MILLIMETER ARRAY
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END MARCH 1999

Financial Statement

The month-end financial statement is attached. This statement reports by WBS-1 category for the project (1) the current allocations, (2) the February 1999 expenditure, (3) the Project to date expenditure, (4) the commitments, and (5) the uncommitted balance. The Project as a whole is spending at the rate planned. To this point it has been possible to negotiate all the planned contract services at amounts at or below the costs budgeted.

Milestones and Deliverables

The table of milestones and deliverables is appended to this report. This table is kept up-to-date in an electronic form on the MMA WWW pages and may be accessed at any time. The important Project milestones are being met. Most importantly, the key deliverable of the MMA Design and Development Project, a prototype antenna of 12-meters diameter to be delivered to the NRAO VLA site by June 2001, is on track with the issuance of the Request for Proposals (RFP) as scheduled on March 30, 1999. The RFP is being made available to all antenna vendors expressing an interest in reviewing it. Responses to the RFP are due by June 30, 1999; the Project goal is to negotiate and sign the antenna contract by 1 October 1999. This one contract is expected to require the commitment of approximately one-third of the total $26M funding available over 3 years for the entire MMA Design and Development Project.

Other project deliverables realized in March 1999 include publication of the Project Interface Control Standards established by the System Engineer, adoption of the Project Documentation Policy and distribution of the preliminary WBS for the entire US-only MMA project for review by the Division Heads.

International Partnership

One of the foremost goals of the MMA Design and Development Project is to secure international partners in the project. On March 30, 1999 a critical step was taken toward this goal: the NSF and representatives of five European organizations initialed a Memorandum of Understanding for the joint Design and Development of a large millimeter and submillimeter wavelength array to be known as the Atacama Large Millimeter Array (ALMA). Once the MOU is signed by all parties the MMA Project will be subsumed by US participation in the ALMA

MILLIMETER ARRAY
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END APRIL 1999

Financial Statement

The month-end financial statement organized by WBS level-1 category is attached. At the end of April $6.25M of the $17.9M available for expenditure had been expended or committed; this represents 34.8% of the total. The Project is spending at the rate planned; it has been possible to negotiate each expected contract service at the rate anticipated in the project baseline. A major goal is to husband the project contingency until the contract for the prototype antenna can be placed.

Milestones and Deliverables

The table of milestones and deliverables is appended to this report. The report, which is kept up-to-date in an electronic form on the MMA web pages, reports the baseline plan for the milestone dates, the current plan and the actual delivery date. In April 1999 only one milestone was scheduled, that for the design review of the holography system. This particular milestone review was deliberately delayed by 3 weeks to permit the European representative of the LSA project, Richard Hills, to participate.

In April a decision was adopted by the Project to use VxWorks as the real-time operating system (RTOS) for the test correlator. The test correlator is the single baseline correlator to be used for the 2-element test interferometer made up of the MMA prototype antenna and the European LSA prototype antenna that are to be erected at the VLA site. Although this particular decision was not an identified project milestone, it represents another area where the MMA Project decision was made in concert with the desires of the European LSA group. However, in this particular case the Europeans approved VxWorks as the RTOS for the test correlator only; the RTOS decision for the test interferometer antenna control, and for the ALMA Project, will be made jointly later.

International Partnership

As the two examples noted above illustrate, the MMA Project team is working now with the European group in anticipation that the MOU for the joint US-European ALMA Project soon will be signed. An important aspect of that collaboration, the simultaneous procurement of two prototype antennas–one by the MMA Project and the other by the European LSA Project–is proceeding successfully.

MILLIMETER ARRAY
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END MAY 1999

Financial Statement

The month-end financial statement organized by WBS level-1 category is attached. At the end of May $6.77M of the $17.9M available for expenditure had been expended or committed. This represents 37.7% of the total. The project is spending at the rate planned. A major goal continues to be to resist expenditure from the contingency funds until the major contract of the design and development phase, the contract for the prototype antenna, is placed.

Milestones and Deliverables

The table of milestones and deliverables is appended to this report. The report, which is kept up-to-date in an electronic form on the MMA web pages, reports the baseline plan for the milestone dates, the current plan and the actual delivery date. In May 1999 there was a major Preliminary Design Review (PDR) for the intermediate frequency (IF) system, and for the fiber optics (FO) system. The design of both these systems is heavily dependent on whether the IF data is to be transmitted in analog or digital form; because both are viable options the MMA Design and Development planning has included design work on both leading to a decision scheduled for October 29, 1999. The experts assembled for the IF and FO PDRs strongly recommended that a decision be taken now in favor of digital transmission. Since those experts included not only individuals from U.S. institutions but also people from institutions in Europe who are our potential colleagues in the ALMA project, this recommendation was forwarded to the Project Change Board. The change was approved and digital IF transmission is now the Project Baseline.

International Partnership

Involvement of the European groups in the MMA PDRs has the advantage not only of broadening the technical participation in the PDRs, and hence putting the MMA decision basis on still firmer ground, but it also serves to jump-start the agreement on the same issues that ultimately will be needed for the ALMA Project.

Progress Report: Level-1 WBS Tasks

1. Administration

The MMA Oversight Committee met May 12-14 at the NRAO offices in Tucson, AZ. In preparation for that meeting the two principal MMA Planning documents, the *MMA Project*

MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END JUNE 1999

Financial Statement

The month-end financial statement organized by WBS level-1 category is attached. A total of $528k was expended in the month of June 1999. The Project total expended and committed at the end of June was $7.268M, an amount that is 40.5% of the funds received to this date and available for expenditure. In the past month there have been no unexpected expenditures; the Project continues to expend at the rate planned. At month's end $953k remains in the contingency account, an amount that is unchanged from the previous month.

Milestones and Deliverables

The table of milestones and deliverables is appended to this report. This table may be accessed at any time on the web where it is kept in electronic form and updated following each weekly meeting of the MMA Division Heads. At the end of June bids were received from four contractors for the MMA/ALMA prototype antenna. This is one of the major milestones of the Design and Development phase of the MMA Project. The fact that four manufacturers were willing to commit to fixed price bids on the prototype antenna indicates that the technical goals specified by the Project for the antenna are both feasible from an engineering standpoint and practical from a manufacturing standpoint.

International Partnership

On June 10, 1999 the NSF and partner agencies and institutions in Europe signed a Memorandum of Understanding for joint cooperation on the Design and Development phase of the Atacama Large Millimeter Array (ALMA). This represents completion of the second major milestone of the MMA D&D Project, viz. an international partnership in the project.

Progress Report: Level-1 WBS Tasks

1. Administration

The principal administrative activity in June was preparation for the Project Audit Panel meeting to be held July 7-9, 1999 in Charlottesville. The construction cost estimates for the MMA U.S. Reference Project were refined by using the technique for establishing contingency costs that was used by the LIGO project. This involves establishing, separately, contingency percentages for technical risk, schedule risk and cost risk for each item in the WBS. These individual contingency costs are then *rolled-up* to the final

figure. The resulting construction costs were summarized in an addendum to the May 1999 cost estimate for construction of the MMA U.S. Reference Project. That Addendum was printed for distribution to the Audit Panel.

2. Site Development

A contract was let to a U.S. Architecture and Engineering firm to review critically the electrical power system planned for the MMA Chajnantor site.

3. Antenna

At the deadline on June 30 four antenna vendors submitted bids for the MMA/ALMA 12m prototype antenna. All four appear to be compliant with the terms of the antenna Request for Proposals. The firms submitting bids are: Vertex, Mitsubishi, Agra Coast, and Antedo. A proposal review process involving three committees (Technical evaluation, Business evaluation and Contract selection) has begun.

4. Receivers

The required two type-D 3mm SIS mixers were delivered to Tucson for use in the antenna evaluation receiver. Refinements were completed to the vacuum window design and to the window fabrication process. Software controllers for the two automated test racks that are used to characterize SIS mixers were completed. A common interface is being developed for testing either single-ended SIS mixers (the "JT-1" rack) or balanced mixers (the "JT-2" rack).

5. Local Oscillator

The phase noise performance of all components in the prototype tunable phase locked LO source was verified to be within the specifications. Initial design of the phase lock loop was completed and parts for the prototype system were ordered. Results from the university group working on development of a photomixer for a possible photonic-based LO source remain unsatisfactory. Further design iterations are underway. Meanwhile, the MMA staff working on this development is exploring other photomixer design options in partnership with commercial and university groups.

6. IF System

Test equipment was requisitioned as necessary for the breadboard prototype of the intermediate frequency (IF) total-power subsystem. Many budgetary cost estimates and some quotations were obtained from vendors for many components. These were the basis for a detailed bottom-up estimate of the cost-of-construction of the IF system for the MMA U.S. Reference array. Most of the group effort was in preparation for the NSF Audit Panel of July 7-9.

7. Fiber Optics System

A HP logic analyzer for the digital IF transmission subsystem has been defined as a major expense item for test equipment procurement. The FO Project Engineer attended the IEEE Microwave Symposium for information on high-speed fiber optics. Cost estimates and quotations were obtained for all components needed in the bench prototype systems. Considerable effort was expended in preparation for the NSF Audit Panel.

8. Correlator

The numerical program that simulates performance of the digital filter is complete and has been delivered to the filter design engineers for their use. Software to control the correlator to be used for the test interferometer will be derived from the software that controls the correlation spectrometer at the NRAO Kitt Peak telescope; the enhancements needed to that software for MMA purposes are being investigated.

9. Computing

A draft interface specification document for the monitor and control system (WBS Milestone 9.4.4) was circulated within the project. This interface defines how devices are physically connected to the monitor and control field bus, and to what protocols they respond. The system is based on the Controller Area Network (CAN) protocol using COTS devices.

A U.S. group from NRAO, BIMA/NCSA and OVRO attended a joint software meeting at ESO for initial discussions about how the software effort should be divided between the U.S. and Europe for the D&D and later phases of the joint ALMA project. The MMA team agreed to evaluate the ESO Common Software that was developed for the VLT Project.

10. System Integration

The overall MMA system block diagram is being specified to the next level of detail. Current Project issues concern the precise specification of the IF band limits and of the detailed specification for the power distribution system. A system specification for response of the system to shock acceleration (e.g. from a seismological event) is needed and a draft of such a specification is being circulated. This affects all elements of the system including receiver and rack mounting fixtures.

11. Calibration and Imaging

Simulations of CO observations of high redshift galaxies based on the molecular distribution in the nearby galaxy M51 are being used to set instrumental specifications for the ALMA project. One part of this process is the setting of image fidelity standards by which the simulated images can be compared. A draft of such *rules* is being constructed for review by all groups involved in the ALMA project. Costing of the 183 GHz water vapor radiometer is being based on the experience of the Canadian group in purchasing such a radiometer for the JCMT. A design review was held with the European and Japanese groups regarding the ALMA plan for water vapor radiometry. A meeting summary was posted to the web.

MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END JULY 1999

Financial Statement

The month-end financial statement organized by the principal WBS categories is attached. A total of $418k was expended in the month of July 1999; this is nearly $100k less than has been expended in previous months, a decrease that is directly attributable to the fact that the MMA Project staff were occupied with preparations for the NSF Audit Panel meeting and could give only partial attention to their Project tasks. The reduced monthly expenditures, and the diverted attention, will introduce some delays from which we will have to take measures to recover. The Project total expended and committed at the end of July was $7.945M, an amount that is 44.3% of the funds received to this date and available for expenditure. The Project continues to expend at the rate planned and continues to guard the contingency in anticipation of the antenna procurement in October 1999.

In addition to the chart of accounts that tabulate the spending for the month of July 1999 we also include this month a concise two-page summary of all the MMA accounts. The account numbers are derived in a transparent way from the associated WBS numbers. Since this is our first use of the particular tabular presentation a few words of description are in order.

The three columns labeled *Account Budgets* are the allocations for the years 1998, 1999 and 2000 respectively. The percentage in the second row of these columns indicates the percentage of those allocated funds that has been received by the Project–hence, 100% of the funds for both 1998 and 1999 have been received and none of the funds for 2000 have been received. The second block of three columns, those labeled *Expenditures and Commitments,* are the funds that have been spent or committed in each budget category for each year. Finally, the third block of two columns, those labeled *Totals Project to Date,* is the total amount budgeted–the sum of the funds allocated that have been received–and the total amount, in dollars, of those funds that have been expended and committed (called *Exp & C)*.

This concise tabular presentation of the MMA/ALMA-US accounts is given here, and will be included in all future Monthly Reports, as the material from which the Project will report Earned Value. The Earned Value analysis will begin with the August 1999 Monthly Report.

Following the budgetary tables there is also presented this month a table of the MMA Project staffing by WBS level-1 category. The numbers of people reported in the two columns of this table differ in the following respect. In the column labeled *Number of Persons Participating in the Activity* we tabulate all those people who contribute to the indicated WBS activity; many of

these contributions are part-time but the participating individuals are counted as integral units. Several people contribute in more than one WBS activity and when that is the case they are counted, in this column, more than once. The column on the far right, the column labeled *Full Time Equivalent Staff* rectifies the preceding column and properly accounts for the fractional contributions of each person, if any, such that the sum of any person's contribution is no more than 1.0. In this column are all, and only, the FTEs whose salary is paid by the MMA Project.

Milestones and Deliverables

The table of milestones and deliverables is appended to this report. This table may be accessed at any time on the web where it is kept in electronic form and updated following each weekly meeting of the MMA Division Heads. By the end of July 1999 three of the four major milestones of the MMA Design and Development phase of the Project had been met; these are:

1. Recommendation to the NSF of an international partnership in the Project (completed June 10, 1999);
2. Provision to the NSF of a thorough cost estimate for the construction of the MMA that could be audited (that estimate and the audit process were completed July 9, 1999);
3. Receipt of bids from antenna contractors for fabrication of a prototype antenna that meets the MMA specifications and is within the budget envelope specified by the Project (received June 30, 1999).

The fourth major Project milestone in the Design and Development phase, permission to use the selected site in Chile, is one that the NSF and our European partners in the ALMA Project agreed would be done in common; its achievement is no longer solely in the province of the U.S. MMA Project.

The milestones and deliverables remaining on the MMA Project list are all focused on preparing for the construction phase of the Project. They include hardware designs and prototypes, many of which will be evaluated on the test interferometer, together with the preliminary and critical design reviews that are part of the process by which the design for each major subsystem is adopted by the Project. These steps will all be done in close collaboration with our European partners in the ALMA Project.

International Partnership

Agreement was reached between the U.S. Division Heads and the European Team Managers that all future design reviews would be conducted jointly with both partners participating as those being reviewed. The reviewers will be chosen from the U.S. and Europe for every future review and the dates for the reviews will be revised, as needed, to assure full European participation.

At month's end, the European group had received several bids from European antenna vendors in response to their Call for Tender for a prototype ALMA antenna. These bids refer to a prototype antenna with specifications identical to those specified in the U.S. Request for Proposals. The joint U.S.-European procurement for two prototype ALMA antennas is therefore proceeding as planned and is on schedule.

Progress Report: Level-1 WBS Tasks

1. Administration

On July 7-9, 1999 the NSF MMA Project Audit Panel met in Charlottesville to review the planning and cost of the U.S. Reference Project., a fiducial array of 36 10m antennas built on the Chilean Altiplano. Preparations for this meeting, and later discussion of the ideas presented by the Panel, occupied the MMA Division Heads and many of their staff this month. Meanwhile, in Chile an agreement was signed by AUI with CONICYT to facilitate the site characterization tests that are on-going on the Chajnantor site. A formal request was submitted to the Chilean Ministry of Finances related to the tax treatment of AUI in Chile for the purpose of building and operating the MMA.

2. Site Development

An engineering study of the proposed MMA electrical power system was carried out under contract by M3, an Architect and Engineering firm in Tucson, AZ. The deliverable of this contract was received in July 1999; it highlighted engineering requirements for handling the fluctuating electrical load for the antennas. A list of questions was assembled related to *standards* that should be followed for site construction. These questions will be shared with the ESO engineering team who built the VLT in Chile, and with other officials as appropriate.

3. Antenna

An intense review is being conducted of the four proposals received for the 12-meter MMA prototype antenna. Three committees have been formed to evaluate the proposals: (1) a technical committee consisting of MMA and MDC scientists/engineers; (2) a business committee and (3) a contract selection committee. At month's end committee reports from both the technical and business committee had been received by the contract selection committee and they were being reviewed.

4. Receivers

Draft standards were developed for the working dimensions of SIS mixers and for anti-cocking waveguide flanges. Analysis began of SIS mixer design with internal IF pre-amplifiers using two new MMIC IF amplifier designs from S. Weinreb. These designs appear promising with the MMA 4-12 GHz IF. The designs are presently being fabricated at TRW and are scheduled for evaluation in October. As an alternative to the MMIC SIS designs being pursued at NRAO, an experimental SIS mixer for the 210-270 GHz band using a waveguide quadrature hybrid was designed; this will be fabricated by our potential Canadian ALMA collaborators at the Hertzberg Institute. The W-band amplifiers covering 85-116 GHz needed for the antenna evaluation receiver were completed and delivered to Tucson two months ahead of schedule.

5. Local Oscillator

Meetings were held to finalize the design of the first local oscillator. There are three separate options available, each of which needs to be evaluated and a decision made among them.

Initial evaluation of the 110/220 GHz doubler yielded output power far below that expected from circuit modeling. The problem was traced to a large dimensional inconsistency between the

diodes used in the circuit design and the ones delivered. Design of a new mask set for the proper batch of diodes is underway in expectation of delivery within a month. Meanwhile, progress on the design of a 81/243 GHz tripler continues. Several circuit topologies have been examined that would give adequate performance over the ALMA 223-263 GHz band and that are potentially scalable to meet the ALMA requirements for the 614-708 GHz LO. This design work is planned to continue for the next 2 months.

Discussions are underway with JPL to secure a set of power amplifier chips for evaluation as the source driver. These chips will produce 200 mW in the 103-109 GHz band. In return for the chips we will provide JPL with designs to solve oscillation problems related to chip packaging.

Experimental work on a photonic LO reference system continues to progress well. We have proved that it is possible to maintain coherence over fiber 50 km long (well in excess of the ALMA requirement) and that polarization changes in the fiber occur only over long timescales, e.g. minutes, that can be easily monitored and corrected. Polarization mode dispersion will not prevent distribution of the first LO.

6. IF System

Following the MMA Cost Audit, the IF System group established the specifications for the major hardware requirements and requested quotations for those components in the total power subsystem, namely for the detectors, the PIN diode variable attenuators and the bandpass filters.

7. Fiber Optics System

Essentially all the components have been ordered for the prototype digital IF system. The design and components for the digital MUX and DEMUX (i.e. the multiplexor and de-multiplexor) board assumed that the FIR filter would be located at the antennas. A modified design will be necessary to reflect the Project design decision to digitize at the antennas.

8. Correlator

The ALMA test correlator (the single-baseline GBT clone correlator for the test interferometer) is complete except for installation of the VME computer. The correlator system has been timed and the data path has been tested error free from the digitizers to the long term accumulator input.

The correlator design group has been modifying the ALMA correlator design to put the digital filter at the antenna (instead of in the main control room) and to make the correlator system *heartbeat* an even 1.0000 millisecond instead of the previously planned 1.048576 msec. Since the digitizer and filter sections of the correlator both require adjustment for delay model tracking it was decided to put the delay lines at the antenna so the entire tracking delay will now be performed at the antenna. The delay function was moved into the mode selection logic and hence only a modest increase in the amount of logic (and hence, power and RFI) will be required. A block diagram of the current correlator design can be found on the ALMA correlator homepage.

One of the recommendations of the NSF Project Audit committee was that there should be an

alternative way of acquiring the correlator chip design, i.e. an alternative to that previously planned by the Project. Such plans are being developed to allow a more graceful recovery in the event the primary supplier is unable to complete the chip design.

9. Computing

A complete revision of the Monitor and Control interface specifications has been finished and made available to the Project. A programmer from the ESO VLT project will visit the NRAO in Socorro for three months in order to install the ESO *common software* and lead the MMA group in its evaluation. As part of the effort to assemble a single dish control package for the test interferometer, the software control for the NRAO 12-m telescope is being converted to a PowerPC system. Other software being *reused* for ALMA includes the delay model server being adopted from the VLBA system.

A memo was distributed in draft form specifying the data rate output of the ALMA correlator and the computing rates needed for processing this data. Comments on the rates specified in this memo will be used to establish the specifications for the ALMA long term accumulator.

10. System Integration

Overall block diagrams for the ALMA system were completed and released for comment. These are meant to be drafts and they are expected to change based on the comments received by those in the U.S. Project as well as those on the European side of the Project. A memo was distributed summarizing issues related to the optimum choice of frequency band edges for the IF. The Project decision is that the 4-12 GHz band be retained as the baseline.

11. Calibration and Imaging

A Project decision was made to adopt water vapor radiometry for phase calibration based on the 183 GHz atmospheric water line. This choice was made in preference to using the 22 GHz line.

Configuration layout on site is being aided by a collection of aerial photographs that has been made available, and indexed, on the web.

