce the standing waves, a subreflector with an aperture in the centre (if the calibration loads are placed there), and the same system but with a reversed cone within it. A scattering cone is found to reduce the baseline ripple by a factor of 10 with respect to the “naked subreflector,” whereas the aperture increases it by a factor of 2. The reversed cone within the aperture can reduce them by a factor of 2, to about the 1% level. Hills has carried out calculations of these effects using a somewhat different approach which focuses on the spatial distribution of the reflected signals. The results are consistent.

Bacmann and Guilloteau also made some progress on bandpass calibration. The required precision of the sideband gain ratio and consequent integration times as functions of frequency were derived, and are currently being used to estimate the error induced by the calibration method on the frequency dependence of the calibration temperature.

Hills and Isaak have prepared a detailed note on the calibration and internal processing of the water vapour radiometer data and investigated the effect of elevation differences between the source and the phase calibrator.

Martin-Pintado and others finished the design and construction of the first semitransparent (S/T) vane device for tests. Several hours were scheduled at the IRAM 30-m for implementation and first tests of the S/T vane calibration scheme at 3 mm. Due to the limited amount of telescope time and the bad weather conditions, most of the tests were made with the cold and ambient loads to characterize the absorption coefficient of the S/T vane as a function of frequency. Additional data have been taken in a different day and the reduction is underway.

Following a query from the Front End IPT, the Science IPT discussed the appropriate band for use with the 'polarization widget' lying above the dewar. After much discussion involving a large segment of the user community, a consensus was reached that the widget should be employed in conjunction with Band 7 centered at 345 Ghz.

2.9.5 Site Characterization

Radford and Nyman proposed milestones for the site characterization group, which were discussed and merged into the Science IPT milestones. Rivero and others have made one trip per month to the Chajnantor site for maintenance and repairs. A weather station to be used at the OSF site has been purchased.

Working with NRAO-Green Bank employees C. Beaudet and G. Watts, an initial radio frequency interference survey was made of Chajnantor during December 2002 (see Figure 22 above). This survey will enable specifications to be set for limits to emission from other projects such as the Cosmic Background Interferometer (CBI), ASTE, APEX, and others.

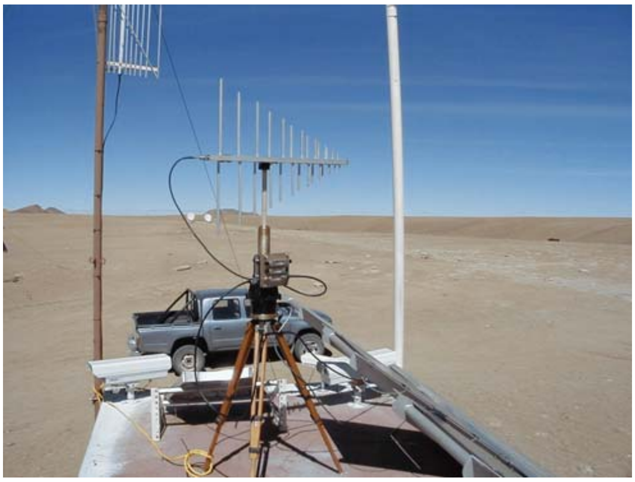

Figure 22. Equipment for a spectrum survey of the site conducted by the NRAO - Green Bank spectrum

Nyman, Rantakyroe, Perez, and Rivero have finished an ALMA Memo with Delgado as first author on methods to determine the precipatable water vapor and delay from the 183 GHz radiometers on Chajnantor. The analysis of new 183 GHz radiometer data has continued. The aim is to achieve the best possible determination of the water vapor, both for phase correction analysis and for comparison with the water vapor determined from satellite data obtained recently by Erasmus. The work on the wind spectrum analysis using data from the fast anemometer has started.

2.9.6 Science Software Requirements

This group met face-to-face in Garching in December, with various members of the Science IPT present; much of the effort went to discussions of AIPS++. Since this group belongs to the Software IPT, details should be sought in that report.

2.9.7 Imaging

Pety worked with Japanese colleagues to help them set up new ACA - ALMA simulations using the IRAM software including thermal noise and the effects of source declination. The expertise was successfully transferred to Tsutsumi during a week-long visit to IRAM Grenoble, and subsequently used in Japan to investigate different ACA options. Pety also coordinated the Phase II part of the "AIPS++ Reuse Analysis Test", specifically the testing of the calibration steps needed to reduce PdBI data within AIPS++.

Holdaway proposed a series of tests to ensure that prototype antennas may be capable of meeting the fast switching expectations. The Science IPT discussed these, making several suggestions.

Although it would be over-reaching to call it imaging, the first of the ALMA prototype antennas successfully detected the Moon in January.

2.9.8 Organization

The organization and planning for the Science IPT during the construction phase of ALMA was reviewed and discussed during the face-to-face meeting in Leiden. Telecons between the three project scientists continue, a monthly teleconference for the whole Science IPT, and weekly teleconferences of the North American Science Team.

