MMA Project Book, Chapter 17

CONSTRUCTION, INTEGRATION AND INTERIM OPERATIONS

Robert Brown
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I. GENERAL PRINCIPLES

Organization of the construction phase of the MMA project will be structured around the interests and capabilities of the countries or international organizations that become partners with the NRAO in the MMA or in a conceptually larger array that subsumes the MMA. Because pending partnership arrangements are not yet finalized it is not possible to specify in detail how the array hardware will be constructed and by which organization it will be constructed. Nevertheless, there are clearly identifiable goals that will guide the construction phase of the MMA or an enlarged array irrespective of the partners that may become involved. These goals, or principles, include the following:

- The antennas, the single most costly piece of the array, will be fabricated and assembled by an antenna contractor. The antenna design will be the responsibility of the contractor and it will be the contractor's responsibility to validate the antenna performance to the specifications set for the MMA;
- As many instrumentation sub-assemblies as possible will be fabricated under commercial contracts. This would include such items as machining of the receiver dewars, and mounting of the correlator chips on the boards;
- There will be no in-house development and fabrication of hardware that can be purchased commercially. Items such as cryogenic refrigerators, cryogenic compressors, optical fiber transmission lines and connectors, and lasers for metrology or calibration all will be purchased;
- Fabrication of specialized RF devices including the superconducting millimeter and sub-millimeter wavelength mixer chips, discrete transistors or MMIC chips, and varactor diodes used for LO multiplication will be done under contract to commercial, university or government laboratories currently specializing in such work. No device fabrication facilities will be set up at the NRAO for the MMA. In addition, some part of the assembly of discrete devices into finished components such as mixer blocks, amplifiers, and frequency multipliers may be performed where appropriate and cost effective by commercial or other organizations. Evaluation and testing of components is likely to remain a function of the NRAO;
- Final assembly and test of the instrumentation systems--the integration of subassemblies--will be done by MMA personnel at the NRAO or at those observatories who are partners in the MMA or that larger array that subsumes the MMA. This includes assembly of the receiver inserts for each of the MMA frequency bands, assembly of those receiver inserts in the cryogenic dewars, assembly of the local oscillator system and assembly and wiring of the correlator boards into the correlator racks.

In all of the above the guiding principle is this: Fabrication of production quantity MMA hardware will be done under contract whenever the experience in fabricating such hardware exists within industry, university or government laboratories; when such experience exists only at the NRAO (or within participating partner observatories) the fabrication will be done at the NRAO with MMA personnel hired and trained for that purpose. The NRAO will not attempt to *teach* industry skills needed for the MMA that it does not already have, nor will the NRAO attempt to duplicate industrial skills in-house when needed

services are available commercially.

II. CONSTRUCTION

The construction plan for the MMA is organized around two realities: First, the MMA will be built on a presently undeveloped site in the Altiplano of northern Chile; and second as an interferometric array the MMA is an assembly of multiple copies of functionally similar hardware and for this reason it can be *brought to life* incrementally. The former criterion, or reality, establishes a priority for development of the site infrastructure early in the construction phase of the project. The latter criterion provides an opportunity to make productive scientific use of early subsets of the array capabilities with those capabilities growing as hardware is added incrementally. But to exploit this opportunity demands that a high priority be placed in the construction phase on all *one-off* pieces of the array instrumentation; this would include things such as the correlator (or a subset of it), monitor and control hardware and software (or a functional subset of it), and the IF and LO signal transmission system (or a subset of it). These two realities are the cornerstones of the MMA construction plan.

Development of the array site on the Llano de Chajnantor at 5000 meters elevation and development of the array support facility near the village of San Pedro de Atacama that is located at 2425 meters elevation is the emphasis of the initial construction phase. The site development will involve construction of all the concrete antenna foundations, optical fiber and power communications to all the antenna stations, roads and site buildings. It will also include drilling for a source of water and plans for sewage disposal. Electrical power on site and communications between the site and the support facility near San Pedro are major construction enterprises. The plan for electrical power involves local generation from natural gas provided by a convenient tap to a gas pipeline that runs near the MMA site and is operated by the multi-national firm GasAtacama. There are no commercial facilities for communication between the site and the support facility near San Pedro; we will excavate a trench adjacent to the GasAtacama pipeline right of way and lay the cable for the 50 kilometers that separates these two operational sites. Development of the support facility will proceed apace with construction on the array site. The San Pedro base will incorporate laboratory, office and residential facilities suitable for the immediate needs of employees who are integrating the MMA instrumentation and suitable also for the longer term needs of the MMA operational staff.