A recommendation was made to the AIPS++ group to put an important emphasis on mosaic simulation software. Having such a common facility available to all those working on optimizing the ALMA imaging performance is highly desirable for evaluating the competing configuration ideas. The AIPS++ Project agreed to this request and will deliver a system with the functionality desired within six months. The ALMA imaging and calibration group will contribute imaging evaluation software.

Imaging studies are underway by both the U.S. and European groups designed to reconstruct, experimentally, images using interferometric and single dish data all taken with antennas of the same diameter.

MILLIMETER ARRAY/ALMA-US
PROJECT STAFFING

MONTH END JULY 1999

WBS Task Name	Number of Persons participating in the Activity*	Full-Time Equivalent Employees
Administration	8	5
Site Development	1	0.5
Antenna	4	3
Receivers	17	13.75
Local Oscillator	9	6.75
Intermediate Frequency	4	3
Fiber Optics	3	2
Correlator	5	4
Computing	5	5
System Integration	2	0.5
Calibration and Imaging	6	4
TOTAL	**64**	**47.5**

* Several persons in this column are counted two or more times; these particular individuals are involved, part-time, in more than one WBS activity.

MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END AUGUST 1999

Financial Statement

The month-end financial statement organized by the principal WBS categories is attached. A total of $819k was expended in the month of August 1999; this is nearly twice that expended in the previous month and reflects both the maturity of the Project and the fact that in July much of the attention of the Project staff was focused on the NSF Audit Panel meeting. The Project total expended and committed at the end of August was $8.589M, an amount that is 47.8% of the funds received to this date and available for expenditure. The Project continues to expend at the rate planned and continues to guard the contingency in anticipation of the procurement of the prototype antenna expected in October 1999.

In addition to the chart of accounts that tabulate the spending for the month of August 1999 we also include a concise two-page summary of all the MMA/ALMA-US accounts. This tabulation summarizes the allocations and expenditures for all the WBS tasks to which funds are assigned. The earned value report, see below, is based on these figures.

Earned Value

The progress of the Project to date as measured against the Project baseline plan is reported in terms of earned value. This report follows the financial tables and is presented in both graphical and tabular forms. A guide to the report is included this month as a way explaining the conventional terms and concepts being used for this, our initial use of the earned value analysis of the Project.

The earned value computation depends on the existence of a detailed baseline project plan defined in the WBS for that project. The MMA baseline plan is the US-only project done at the NRAO. With the transition to the joint US-European ALMA Project that baseline for the U.S. share of the effort will change. The ALMA Project WBS is being assembled now by the ALMA Executive Committee with the expectation that it will be presented to the ALMA Coordinating Committee (ACC) in November 1999. With the approval of the ACC the joint ALMA WBS will be used as the baseline against which ALMA-US progress will be measured and subsequently reported as earned value.

Personnel

The MMA Project staffing is reported below by WBS level-1 category. In August the FTEs

MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END SEPTEMBER 1999

Financial Statement

The month-end financial statement organized by the principal WBS categories is attached. A total of $663k was expended in the month of September. The project total expended and committed at the end of September was $9.297M an amount that is 51.7% of the funds received to this date and available for expenditure. Expenses for contracts and services continue to be no greater than the budgeted costs.

In addition to the chart of accounts that tabulate the spending for the month of September 1999, we also include a concise two-page summary of all the MMA/ALMA-US accounts. This tabulation summarizes the allocations and expenditures for all the WBS tasks to which funds are assigned. Beginning in September the Project baseline is being restructured to become the baseline for the U.S. tasks of the joint U.S.-European ALMA Project. While the Project baseline is evolving it is not possible to compute the earned value. It is anticipated that the new joint Project baseline will be complete following agreement for division of the ALMA Phase 1 WBS tasks at the November 1999 meeting of the ALMA Coordinating Committee.

Personnel

The MMA Project staffing is reported in the table below by WBS level-1 category. In September the staffing levels were unchanged from the levels in August.

Milestones and Deliverables

The table of Milestones and Deliverables is attached to this report. The table may be accessed at any time on the web where it is kept in electronic form and updated following each weekly meeting of the MMA Division Heads. In September the Preliminary Design Review for the photonic phase calibration system, the PDR for the optical round-trip phase measurement system, and the PDR for the photonic local oscillator system were conducted as scheduled. This joint PDR was attended by two reviewers external to the Project nominated by the U.S. partners and one external reviewer nominated by the European side of the ALMA Project. The report of the PDRs is on the web.

MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END OCTOBER 1999

Financial Statement

The month-end financial statement organized by WBS level-1 category is attached. A total of $551k was expended in the month of October 1999. This is approximately $100k less than that expended in September but is consistent with the planned expenditure for the month. The Project total expended and committed at the end of October was $9.771M, an amount that is 54.4% of the funds received to this date and available for expenditure. The Project continues to expend at the rate planned. Contingency funds are being guarded as the large contract for the prototype antenna is being negotiated.

Personnel

The MMA Project staffing is reported in the table below by WBS level-1 category. In October the staffing levels were unchanged from the levels in September.

Milestones and Deliverables

The table of milestones and deliverables is being revised to recognize the involvement of the European ALMA groups in the Design and Development phase of the ALMA project. The Project baseline, including division of effort between the US and European partners, is incomplete. The initial table of Milestones and Deliverables for the joint project will be included in the December 1999 month-end report.

International Partnership

In October the first joint US-European ALMA Science Meeting, *Science with the Atacama Large Millimeter Array,* was held in Washington, DC. Three days of science talks by scientists from Europe, the US, and Japan highlighted the enormous *discovery space* to be opened for science by ALMA. The meeting also provided a forum for astronomers from all over the world to begin to work together on confirming the science requirements and technical specifications for ALMA.

MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END NOVEMBER 1999

Financial Statement

The month-end financial statement organized by WBS level-1 category is attached. A total of $561k was expended in the month of November 1999. This is approximately $10k more than that expended in October and is consistent with the planned expenditure for the month. The Project total expended and committed at the end of November was $10.281M, an amount that is 57.2% of the funds received to this date and available for expenditure. The Project continues to expend at the rate planned. Contingency funds are being guarded as the large contract for the prototype antenna is being negotiated.

In addition to the chart of accounts that tabulate the spending for the month of November 1999 we also include a concise two-page summary of all the MMA/ALMA-US accounts. This tabulation summarizes the allocations and expenditures for all the WBS tasks to which funds are assigned.

Personnel

The MMA Project staffing is reported in the table below by WBS level-1 category. In November the number of staff participating in the Project was unchanged from the number in October, which is the same number as in the three months prior to that, but the number of full-time equivalent employees assigned to the Project increased by one from the number at the end of October. That one additional FTE was made up by half of two people that are now assigned to the Project System Integration task.

Milestones and Deliverables

The table of milestones and deliverables is being revised to recognize the involvement of the European ALMA groups in the Design and Development phase of the ALMA project. The Project baseline, including division of effort between the US and European partners, is incomplete. The table of Milestones and Deliverables attached to this report still represents the transition between the US-only MMA project and the agreed milestones and deliverables for the joint ALMA Project. This initial table of Milestones and Deliverables for the joint project will be refined and expanded in subsequent monthly reports.

International Partnership

At the Meeting of the ALMA Coordinating Committee on November 12 the ALMA Executive

Progress Report: Level-1 WBS Tasks

4. Receivers

The 211-275 GHz double-sideband SIS mixers for the evaluation receiver were completed by the Herzberg Institute using NRAO designs and mixer chips.

Design of a 211-275 GHz SIS mixer chip which incorporates both sideband separation and balanced operation was begun. Both these features have been tested separately with success; the new chip will be the first attempt at a design which meets the ALMA goals and is intended to go into the production receivers. Calculations of unwanted signal propagation modes were performed in order to try to avoid some features of previous prototypes which limited the degree of sideband separation achieved.

The design of a double-sideband "building block" mixer for 602-720 GHz was completed. Mask layout was begun and is expected to be complete by the first week of January. In preparation for tests at this frequency, several items of test equipment are required, and progress was made in designing receiver optics, measurement of window materials, tests on a calibration gas cell, and other items.

Progress was made on several items related to SIS mixer automatic testing. Problems with controlling attenuators and filters were resolved. Design of electrical interfaces in the new closed-cycle 4K dewar was completed. The construction of new bias supplies was started.

In order to achieve the wide bandwidths required by the ALMA project, the SIS mixer must be followed by an IF amplifier which is built into the mixer block. A prototype IF amplifier using discrete InP transistors and covering 3-12 GHz was built and tested with excellent results: its noise temperature is less than 5K over much of this frequency range. An MMIC integrated amplifier chip developed at UMass/JPL was packaged and tested; this particular amplifier did not perform as well as the one
developed at the NRAO (other, different chips are expected in the near future). Also, the discrete MIC amplifier had 10 dB more gain and consumed half the power of the MMIC chip. The decision was made to proceed with interfacing the discrete MIC NRAO amplifier to the 211-275 GHz mixer, which is designed with low output capacitance with the wide bandwidth specifically in mind. Calculations indicate that the combination of SIS mixer and IF amplifier should have about 20 dB net gain and noise less than 10K from 5-11 GHz, rising to about 20K at 4 and 12 Ghz. Unmodeled effects will add about 5-10K to this value. Detailed design of how to mount the IF amplifier in the mixer block will begin shortly. There was good progress on building the liquid He dewar system which will be used
for integrated IF amplifier testing.

5. Local Oscillator System

Phase and amplitude noise performance of the local oscillator system are critical for ALMA. An LO chain consisting of a YIG-tuned oscillator (YTO) followed by a power amplifier and tripler to reach 84 GHz was built and tested; although this chain is not wide band and high power, it allows testing of the concepts of the baseline LO plan. The results were very encouraging with respect to phase noise: the phase noise was low enough that multiplication to 900 GHz should produce satisfactory performance. No unexpected contributions to the phase noise were produced either by the amplifier or the multiplier. The YTO manufactured by Microlambda was tested over its whole frequency range of 18-30 GHz; the phase noise rises sharply at the upper end, probably due to noise characteristics of the transistor oscillator. It may be preferable to use a YTO at somewhat lower frequencies than originally planned, and multiply one extra time, in order to achieve best noise performance.

A critical element of the planned LO chain is MMIC power amplifier chips in the range 60-120 GHz. A cooperative agreement with engineers at JPL working on FIRST/HIFI was reached in which the NRAO will receive MMIC power amplifiers for test and, later, chips customized for the exact ALMA
frequency bands. Commercially available MMIC chips for lower frequency ranges were also packaged and tested. Visits to TRW and HRL, both of whom produce MMIC power amplifiers, resulted in the beginnings of collaboration with these commercial suppliers for this purpose.