2.9.9 Meetings, Outreach and Public Education

Most of the European members of the Science IPT, along with Butler (North American member of the Science IPT), and part of the ESAC, met face-to-face in Leiden December 18-20. The first day of the meeting coincided with the last day of a large meeting on the science program for the HIFI instrument on the Herschel Submillimeter Observatory. Joint preparatory studies for these missions, ranging from the availability of line catalogs to modeling tools, were discussed. A joint HIFI-ALMA calibration meeting was held on the second day. The plan of work for the European members of the Science IPT and related milestones were discussed, and progress reports on calibration tasks were presented for the remainder of the meeting. Presentations and minutes are available through ALMAEDM.

Wootten represented ALMA at the NRAO booth at the American Astronomical Society meeting in Seattle Washington. At Caltech on other business, he discussed the state of ALMA informally with astronomers in the Caltech Submillimeter Observatory group, and with the Owens Valley Radio Observatory (OVRO) group. Discussions included a meeting with postdocs and graduate students. In February he visited OVRO for discussions on practical issues and for observing.

Following the November 8 community meeting at ESO on "Science Operations with ALMA", a questionnaire was sent to the participants on issues related to plans for the European Regional Support Center, software and enhancements to the baseline ALMA project. The responses have been summarized and are posted, together with a set of recommendations by the ESAC, at http://www.eso.org/projects/alma.

Cox, Dutrey, Guilloteau and other French members of the Science IPT organized and participated in a French national meeting on ALMA in early January, attended by about 100 astronomers. Van Dishoeck continued to give presentations on ALMA to various Dutch astronomy and chemistry (student) audiences.

2.9.10 Concerns

The Science IPT re-iterates its concern whether the Level 2 Milestone of “Review of Tests of Calibration Strategies on Prototype Interferometer” can be met by December 2004. Although most elements of the prototype interferometer will be in place at the ATF by early 2004, the prototype receivers may not arrive until mid 2005 for testing later that year. The Science IPT believes that this must be done earlier, if these calibration tests are to involve the actual ALMA receivers. Differences between the evaluation receiver interfaces and those of the prototype receiver suggest that substantial work would be required to implement the evaluation receivers for the prototype interferometer. The project should construct a plan for component verification at the prototype interferometer as soon as possible. Since the Science IPT interacts with many other IPTs, a critical look whether its milestones are compatible with those of different IPTs is needed.

Acronym Definitions

ABM	ALMA Bus Master
ACA	Atacama Compact Array
AEC	Alcatel/EIE Consortium
ACS	ALMA Common Software
ACU	Antenna Control Unit
AEG	Antenna Evaluation Group
AEWG	Antenna Evaluation Working Group
AIPS++	Astronomical Information Processing System
ALMAEDM	ALMA Electronic Document Manager
AOS	Array Operations Site
ASAC	ALMA Science Advisory Committee
ATF	Antenna Test Facility
BIMA	Berkeley Illinois Maryland Association
BUS	Back Up Structure
CDR	Critical Design Review
CFRP	Carbon Fiber Reinforced Plastic
CSIC	Consejo Superior de Investigacion Cientificas
CVS	Concurrent Version System
DC	Direct Current
DSB	Double Side Band
DTS	Data Transmission System
EAB	European ALMA Board
ESAC	European Scientific Advisory Committee
ESO	European Southern Observatory
FE	Front End
FEIC	Front End Integration Center
FIR	Finite Impulse Response
FPGA	Field Programmable Gate Array
FO	Fiber Optics
FTE	Full Time Equivalent
FTS	Fourier Transform Spectrometer
HIA	Herzberg Insititute of Astrophysics
ICD	Interface Control Document
IF	Intermediate Frequency
IPT	Integrated Product Team
IRAM	Institut Radio Astronomie Millimetrique
JAO	Joint ALMA Office
JBO	Jodrell Bank Observatory
LO	Local Oscillator
LORR	Local Oscillator Reference Receiver
LTA	Long Term Accumulator
LVDS	Low Voltage Digital Signal
MMIC	Millimeter Integrated Circuit
MRAO	Mullard Radio Astronomy Observatory
NAOJ	National Astronomical Observatory of Japan
NOVA	Netherlands Research School for Astronomy
NRAO	National Radio Astronomy Observatory

OAN	Observatorio Astronomico Nacional
OSF	Operations Support Facility
OVRO	Owens Valley Radio Observatory
PCB	Printed Circuit Board
PDR	Preliminary Design Review
PTC	PoinTing Computer
RAL	Rutherford Appleton Laboratory
RF	Radio Frequency
SE&I	System Engineering and Integration
SIS	Superconducting Insulator Superconducting
SRON	Space Research Organization Netherlands
SSR	Scientific Software Requirements
UI	User Interface
XML	Extended Markup Language
YO	Yebes Observatory
2GC	2nd Generation Correlator