As each antenna is completed at the contractors facility it will be assembled and validated. Afterward it will be shipped to the MMA Operations Support Facility (OSF) near San Pedro de Atacama (SPdA) with as little disassembly as possible consistent with the needs prescribed by ocean shipment. Once at the OSF it will be re-assembled and checked for optical and mechanical performance. It will be fully cabled and mated with its cryogenic equipment and receiver dewar. The initial dewar will contain a small subset of the eventual complement of receiver inserts. The RF performance of the antenna will be checked and, once verified, the fully-functional antenna will be transported from the OSF to the array site. This process will be repeated for each antenna and the MMA on site will grow incrementally in number of antennas on-site. As receiver inserts for new frequency bands become complete they will become part of the initial complement of instrumentation on each new antenna and they will be retrofitted to the antennas on site at that time. Thus the array will also grow incrementally in scientific capability; at each stage it will be capable of doing productive science.

III. SYSTEM INTEGRATION: ROLE OF THE ENGINEERING TEST INTERFEROMETER

Initially, integration of the MMA instrumentation will be impossible in Chile because neither the equipment nor the staff needed to verify compatibility and integration of new pieces of hardware will be in Chile. Everything and everyone will be in the U.S. or at partner observatories elsewhere. Because the initial integration and validation tasks are near-term in the construction phase and likely to be very demanding on the time of those individuals responsible for major instrumentation systems, we plan to carry them out on an engineering test interferometer made up of the first two MMA antennas; these two antennas initially will be located at the VLA site on the Plains of San Agustin in New Mexico.

As each new piece of equipment is completed, each new receiver insert for example, it will be installed initially on the test interferometer. The purpose of doing so is not to make scientific observations, but rather to verify that new instruments fit mechanically on the structure, that they receive the power and communications they need and that they do not interfere in any way with anything else. Once validated, subsequent quantities of those pieces of instrumentation can be sent directly to the OSF in Chile for installation on the present and future antennas there with the confidence that integration will go smoothly. The test interferometer is to streamline the engineering integration of the MMA in a resource-rich environment.

The engineering test interferometer will need support from software written not only to control the instruments and drive the antennas but also to handle the data flow. This provides an excellent opportunity to experiment on a small scale with the approaches and techniques being adopted for the MMA software and to give astronomers and array operators the chance to criticize the appearance and functionality of the software. Furthermore, an important role for the engineering test interferometer is to provide a platform on which software to support more sophisticated observing techniques or calibration modes can be developed and refined. As successive versions of the software are completed they will be ported to enhance continually the capabilities of the expanding array in Chile.

The operations staff in Chile will receive their initial training on the engineering test interferometer. By working in close consultation with the instrumentation and software developers the operations personnel will not only learn from the experts but they will establish the personal relationships that will bind the long term array operation in Chile to MMA research and development efforts based at the NRAO in the U.S. that will remain an important and continuing part of MMA operations.

When the last of the new instrumentation modules developed for the MMA has been successfully integrated into the engineering test interferometer and verified, and when development of new software is better done on the array in Chile, the engineering test interferometer will be disassembled and shipped to the site in Chile to be incorporated there as part of the final array.

IV. INTERIM OPERATIONS

Owing to its superb site, the fact that it will be in the southern hemisphere, and the quality of its instrumentation, the MMA will be capable of doing unique scientific observations in a very early stage of completion. The plan for interim operations of the MMA is to encourage exactly this. It requires provision for early completion of the things such as the signal transmission system on site and a correlator that may be a throw-away device or as the current planning projects, a subset of the final correlator. Making the developing MMA available to astronomer users as early as possible has the following advantages:

- It forces an early assessment, and refinement, of operational issues. Of special concern are issues involving staff recruitment and retention. An early understanding of what issues are important to employees and potential employees will permit problem solving to occur before issues become a crisis in full MMA operation;
- It provides a tangible motivator to people working on the project by illustrating clearly the purpose toward which everyone is working;
- It allows retrofits to be made to the hardware, software or communications systems such that the astronomer receives the product he or she would like to see; in doing so it gives the MMA staff informed criticism early;
- It develops an educated user community early that can debug the array and speed the commissioning process;
- It brings the Chilean community of scientists, educators, administrators, government and labor officials on board the MMA observatory early enough in the operational phase that community voices can be heard at a time when procedural refinements can be facilitated. In this way the MMA can become an asset not just to astronomy world-wide but also an asset to Chilean institutions and the citizens of the Republic of Chile.

Interim operations can be controlled so that at all times it is a positive force for development of the MMA. Initially we can expect that interim operations will be restricted to the nighttime hours when construction work cannot be done on site. But even this will be a welcome asset to those astronomers who have long anticipated the chance to use the MMA.