Designs were completed for several different high frequency multipliers needed in the LO chains. The University of Virginia began fabrication of the diodes needed for some of these multipliers. UVA has also made some progress in fabricating more complex structures on quartz substrates which will be needed for wider bandwidth multipliers; in particular, a spiral inductor was fabricated and tested by NRAO with good results.

8. Correlator

The vendor for the design of the custom correlator chip was selected (Innotech Systems) and a contract was placed. At the end of the first part of the design phase (about 3 months), a decision is expected on whether to design the chip for the newly-available 0.18 micron CMOS process and
whether to double the chip capacity from 4096 to 8192 lags.

A review of the interconnect system for the correlator (which requires 32,768 cables each carrying 125 Mbit/sec) resulted in the selection of the Xilinx Virtex-E family of FPGA chips and a mass-terminating miniature coaxial cable assembly which is commercially available. Use of the new Virtex-E family
throughout the correlator will result in higher performance and lower power consumption than was previously expected.

Detailed design of most of the boards required has begun. The FIR filter card and the Station Card are 90% done, and are awaiting breadboard tests of the Virtex-E I/O system. The Long-Term Accumulator and LTA adder cards are about 40% done. The concept for the Controller Card is done; detailed design must wait for completion of the other card designs. A test fixture for the FIR Filter and Station cards is under design.

Joint Receiver Development Group

A meeting with US and European receiver engineers was held at IRAM headquarters in Grenoble, France. Designs for the production receiver were reviewed and some decisions made. Further refinement of concepts will be done at the next JRDG meeting in March 2000.

9. Computing

In December the software group prepared for, and held, a joint US/European review of the ICD defining the interface between the antenna and the M&C system. After the review the ICD was updated and referenced by the draft antenna contract.

We prepared material for the test correlator software CDR and circulated it for internal review within the group and within NRAO.

It has been decided to mirror the NRAO web sites at several locations to allow people with slow network connections (particularly across the Atlantic) to use the site more readily. The Socorro portion of the NRAO web site was prepared for this mirroring (files placed under CVS, some directory
rearrangement).

11. Calibration and Imaging

The ALMA Imaging and Calibration group continued to assess the data collected during the 1999 Chajanator Field Campaign last month. Digital maps of the science preserve were produced, upon which the array (and other) locations measured with the differential GPS could be plotted.

The ALMA Scientific Advisory Committee was organized and met, with a preliminary definition of its charter written, a WWW page created and announcments of existence and purpose distributed. Its first face-to-face meeting is planned for Leiden on 10-11 March. The deadline for contributions to the ALMA Science Conference passed, with many interesting articles received. Editing of the Proceedings began.

Widely distributed members of the ALMA consortium with interests in the configuration met at a phone meeting 22 Dec so that results of the on-site investigation could be disseminated, and plans for the definition of the configuration solidified. The group set up a mailing list and plans for regular meetings. Memos relating to configurations by Radford and Conway were published. Butler published VLA Scientific Memo No. 177 on water vapor radiometry issues.

In other areas, an updated version of the US-only MMA costs was produced to help estimate ALMA constructions costs. A new FY2000 budget was produced.

Progress Report: Level-1 WBS Tasks

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MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END JANUARY 2000

Financial Statement

The month-end financial statement organized by WBS level-1 category is attached. It shows a total of only $245k was expended in the month of January 2000. This is approximately half of the average monthly Project expenditure for each of the last 4 months and is an accounting artifact: The NRAO fiscal system will not post spending against personnel accounts for which allocations have not been made. By the end of January 2000 the FY2000 NSF funds for support of the MMA Project had not been received by the NRAO. Once those funds are received the accounts will be rectified. The Project total expended and committed at the end of January was $11.137M.

For the last several months the U.S. Project has been negotiating with the European side of the ALMA Project to establish a joint work plan for the joint Phase 1 (Design and Development). While this effort is still incomplete in some areas, it is sufficiently advanced that it is possible to re-baseline the U.S. Project in accord with the tasks assigned to the U.S. side and to reallocate, where necessary, the U.S. Project resources to those tasks. The re-baselining for the year 2000 is complete. Following the chart of accounts for month-end January 2000 we include a concise two-page summary of all the U.S. ALMA Project accounts for 2000. This tabulation summarizes the allocations for all 3 years of the Project and specifically includes the allocation of $8M in new NSF funds for the year 2000, even though those funds have yet to be transmitted to the Project from the NSF. The actual Project expenditures for 1998 and 1999 are shown for each WBS task to which funds are allocated. The final (rightmost) column sums the total amounts expended and committed for each task; its sum at month end is the $11M noted above. The column to the left of this, the column labeled *Totals Project to date, Budget*, is the sum of all funds budgeted to each particular WBS task; the sum of this column is the amount allocated to the Project, $26M, less that held by the NSF for administrative purposes or held by the Project as contingency. [For the electronic version of this Monthly Report the budget table can be accessed as a PDF file at
http://www.cv.nrao.edu/mmaplan/budget/budget.pdf
For the hardcopy version of this Monthly Report the budget table is attached].

Personnel

The MMA Project staffing is reported in the table below by WBS level-1 category. Note that in accord with the WBS being developed for the joint Project, two former WBS level-1 categories, IF System and Fiber Optics System, have been consolidated into a

single category. This is a change from versions of the Project Personnel table presented in previous Monthly Reports. In January the number of full-time equivalent employees assigned to the Project was unchanged from the previous month..

Milestones and Deliverables

The table of Milestones and Deliverables for the Project is attached. This tabulation reflects only those milestones that are on the development path for tasks assigned to the U.S. side of the Project. The complete table, including tasks assigned to the European group, is still a subject of negotiation within the management of the joint Project. The major milestones for the U.S. Project are being met within the slack allowances built into the schedule. In particular, the contract for the prototype antenna which was scheduled to be signed in November 1999 will now be signed in February 2000. It is possible to recover from this delay by a more aggressive delivery schedule that will have the prototype antenna delivered, as scheduled, in the fall of 2001. Other major deliverables of the Design and Development phase, including delivery of the receiver to go on the prototype antenna for the antenna evaluation, and delivery of the correlator to be used for the test interferometer, are on schedule. For hardcopy users of this Monthly Report the chart of Milestones and Deliverables is attached; for electronic users it is available at http://www.cv.nrao.edu/mmaplan/mmamlstn2000jan11.pdf

International Partnership

In January the joint US-European Project successfully held a Preliminary Design Review for the Correlator task. The PDR panel reviewed both the planning for the ALMA baseline correlator as well as the plans for the future correlator development. The report of the PDR panel is available on the web.

Other notable steps taken in January included (1) a meeting of the AUI with representatives of ESO addressed to developing a plan for ALMA construction and operations in Chile; and (2) meetings of the US and European Site Development groups aimed at an assessment of the options for location of the ALMA Operations Support Facility (OSF) near San Pedro de Atacama and at development of an evolutionary personnel staffing plan for ALMA.

Progress Report: Level-1 WBS Tasks

1. Administration

In a series of meetings this week between the managers of the US Project and the European Project a number of planning issues for the project were sorted out. A revised WBS for the project is nearly completed, which will form the basis for the cost estimate which the joint Project must prepare for the ACC. The result will be a single integrated WBS, which includes all Phase II (construction) activities for the project, and it also includes Phase I (D&D) activities.

We also developed the plans for collecting the costing information we

will need, including parameterization of our costs. A revised spreadsheet for costing has been completed and distributed to the cost estimators, the US Division Heads and the European Team Leaders. One major change from the similar exercise done last July for the U.S. Reference Project is that the year-by-year plans are not included; the emphasis now is on the total cost of a task with appropriate parameters allowed to adjust the task for everything from the final number of antennas to the overall duration of the project. The new spreadsheet is much simpler than the old, with no embedded software, so it exports easily to Excel for use by our European colleagues.

2. Site Development

We are pleased to report that the Chilean Finance Minister has signed a decree listing explicitly the exemptions AUI shall enjoy in relation to the construction, installation, maintenance and operation of the MMA in Chile. The list includes import duties, Value Added Tax, property taxes, Municipal taxes and fees, diesel oil taxes, and some other minor exemptions. We requested this decree because otherwise some of the exemptions, such as the 18% VAT, by virtue of being only implicit in the decree of 1998, could not have been claimed.

Interaction of the US group with Daniel Hofstadt (ESO) began in earnest on issues related to the AUI-ESO mode of joint operation in Chile. An outline of an operations plan and a baseline list of personnel to staff the observatory operations was produced. This information will be input to the cost estimation process.

3. Antennas

The final negotiations with the antenna contractor, Vertex Antenna Systems, took place on 19 Jan and went well with agreement being achieved on all issues. The remaining task is to have the final contract approved by AUI and NSF and signed by the contractor, hopefully by the end of January. The contract calls for delivery of the antenna 20 months after contract signing.

Effort continued in getting the ICDs and some other minor changes into the final antenna specification. This required a lot of interaction with the ESO/Lund antenna group to coordinate the specifications. It has been decided that the nutator for testing the prototype antennas will be reactionless so that it will be compatible with the antenna design specifications. (WBS 3.3.35.1)

A phone meeting with Vertex Antennentechnik was held on the conversion of the FEA models from ASKA to NASTRAN. Models now run but a few details still remain before the conversion program is declared compatible. (WBS 3.3.35.1)

4. Receivers

Work was continued on the design of the complete sideband-separating, balanced mixer design for the 211-275 GHz band. This design will be fabricated using the NRAO standard 211-275 elemental mixers by the University of Virginia.

Two new SIS wafers were delivered by the University of Virginia: one with elemental mixers, and one with balanced mixers. The I-V (current-voltage) curves for the junctions on these new wafers look very good and are expected to yield good noise temperatures.

Work on the layout of the first 650 GHz SIS mixer wafer for fabrication at the State University of New York at Stony Brook was completed. The design is now at Stony Brook and they have begun the detailed layout. We hope to have mixers to test about the first of April 2000.

Detailed simulations were performed on the integration of an internal IF amplifier with an SIS mixer, using the excellent 4-12 GHz amplifier developed by Marian Pospieszalski. This amplifier uses 3 discrete transistors, provides 30 dB gain, and has 5K noise temperature over much of the targeted 4-12 GHz IF band. The simulations have investigated the effects of using a different IF range and various gate widths of the transistors. The computer model predicts excellent performance over a wide range of possible parameters, and a plan has been conceived for an early test using mostly existing hardware.

Investigations of the properties of various materials which may be suitable for the construction of low-loss, wide band, zero leakage vacuum windows were carried out. Most of this work was done at Brookhaven National Laboratories using the National Synchrotron Light Source, which is the highest intensity source available at mm wavelengths. Investigations of various possible Fourier Transform Spectrometers which may be suitable for test of materials were continued, but no definite conclusion was reached.

Progress was made in automatic SIS mixer evaluation. Improvements in circuitry reduced the measurement noise to the point that it is dominated by the intrinsic properties of a mixer; the software effort is now on optimizing data acquisition and processing procedures. Some new chassis for the second mixer test station were completed.

5. Local Oscillator System

The investigation of how to minimize local oscillator phase noise continued with detailed measurements on individual components in the LO chain: intrinsic YTO noise, amplifier noise, and multiplier noise. This noise is best characterized in the time domain, since in the case of ideal noiseless components it will be the same at all frequencies. The expected noise from the antennas and atmosphere at Chajnantor on a typical good day is about 100 femtoseconds rms. The oscillator chain presently under test exhibits about 20 femtoseconds rms, so that if the higher frequency components are close to ideal, the electronic contribution to phase noise will be satisfactorily small. We obtained the excellent result that the phase noise contribution of a 22 GHz power amplifier is the same whether it is operated in a saturated or non-saturated mode, which is an important factor in providing sufficient LO drive power. We received an 80 GHz MMIC power amplifier from JPL on loan for test and expect to measure its characteristics in February. Work is

continuing on optimizing the performance of the phase-locked loop circuit which drives the fundamental oscillator.

Research was completed on the availability of lasers, laser drivers, and temperature controllers for setting up a phase cal test box which would supply a phase cal signal at a frequency from DC-300 GHz by temperature control of two lasers. Further discussions were held with u2t, a company in Berlin that sells photodiode chips. We will be purchasing several of these chips for evaluation with the hope that they will be suitable for the photomixers that will go on the test interferometer. These will be used to provide the reference for locking the YIGs and Gunns.

6. IF System

The design of the micro controller portion of the second synthesizer/fringe generator was refined. The design will be reviewed at the ALMA System review in March. The laser controller was successfully instructed to communicate over the CAN bus and its functionality appears satisfactory. The next step involves writing routines to communicate with the DS1820 temperature monitor and serial number generator.

7. Fiber Optics System

Research was conducted on the availability of Optical Wavelength Lockers for maintaining laser operating wavelength over extended periods of time. $1,200 each in quantities >100 pieces.

An analysis was completed on the options for locating the FIR filter and for alternative schemes of FO transmission. The current baseline scheme is found to adequately addresses the existing correlator chip and system design. An estimate for the cost of hardware for 10Gbps Tx/Rx sets will be between $15k and $10k. Alternatives may require a significant redesign of the correlator to match a ~155MHz clock speed.

We are also researching the cost and availability of 2.5 Gbps FO components as requested by the system integration group. We have determined that the cost of 2.5 Gb/s logic is comparable to the 10Gbps hardware - mainly because of the added cost of DWDM Mux and Demux hardware. Added complexity and difficulty exist because of the problem of retiming data arriving on different fibers (3 fibers for 2.5 Gbps solution), and changing the correlator clock from 125 MHz to 155 MHz. Changing the clock to 155 MHz simplifies both 2.5 and 10 Gbps systems. The cost of 3 fiber s versus 1 is part of the analysis.

Discussions were held with the ESO FO group (Marc Torres) on the performance of the Diamond E-2000 series optical connector. Torres uses this at the IRAM array and finds that this connector is far superior to other connectors for phase stability as a function of applied mechanical forces.

8. Correlator

Work continued on designing the signal interfaces for the digital FIR filter card. Laboratory tests of Xilinx Virtex series chips produced data on how to configure the chip-to-chip interfaces.

A kick-off meeting was held with selected custom correlator chip designer. Detailed exploration of the design alternatives was begun; this will lead to a decision on whether to select 0.25 or 0.18 micron technology, and whether to double the spectral resolution by designing a chip with 8K instead of 4K lags.

Design work continued on all parts of the ALMA correlator. Software work continued for the test correlator.

The correlator Preliminary Design Review was held in Charlottesville on January 20-21. There were 26 attendees for at least part of the proceedings. The committee reached the conclusion that the ALMA correlator design is excellent, providing the capabilities specified by the science goals at minimal cost. A draft report was written and will be distributed and posted on the ALMA web site after review and approval.

9. Computing

In January 2000 the standard interface daughtercard was laid out and bids were received for prototype manufacturing. An initial VxWorks M&C device binding was written. A Frequently Asked Questions document was written for the M&C interface to answer questions about why some design decisions were taken. Besides lab testing, the standard interface will be used for compressor monitoring at the NRAO 12m telescope, a real world test. A discussion of time distribution and device synchronization was started with the system group. A test correlator software design document was released, and a panel for its CDR is being solicited. The ALMA Science Software Requirements committee met in Socorro to further their work on a first report for software requirements, to be issued as an ALMA memo in late February. The US and European software groups held a first joint phone meeting, to be repeated at monthly intervals.

10. System Integration

A practical test of the viability of using optical offset pointing to refine and maintain the pointing of the ALMA antennas was conducted at the NRAO12 Meter Telescope. The system integration group used the optical pointing camera on the telescope: it is normally used for optical pointing runs, recording the data for later processing in order to derive pointing model constants. The new experiment was designed to test the viability of using real-time feedback into the control system to guide the telescope. That is, true offset guiding, locking on to a star optically to control the radio telescope pointing.

In operation, data from the CCD were processed in real time by 2 orthogonal one-dimensional gauss fits (i.e. nominally in azimuth and elevation) to the star image, to derive offsets from the nominal CCD field center. These offsets were then fed continuously to the telescope real-time tracking system, as additional pointing corrections. The cycle time of the feedback was about 5 seconds. The 12 Meter tracking was held to significantly better than an arc second with this technique, over a period of several hours. Because the optical images (recorded at up to a 30 Hz rate) were averaged over a few seconds, it's possible to do much better than the normal optical seeing limit. This technique will be followed up on the ALMA prototype antennas.

11. Calibration and Imaging

During January, the Calibration and Imaging Division concentrated on configuration issues, including continuing work on the problem of where to place the compact configuration at the site, given topographic and other constraints, and the creation of a mask for antenna placement. An e-mail reflector was arranged for the configuration working group. A work plan was created, identifying issues and designating individuals to lead the efforts. Planning continued for the CoDR 20-21 March in Tucson. A Site Monitoring Review was scheduled for 22 March in Tucson. WWW sites with Interest Groups and email addresses were set up for configurations, water vapor radiometry and site testing. Representatives attended the Science and Software Requirements meeting and the AIPS++ sponsored "Pipelines in Radio Astronomy" meeting in Socorro. Wootten attended the Correlator PDR; the proposed correlator design can fulfull nearly all the science requirements which now exist or can be reasonably forseen, with good upgrade paths for future needs. The ASAC meeting was held on 10 Jan, at which the ASAC charter was developed and plans for the 10-11 March meeting developed. Work began on Project Book updates and on the ALMA construction costing exercise.

The malfunctioning radiotheodolite was shipped from Chajnantor and tested it in the lab prior to return to vendor. Subsequently, it was sent to the shop for mechanical repairs. A list of coordinates of landmarks, etc. on site was compiled and added to the web pages. The 350 um tipper data was analyzed and the results were inserted in the compilation on the web. An upgrade to the seismometer firmware was received from the manufacturer Kinemetrics. An exchange of correspondence with Y. Robson (MRAO) about cross correlation of interferometer data was used to help define the WBS task for WVR radiometery.

The NRAO instruments at Chajnantor were shut down by Angel Otarola about 1999 December 29 because cloud cover had prevented the battery bank from charging. On Saturday, 2000 January 15, Steve Padin and Tim Pearson restarted them.

MILLIMETER ARRAY/ALMA-US
PROJECT STAFFING

MONTH END JANUARY 2000

WBS Task Name	Number of Persons participating in the Activity*	Full-Time Equivalent Employees
Administration	8	5
Site Development	1	0.5
Antenna	4	3
Receivers	15	12.25
Local Oscillator	9	6.75
IF and Fiber Optics Systems	5	4
Correlator	5	4
Computing	6	6
System Integration	2	0.5
Calibration and Imaging	5	3.5
TOTAL	**60**	**46.5**

* Several persons in this column are counted two or more times; these particular individuals are involved, part-time, in more than one WBS activity.

Progress Report: Level-1 WBS Tasks

1. Administration

On February 7th the new ALMA Project Manager, Dr. Marc Rafal, joined the NRAO. Dr. Rafal comes to NRAO from the Space Telescope Science Institute where he has been serving as Project Manager and Systems Engineer assigned to the Wide Field Camera Three Project for the Hubble Space Telescope.

The Work Breakdown Structure (WBS) for the combined phase 1 and phase 2 of the joint US-European ALMA Project is complete. This WBS is being used as the basis for the cost estimate to be presented to the ALMA Coordinating Committee in April. Instructions for the costing were distributed to the US Division Heads and the European Team Managers.

2. Site Development

An initial version of the Gantt chart for site development was completed. It describes the site development in two phases, an initial phase designed to put in place the facilities needed to receive the first of the production antennas, and a later phase designed to accommodate the people and activities needed for commissioning and interim operations.

A draft operations plan is being assembled as the basis for discussion with the European side. It includes personnel staffing levels which, after agreement with the Europeans, can be used as input to the process by which an operations cost is estimated.

3. Antennas

On February 22nd a contract for the ALMA prototype antenna was signed with Vertex Antenna Systems, LLC. A twenty month delivery schedule is specified in the contract. The antenna will be erected on a foundation prepared for it at the VLA site. It will then undergo thorough tests for the next 24-30 months. The finite element model of the antenna was received from Vertex and the data files were read into the NRAO version of NASTRAN; we will monitor progress and changes as final design and fabrication proceeds.

4. Receivers

Construction began on mating the IF amplifier block to the SIS mixer block so as to produce an integrated SIS mixer circuit from these two *discrete* components. Construction began on the InP IF amplifier itself. Tests were done on evaluating a conical inductor that could be used as part of the bias network for the SIS mixers. The performance of this device as a RF choke for the DC bias to the mixer were confirmed at cryogenic temperatures.

Authorization was received from the European group for the NRAO to build an identical copy of the evaluation receiver for use on the European prototype antenna. The Europeans will fund this work.

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LO Drivers: Design refinements to the Ka-band power amplifier eliminated unwanted oscillations and improved the bias network. The amplifier now has the required >15db gain from 20-43 Ghz. The measured saturated output power is 100 mW. A 20-40 Ghz doubler was fabricated from a HP HMMC-5040 MMIC chip. Additive phase noise measurements on this doubler and a passive doubler from Miteq were made. These measurements showed on phase noise contribution from either doubler within the measurement tolerance of the test set. A 80 Ghz, 150-mW power amplifier was received from JPL. This power amplifier, plus the 40-80 Ghz doubler, the Miteq 20-40 Ghz doubler and the 20-43 Ghz power amplifier gives us a complete, low-noise, 80 Ghz YTO LO chain for measurement of amplitude noise. We compared the phase noise in this chain to the noise of a fundamental Gunn oscillator at 80 Ghz and found no measurable difference. The LO chain will serve as the driver for the 80-240 Ghz tripler needed for ALMA band 6.

Photonics: Measurements were completed on the wideband noise of the photonic LO. The results are being written up as an ALMA memo.

6. Backend Subsystem

The design of the digital electronics and the PC board layout of the 2nd LO synthesizer is finished. It has been decided to extend the tuning range of the 2nd LO from 6-10 Ghz to a wider range of 6 - 14 Ghz in order to suppress spurious responses to an acceptable level. This will require a custom YIG oscillator design for the final design. Meanwhile the breadboard system will use an available 4 - 12 Ghz model.

A lively discussion is in progress regarding the digital addressing protocol. Briefly, the baseline plan is to use separate addresses for each function of a CAN module, i.e. *set frequency, read power, read status, etc.* Since the CAN controller chip can only filter either one address of all addresses above a certain number, this opens the door to the possibility of lots of interrupts being issued to the main microprocessor for commands not concerning the subsystem in question but residing at a higher address. An alternative scheme would be to use only one address per module and resolve the function with the first data byte. This puts more of the burden on the control computer but considerably less on the microprocessor in the module. Either option will work; the system implications are being assessed.

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7. Correlator

The initial design was completed of the VIRTEX-E field programmable gate array to be used for the filter tap weight multiplier chip. It was possible to get a comfortable speed margin using the slowest speed grad XVC400E chip. Specifications for the custom correlator chip were finalized and sent to Innotech, the company chosen to do the chip design. As a result of recent ALMA budget problems it was decided to design the correlator chip using a 0.25 micron process. Design of the interface between the correlator system and the long term accumulator (LTA) is

sufficiently advanced that a new specification for the LTA was released to the Project. Documentation of the test correlator hardware and software is a continuing background task.

8. Computing

A new schedulability analysis was finished of the antenna CAN bus using more recent Monitor and Control (M&C) information provided by hardware designers. Actual transaction performance times were measured in the lab. The results were documented and distributed to the Project. Delivery was taken of the first of the M&C Standard Interface boards; they have been bussed out and we are awaiting delivery of the flash memory and micro-controllers before tests start. A PDR of the M&C Interface Specifications was held on February 24.

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A Preliminary Design Review of the ALMA system and a Critical Design Review of the test interferometer system was held jointly with the European group in Garching on February 28 and 29. Reports of these reviews are available on the ALMA web pages. Version one of the Project Book for the Test Interferometer was released to the Project; it is controlled and maintained by the System Engineer.

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An initial draft of the compressor M&C Interface Specification was completed and made available for review. A PDR of the M&C Interface Specifications was conducted by teleconference on February 24th.

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The ALMA web pages for the calibration and imaging group and the configuration group were updated in their entirety. A draft of a revised Chapter 15 of the ALMA Project Book was circulated for comments. This new chapter includes the recent configurations being adopted as the project baseline. Digital masks for the site were prepared that outline areas that meet several criteria, including slope, and unobstructed horizon.

In conjunction with the Japanese group working on the Large Millimeter and Submillimeter Array project (LMSA) soil core samplings were made at six locations on the site. The data are still being analyzed, but in broad measure it was found that the soil cores taken from 5 of the 6 spots showed surface detritus for the first meter or two, below which was solid rock. Only on the *saddle* separating the two mountains, Cerro Chajnantor and Cerro El Chascon, at the closest point did the soil sample show only soil, no rock.

Progress Report: Level-1 WBS Tasks

1. Administration

On February 7th the new ALMA Project Manager, Dr. Marc Rafal, joined the NRAO. Dr. Rafal comes to NRAO from the Space Telescope Science Institute where he has been serving as Project Manager and Systems Engineer assigned to the Wide Field Camera Three Project for the Hubble Space Telescope.

The Work Breakdown Structure (WBS) for the combined phase 1 and phase 2 of the joint US-European ALMA Project is complete. This WBS is being used as the basis for the cost estimate to be presented to the ALMA Coordinating Committee in April. Instructions for the costing were distributed to the US Division Heads and the European Team Managers.

2. Site Development

An initial version of the Gantt chart for site development was completed. It describes the site development in two phases, an initial phase designed to put in place the facilities needed to receive the first of the production antennas, and a later phase designed to accommodate the people and activities needed for commissioning and interim operations.

A draft operations plan is being assembled as the basis for discussion with the European side. It includes personnel staffing levels which, after agreement with the Europeans, can be used as input to the process by which an operations cost is estimated.

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MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT

MONTH END MARCH 2000

Financial Statement

The month-end financial statement organized by WBS level-1 category is attached. It shows an expenditure of $575k and a major commitment to the prototype antenna contract of $6157k in the month of February 2000. The expenditure for the month is in keeping with the rate experienced over the past six months; the stability reflects the stability of the Project staff and the maturity of the design and development effort. The Project total expended and committed at the end of February was $18.369M, an amount that is 70.9% of the $25.920M received for the design and development phase of the Project and available for expenditure.

Personnel

The MMA Project staffing is reported in the table below by WBS level-1 category. Note that in accord with the WBS being developed for the joint Project, two former WBS level-1 categories that pertained to the US-only Project, viz. IF System and Fiber Optics System, have been consolidated into a single category for the joint US-European ALMA Project. In February the number of full-time equivalent employees assigned to the Project was 46.5, a number that is unchanged from the previous month.

Milestones and Deliverables

International Partnership

Progress Report: Level-1 WBS Tasks

MILLIMETER ARRAY/ALMA-US
DESIGN AND DEVELOPMENT

MONTHLY REPORT
MONTH END OCTOBER 2000

1 Executive Summary

At the meeting of the ALMA Coordinating Committee (ACC) on October 13, 2000 in Paris, Mr. Takayoshi Seiki, Director of the Research Institutes Division of the Japanese Ministry of Education, Science, Sports and Culture was invited to address the ACC. Mr. Seiki distributed a prepared statement in which he formally records the interest of Monbusho in being a third, equal, partner in the ALMA Project. His statement that Monbusho will use its best efforts to secure funding for ALMA is identical to the status of the commitments made so far by the U.S. and Europeans.

The ACC drafted a response which makes the following points: 1) It warmly welcomes Mr. Seiki's statement; 2) It affirms the desire of the American and European partners to work with Japan in common pursuit of a successful ALMA Project; and 3) It sets up a process tying confirmation of the tripartite project to an expansion of the ACC that will include members from Japan.

The ACC also endorsed a recommendation by the ALMA Executive Committee (AEC) to organize the international project using an Integrated Product Team (IPT) approach. IPTs are an established means of managing complex tasks that span organizational and geographic boundaries. They are well suited to the ALMA Project as they provide a means of bringing together the necessary resources under common technical leadership without requiring that those resources be part of a single organization. The AEC is currently using this approach to complete a detailed Management Plan that will be presented to the ACC for approval.

Programmatically, the project continues to make important progress across the entire WBS. Details of progress are reported in Section 4. Some of the highlights include:

- The antenna contractors are on-track to hold Critical Design Reviews (CDR) in November.
- With agreements on requirements and implementation decisions for the production frontends, work is accelerating on the design. A PDR on the production frontends is now planned for February.
- The design was completed for the data transmission protocol of the fiber optic link that carries information from each antenna. Detailed design of the embedded logic to implement the protocol is already under way.

- A Critical Design Review for the holography system was held. Holographic measurements of the prototype antennas panel surface accuracy will be the primary means of demonstrating compliance with contract specifications.

2 Programmatics

2.1 Financial Statement

The month-end financial statement organized by WBS Level-1 category is attached. The expenditure is in keeping with our current spending plan. The Project total expended and committed at the end of August was $23.03M, an amount that is 88.8% of the total $25.920M received for the design and development phase of the project and available for expenditure. Continuous detailed review of spending for the remainder of the year will be carried out to assure that the budget is not exceeded.

Planned spending for a fourth year of design and development shows that the proposed $6M will, at best, carry the project to the assumed availability of construction funds in October 2001. The desire to minimize the potential schedule impact of this funding shortfall requires that all available budget contingency be applied to funding tasks critical to the test interferometer. The test interferometer is the primary critical path item. The lack of any budget contingency for 2001 translates to an extremely high budget risk through the end of the design and development phase. This will become especially critical should construction funds not be available in October 2001. Additional funding prior to the start of construction would significantly reduce the budget risk as well as allow additional tasks to be started that would further reduce the remaining schedule risk.

2.2 Personnel

The ALMA Project staffing is reported by WBS Level-1 category based on the joint project WBS. The total number of full-time equivalent employees was 58.4.

3 Meetings

OCTOBER 2000:

ALMA Joint DH/TL Teleconference - October 2
ALMA Joint Receiver Development Group Teleconference - October 5
ASAC Teleconference - October 9
ALMA Holography CDR - October 10
ALMA Test Interferometer Planning Meeting - October 11
ALMA LO Construction Planning Meeting - October 12
ALMA SSR Meeting - October 12-13
ALMA Coordination Committee Meeting - October 13

ALMA U.S. DH Meeting Teleconference - October 16
ALMA Executive Committee Meeting - weekly teleconferences
ALMA Test Interferometer Bi-Weekly Teleconferences
ALMA/NSF Meeting - weekly teleconferences
ALMA Lo/Rx Meeting - weekly teleconferences
ALMA Imaging and Calibration Meeting - weekly teleconferences

NOVEMBER 2000

ALMA Photonics Meeting - November 7-8
ALMA Site Teleconference - November 8
ASAC Teleconference - November 13
ALMA U.S. Antenna Prototype CDR - November 15-16
ALMA Joint Software Meeting - November 20-21
ALMA European Antenna Prototype CDR - November 28-29
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ALMA Imaging and Calibration Meeting - weekly teleconferences
ALMA Executive Committee Meeting - weekly teleconferences

4 Technical Progress Reports

4.1 Antennas

Work continued on supervision of the prototype antenna contract with Vertex. ALMA-US personnel were at the Vertex facilities in Duisburg, Germany on 24-26 October for contract progress review and technical discussions. The option on the antenna contract for the installation of the laser metrology system was declined due to lack of funding. Quotations were received from Vertex for two additions requested by NRAO: a specialized forklift to enable receiver installation in the receiver cabin and an additional equipment enclosure mounted on the azimuth platform. A consultant in Carbon Fiber Reinforced Plastic (CFRP), Mr Robert Romeo, President of Composite Mirror Applications, Inc in Tucson, was engaged to advise the ALMA-US antenna group on CFRP issues. He will attend the Critical Design Review.

A major activity for the contractor during the latter part of the month was the preparation of the documentation for the CDR scheduled for 15-16 November. This documentation was received by NRAO at the end of the month and distributed to the reviewers. A significant design decision made by Vertex during the month was to fabricate the upper part of the antenna receiver cabin out of Invar in order to meet the thermal performance requirements. This decision will cause a small increase in the mass of the antenna and the cost of the production antennas.

At NRAO work continued on the antenna components being built in-house, including the subreflector nutator and optical pointing camera.

4.2 Frontend

Front End Status

Final arrangements have been made this month regarding the production and testing of the orthomode transducers (OMTs) for the 3mm wavelength. A collaboration with the AMiBA project in Taiwan has resulted in a plan for the production and testing of eight initial OMTs, three of which are needed for the evaluation receivers which will be used on the test interferometer.

Plans for the production of the ALMA receivers are evolving. An initial meeting between the European, Japanese, and US partners will take place at the ESO headquarters in Garching on 30 November. A draft agenda for this meeting has been prepared and it is expected that this will be refined over the next week or so.

The evaluation receivers are progressing, although our efforts are manpower-limited at present. Two engineers have accepted positions at NRAO in Tucson, so the situation is likely to improve in the near future. Both engineers need work visas and this may introduce a delay in the hiring process, but we are optimistic in this respect.

Receiver Components

Tests continued on the 211-275 GHz mixer with integrated preamplifier for the 4-12 GHz IF band. Small variations in mixer noise temperature across the IF band have now been successfully modeled and are believed to be understood. Work is now concentrating on optimizing the interface circuit between the mixer and the first IF amplifier (and perhaps slightly modifying the input side of the IF amplifier) in order to achieve flat noise across the IF band.

The first block for the 211-275 GHz sideband-separating, balanced mixers has been completed except for installation of the MMIC mixer chip itself. The test hardware and software are complete and ready.

Work is continuing on improved optics for the test system, including matching layers for windows, lenses, and IR filters. Some experiments in machining the plastic materials are in progress in the shop, and some materials have been characterized. An effort to simulate the performance of overmoded waveguide (for carrying LO signals) has been held back by lack of a computer with sufficient memory to handle the very large number of 3-dimensional cells required for this problem. A new computer with 1 Gbyte of memory was ordered so that such very large computational problems will be amenable to solution. It was determined that the use of a supercomputer facility was not a viable option because the computational problem cannot efficiently be ported to a multiprocessor environment.

Providing clean bias supply current for SIS mixers has been a perennial problem due to multiple grounds in the cables connecting electronics to a typical dewar. A new circuit using two independent current sources has been designed which, in theory, should solve this problem. Investigation of the performance of present bias circuits revealed subtle problems which will be corrected with modified circuits. Test of reed relays for providing programmable shorts for protection of the SIS mixer bias lines showed no unacceptable transients; this method of providing shorting protection will be pursued.

For the Band 6 receiver cartridge, a preliminary specification of the interface required to operate the sideband-separating, balanced mixers, LO multipliers, and two stages of IF amplifiers has been created and circulated. It appears that more than 100 wires will be required. Means of minimizing the conductive heat load produced by this large number of wires are being investigated.

Work continued on refining the data acquisition and processing software for automatic SIS mixer testing. The speed of data acquisition using a power meter was improved by a factor of 2. Further comparisons of noise temperatures measured with a conventional load cone covering the aperture and with a chopper wheel were made, and shown to agree within 5%, which is good enough for mixer testing. A new, smaller, much quieter chopper wheel was designed and built.

The mixer block for 650 GHz, which was returned to the outside contractor for adjustment, is still being worked on. Work is continuing on building up the 650 GHz test receiver optics.

Further analysis of an SIS mixer capable of covering 86-116 GHz was carried out. This is an alternative to using an HFET amplifier, which although it is intrinsically single-sideband and available now with noise temperature comparable to an SIS mixer, has higher 1/f gain noise. Analysis of a previously designed waveguide probe revealed a resonance at 107 GHz which requires the probe to be slightly redesigned. The modified design will then be folded into the overall performance simulation to judge the overall predicted performance.

4.3 Local Oscillator System

Local Oscillator Multipliers

Measurements of the temperature sensitivity and long term phase drift of LO driver components and chains were further analyzed and work was continued on a memo describing the results; this will be complementary to ALMA Memo 311 which describes short-term phase noise characteristics. The settling time of the PLL circuit was investigated in the context of rapid frequency switching for single-dish spectroscopy.

A 2-stage 43-60 GHz power amplifier is being assembled and will be tested soon. The block for an integrated varistor doubler/power amplifier from 50-60 GHz is currently being machined. A design for a W-band balanced Schottky mixer using UVA mixer diodes has been designed and the block drawings have been submitted to the shop. 20 W-band power amplifier bodies are currently being machined in Green Bank. An engineer and technician will travel to JPL in November with several of these blocks to

learn the JPL assembly procedure and take back several amplifiers for ALMA use. HRL MMIC power amplifier chips designed to cover 100-120 GHz with 50mW output should be available within a month.

Several different ways to configure the LO drivers were investigated in detail and discussed at length. It now appears that a Warm Multiplier Assembly will be installed on the outside of each cartridge; this WMA will contain at least the last stage of frequency multiplication and power amplification, in order to avoid distributing high power signals over long, lossy waveguide runs. The choice now appears to be between distributing intermediate frequency signals near 20 GHz over coaxial cable or higher frequency signals near 50 GHz in waveguide.

LO power and noise interface specifications were discussed with the European cartridge designers. A revised project book contribution will be released shortly detailing some of these points.

The major focus in frequency multiplier development continued to center around the evaluation of dielectric materials for use in integrated capacitor structures. These materials include sputtered SiO2, CVD SiO2, and SiN. Aside from the dielectric constant, the material's RF loss characteristics, which play an important role in setting the frequency multiplier's conversion efficiency, must also be measured at millimeter wavelengths. Several RF test structures, suitable for measuring both the dielectric constant and the loss at 100 GHz, were fabricated along with samples of the three materials. Sputtered SiO2 was chosen based on these test results. Design details for the 80/240 GHz tripler are currently being cast in final form; circuit fabrication should commence in November.

The details of the Michigan/JPL collaboration have been finalized. The plan involves transferring the wafer thinning and e-beam fabrication processes developed at JPL to Michigan over a period of nine months. Throughout this period, the Michigan group will concentrate on three ALMA objectives: 1) varactor diode structures suitable for the current ALMA 55/110 and 110/220 GHz doublers, 2) a monolithic 160/320 GHz doubler for Band 7 based on the wafer-thinning process, and 3) a monolithic 220/660 GHz tripler for Band 9 based on both the wafer-thinning and e-beam processes. The collaboration is expected to begin in November.

Photonic LO and Test Interferometer First LO

A trip was made to Japan to participate in a photonics meeting at Mitaka, in Tokyo, to visit the Nobeyama Observatory and to inspect the ASTE 10m antenna which is now operating with two SIS receivers. A full report on the visit will be issued in the near future.

The highlight of the meeting was the results reported by NTT and the predictions for progress in the photonic LO. They intend to produce one milliwatt of power at 100 GHz out of a WR-10 waveguide mount and to have used that as an LO for a single ended SIS mixer (with the intent of measuring the LO noise contribution) by the middle of December 2000. By Feb 2001 their objective is to have measured the power output from a photo diode coupled to a log periodic antenna at a frequency of around 1 THz. The tests

to date of power output at 100GHz seemed very well executed and convincing. Other presentations were made by NRAO, RAL and Duisburg.

Local Oscillator Reference

Central Reference Generator

The Xilinx composite signal was used to experiment with different methods of demodulating the 20.833 Hz from the 25 MHz. A logical X-OR of the composite signal with the phase locked 25 MHz VCXO seems to be a good way to recover the 20.833 Hz signal with a 2.12 nS rise time on the rising edge and to maintain the critical timing requirements. Progress was made on the Xilinx design and the PCB layout for the digital board. An Anacom Systems Fabry-Perot laser Transmitter / Receiver pair to transmit the 25 MHz reference signal was investigated.

Reference Receiver

A low noise 25 MHz VCXO from Wenzel to be used in the Reference Receiver was investigated.

Second LO Synthesizer

Work on the prescaler board continues; the main task is to reduce the VSWR at frequencies above 10 GHz.

Power supplies

DC-DC converters for the sub-system power supplies were investigated. Vicor has all of the components needed in the power levels required and they meet the performance specifications.

4.4 Backend Subsystem

Data Transmission Fiber Optic Link

Protel Service Pack 5 was downloaded and some standard libraries updated. Hopefully the service pack will solve some of the instability problems encountered in the design software. Schematics and PCB footprints for the parts used in the Data Transmission link were entered into the Protel libraries.

Three engineers attended courses on Grounding & Shielding and High Speed Printed Circuit Board Design. Both courses provided excellent background information which will have a great impact on the design of the high speed digital hardware.

The design of the Data Transmission link protocol was completed and a draft memo will be circulated. Block diagrams for the FPGA's can now be generated along schematics, VHDL files and state machine diagrams for the various blocks using the Xilinx Foundation Software.

Module and bin requirements for the Test Interferometer were developed.

Downconverter

Schematics were generated for manual and computer control boxes to test 2x2 matrix switches. The re-analysis continued of mixer spurious responses in the test interferometer and construction versions of the downconverter. A new vendor was found, offering exceptionally good prices, for mixers and tunnel diode detectors in the desirable flatpack configuration. Components were ordered for evaluation. Specifications and a list of vendors was prepared for the RFQ of the 1.65 GHz and 2.0 GHz bandpass filters for the test interferometer downconverter.

Investigation of A/D converters for the Downconverter total power measurement continued. An evaluation board for the sigma/delta A/D converter was set up and is working on one of the lab computers. An evaluation board for one of the SAR A/D's was ordered.

4.5 Correlator

A backplane design for the filter card/station card test fixture was completed and is ready to be routed. A temporary test fixture for the filter card was fabricated by modifying a GBT spectrometer test fixture.

The prototype FIR filter card has begun initial tests. The CPLD which interfaces to the Xilinx Virtex-E chips was successfully programmed. The FPGA personalities for all 14 Xilinx chips on the card were successfully loaded. Work is now in progress on writing software required to test the filter card. It has been noted that the Virtex-E Delay-Lock-Loop circuits appear occasionally to lose lock for no apparent reason; we intend to use these circuits to adjust and distribute clock signals within and between chips. Further investigation is continuing.

A review of the custom correlator chip was held in Charlottesville with the chip designer, and a few final issues were resolved. The chip circuitry is now believed to be complete. Software needed in order simulate the custom correlator chip, now known as ALMA-1, was purchased and installed, and simulations have begun. Initial results indicate that the design meets the requirements as simulated so far.

4.6 Computing

The Control Software Group participated in the Holography CDR in Tucson. The review of the TI Design Concept document was completed. Continued work on porting the

Antenna Mount System (AMS) and Antenna API code to ACE/VxWorks platform. Completed Front End Power Supply embedded code.

Completed revision of Test Correlator control computer software design doc. It will be read internally by a few people and then go to CDR.

Began evaluation of a software testing tool for VxWorks/Tornado called CodeTest. This tool provides similar functionality to a commonly-used tool in Unix called Purify. CodeTest performs memory allocation error checking and code coverage. This type of tool should greatly enhance the quality of software delivered with the correlator control computer.

Revised Computing Memo #7: split it into two documents detailing the bus specification and the AMBSI hardware separately at the behest of the Systems Group

Met with Long, Torres, Jackson, and Sramek on Central Reference Generator (CRG). Follow on discussions with Stauffer and Glendenning.

Commented on Vertex Antenna CDR material. Collated and edited Computing Section comments.

4.7 Systems Engineering

The most significant event of October was the Holography Critical Design Review (CDR), held in Tucson on october 10th. The report of this meeting is available on the ALMA web pages at

http://www.alma.nrao.edu/administration/designreviews/holographycdr.html

Our European collaborators participated fully in this meeting, both in person and by teleconference, and Japanese observers were also present.

A considerable quantity of documentation was prepared for the review panel in advance of this meeting. An index and access to this material is avaialable from http://www.tuc.nrao.edu/~demerson/holocdr/ .

The meeting was very successful, with general approval being given by the review panel to the plans presented. In particular, the plans for a photonic holography transmitter were fully approved; this development had not been foreseen at the time of the PDR, but offers significant savings in cost and manpower over the original, more conventional approach, with little or no increase in risk to the schedule or budget. Some detailed tehnical points were made by the panel, as described in the report from the meeting.

Taking advantage of colleagues from both sides of the Atlantic being in Tucson for the Holography CDR, the following day a review of the Test Interferometer planning was held. This resulted in some action items to refine the schedule for the TI tests, and how the antenna tests will fit in with the timescale for laboratory tests for the electronics.

Similarly taking advantages of the presence of experts in Tucson, a another face-to-face meeting was held in Tucson that same week to discuss details of the ALMA Local Oscillator planning, primarily for the Test Interferometer.

Although less directly related to the immediate needs of ALMA, one member of the US ALMA Systems group participated in an international 9-day Task Group meeting at the ITU in Geneva, concerning primarily the protection of Radio Astronomy spectrum allocations from spurious radiation from satellites with downlinks in adjacent frequency bands. This issue is beginning to concern mm-wave radio astronomy as well as cm-wave observations, so representation at the various national and international spectrum regulation bodies is very important to the long term future of ALMA.

4.8 Imaging and Calibration

I. Imaging - Configuration Studies, Site and Water Vapor Radiometry

The imaging and calibration group held several phone meetings during October, with the agenda, indeces and linked documents to be found at:

http://www.cv.nrao.edu/~awootten/mmaimcal/

A. Configuration Studies

The simulation efforts for the primary ALMA array have re-commenced during October. Steve Heddle in the UK continued to progress on the imaging simulation, producing 1km 'C' Array snapshots and 4 hour tracks for simulations of objects in the image library using both the Kogan double ring and zoom spiral configurations (http://www.stevenheddle.co.uk/ALMA/ALMA_IND.HTM). A teleconference will be held when a sufficient body of intermediate array simulations has been assembled. A Review is planned for early 2001.

Butler worked on finalizing the memo on the location of the compact configuration, which will be issued late in November. Butler and Radford will visit the Chajnantor Altiplano in December, in part to inspect more closely the sites for the compact configurations.

B. Site

G. Delgado has presented a report on a 52-year climatological study for the Chajnantor area done by a consultant; Radford circulated this to the site group. Some long term periodicities in weather can be detected in this data but their amplitude isn't extreme. Apparently, the site is now experiencing a weather nadir period. A meeting will take place next month in Charlottesville to review the CBI experience.

Radford received site characterization data through October 12 from A. Otarola and updated databases and web pages accordingly.

Radford initiated a detailed study of contemporaneous tipping radiometer data at the two sites to determine how the transparency differed between the sites. His preliminary result is that during 1999 June - December tranparency was 15-30% worse over Pampa la Bola than over Chajnantor.

Butler prepared a proto-ALMA Memo on comparison between the Site Testing Interferometers at the Chajnantor and Pampa la Bola sites. He found that the median phase fluctuations at Pampa la Bola are ~12% worse than at Chajnantor, averaged over all times. During the lowest rms phase fluctuations, Pampa la Bola fluctuations are 43% worse than at Chajnantor. Butler also commenced a calculation of sun position on a given day at the site, to verify which satellites the NRAO and ESO STI's are observing.

Butler worked on radiosonde data and analysis (and presentation for the Morocco meeting). Also at that meeting, there will be a Site Characterization Review amongst all of the ALMA folks.

This will consist of Lars-Ake Nyman, Angel Otarola, Guillermo Delgado, Martina Weidner, Roy Booth, Seiichi Sakamoto, Simon Radford, and Bryan Butler.

Plans for visiting prospective pad locations during upcoming visits to the site were discussed.

Radford received repaired Inmarsat M4 (ISDN) terminal and tested voice and data calls. After three days, the terminal failed during a thunderstorm and was returned; the vendor admitted static problems. Deployment of the Inmarsat M4 terminal at Chajnantor will be delayed until 2001 owing to problems inherent in the equipment.

C. ACA

The ALMA ImCal group discussed the need for nutators on the antennas of the ACA. These should be incorporated in the design for at least one of the antennas.

II. Calibration

A. Interferometer/Antenna Amplitude Calibration

Radford started an analysis of the 12m prototype nutator dynamics and control system. He also reviewed the nutator design and status with J. Baars.

Radford revised the nutator mechanical design for easier production. Lab tests of nutator hardware were also performed.

Mangum worked on revisions to ALMA Memo 318 (Amplitude Calibration at Millimeter and Submillimeter Wavelengths). Most modifications are just window-dressing (a more general way to express chopper wheel calibration relation, for example). An analysis of the semi-transparent vane calibration will also be included. He continued to look into implementation issues for the ALMA adaptation of the BIMA prime focus amplitude calibration system. Some issues regarding data acquisition and synchronization need to be worked out for this system. Another area of concern is how the hole, and embedded calibration system, will couple to the astronomical receivers. Calculations indicate that there will possibly be quite a lot of reflected power back to the astronomy receivers, which could lead to standing wave problems.

As part of his participation in the SSR group, Mangum wrote the use case for the amplitude calibration observing mode.

B. Pointing Calibration

Mangum made some progress on the software aspects of the optical pointing system. A frame grabber is now commandable and produces gif images at a user-specified rate. Mangum will continue to develop the image producing and analysis capabilities of this software.

III. Science

A. ALMA studies, including the ASAC

Wootten wrote sections of the ASAC report for which he was the responsible party. The report was disseminated to the ALMA Division Heads/Team Leaders. He produced the agenda and moderated the ASAC teleconference which was held 10 October.

Payne brought up the question of which widgets might be needed for the ALMA optical train. Imaging and Calibration feels that provision should be made for a chopper wheel and for a solar attenuator. A second wheel, or a polarization widget are unnecessary. A review was carried out of polarization widgets in use today. For ALMA, the most appropriate would be a wire grid over a reflector, as used at OVRO and NRO. However, the group felt that the disadvantages of this system outweighed the advantages.

Carter presented a new optics design, which was also discussed. The very far off-axis beams continue to be a source of concern, though no remedies were identified.

Butler (with Gurwell and Wootten) presented an ALMA poster at the DPS meeting in Pasadena. The spectral line capability of the instrument will allow for the observation of multiple molecular species in planetary and cometary atmospheres and protoplanetary disks, providing temperature and wind (for the atmospheres) profiles at high spatial and time resolution and clues as to the chemistry in these places.

Wootten (with Gallimore) finished a paper illustrating the ability of ALMA to image galaxies in the distant Universe in the submillimeter. ALMA's detailed imaging capabilities will be a major step for astronomy, making it possible to study the origins of galaxies, and the state of gas and dust in forming and interacting distant galaxies.

Crystal Brogan has assembled a list of molecular lines

(http://www.cv.nrao.edu/~awootten/mmaimcal/Alma_zeeman.pdf) which will be of particular importance for polarization work on ALMA—she noticed that they come at band edges, by a perfidy of nature, and hence might pose a problem for tuning the polarization response of ALMA to the lines of most interest.

Cleanup work continued on the volume summarizing ALMA Science from the meeting last October.

The ALMA SSR meeting was held in Berkeley; Mangum and Myers attended. Scott and Myers issued a data rate document, and there was lively discussion over many issues relating to the Requirements document and use cases.

Mangum represented Imaging and Calibration at the holography CDR in Tucson and at a face-to-face meeting regarding development plans for the Test Interferometer.

B. Imaging and Calibration Plans for Next Month

Mangum will represent Imaging and Calibration at the Antenna PDR in Germany. A face-to-face meeting between Brown, Wootten, Butler and Radford and Readhead to discuss operating and observing experience at Chajnantor during the past year will occur in Charlottesville. The ASAC teleconference will be held on 13 November.

The Site Characterization Review will occur at the IAU meeting in Morocco. Configuration work will continue, with a focus on finishing the intermediate array set of the simulations.

A phone meeting of the configuration group is planned when this has progressed. Hopefully, with the impending release of AIPS++ mosaicing will become a part of the simulations soon.

Work also continues on the characterization of the ACA.

Issues and concerns

As mentioned above, the very far off-axis optics design continues to raise vexing issues.

MILLIMETER ARRAY/ALMA-US

PROJECT STAFFING

MONTH END OCTOBER 2000

WBS Task Name	Number Of Persons Participating in Activity*	Full-time Equivalent Employees
Administration	11	6.9
Site Development	1	0.0
Antennas	5	4.0
Front-End	21	14.8
Local Oscillator	11	8.8
IF and Fiber Optics	5	5.0
Correlator	5	4.0
Computing	9	8.5
System Integration	5	4.5
Calibration	2	2.0
TOTAL:	76	58.4

* Several persons in this column are counted two or more times. These particular individuals are involved part-time in more than one activity.