

POST-CONSTRUCTION OPERATIONS

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SUMMARY

The operating centers for the MMA will be the instrument itself at the 5,000 m (16,400 ft) site on the Llano de Chajnantor in the Andes mountains near 23° S latitude, the principal operations support facility (OSF) in the nearby village of San Pedro de Atacama at an altitude of 2,450 m (8,040 ft), the freight handling office in the seaport of Antofagasta, a small business office in Santiago, and various facilities of the National Radio Astronomy Observatory (NRAO) in the United States. While a few management personnel will live full time in San Pedro de Atacama, we expect most of the Chilean support staff will commute from other Chilean communities on a rotating work period basis. Despite the plans described here, we believe that the actual mode of operations will evolve over time as the MMA staff gains experience operating in Chile. Analyzing the budgets of observatories now operating in Chile, we suggest that the annual operating cost of the MMA will be about US\$15M 1998 dollars.

1. INTRODUCTION

Operating a complex radio telescope in Chile will be a new experience for the NRAO. While large astronomical observatories have successfully operated in Chile for decades, rural northern Chile lacks sophisticated technical resources and amenities. Our plan results from discussions with the director, the administrator, and two former directors of Cerro Tololo Interamerican Observatory (CTIO), with several administrators of the European Southern Observatory (ESO), with the director of Carnegie Southern Observatory (CARSO), with the project manager of the new Magellan Telescope being built at Las Campanas, and from our own experience operating radio telescopes in the United States. We have also discussed our plans with long-term employees of CTIO and ESO.

The plan described below is necessarily tentative. It presumes an operating mode that may take time to perfect. It presumes that we shall be able to find employees willing to live and work in northern Chile, which depends upon the Chilean economy there at the time the MMA is hiring. In reality, we know that conditions can differ from what we have recently ascertained. To succeed, the MMA operations management must be analytical, flexible, creative, and willing to build on the experience of the CTIO, CARSO, and ESO observatories. Most importantly, the staff in Chile must control the MMA, with the NRAO remaining in a primarily advisory and support role.

Chapter 16 above, Site Development, describes the physical plant we believe is necessary to operate the MMA. These chapters are linked.

2. CONCEPT

The MMA will operate somewhat like the Very Long Baseline Array (VLBA) headquartered in Socorro, New Mexico. It will be a “service” instrument, observing without astronomers present at the operations centers. Astronomers need not travel to Chile to observe, although they may choose to do so. Rather, this observing mode will free them from *having* to travel to the MMA to observe. In addition, service observing will give the local staff the freedom to juggle observing programs to match the current receiver status and atmospheric transparency. Such

a mode requires the MMA to provide astronomers with the capability to monitor the observing over the Internet, so as to make program changes when necessary.

2.1. Operating Centers

Support of MMA operations will require four locales in Chile, and several in the United States. The instrument itself will be situated on the Llano de Chajnantor, a geologic “bench” at an altitude of 5,000 m (16,500 ft) in the Andes mountains east of the village of San Pedro de Atacama. The operations center will be located near this village because of its proximity and its lower altitude of 2,450 m (8,040 ft). The local business office probably will be in Antofagasta, a seaport as well as the capital of Region II of Chile. Finally, a small business office must be located in the capitol of Chile, Santiago, to process duty-free imports and to maintain contacts with the national government. The NRAO sites in the United States will oversee long-term technical development as well as offer high-level technical support when necessary.

Similar to the Very Large Array (VLA) in New Mexico, the principal operating center of the MMA may change with time. San Pedro de Atacama is a small village (population 1,000) with few amenities other than those required to support its tourist industry. Few employees families will want to live there for a long term, especially those with school-age children. As the MMA evolves into stable operations, we believe it likely that some aspects of its operations will move to a larger community with more amenities. Such changes could make long-term employment attractive to skilled professionals. The modern fiber-optic telephone network now being installed in Chile should easily facilitate this relocation. In this case, the San Pedro de Atacama facilities will become principally a maintenance facility.

2.2. Character of Chilean Operations

2.2.1. Management

Management decisions should be local ones. The MMA director should make all decisions involving operations in Chile. All employees in Chile should report to the MMA director, regardless of whether they are “permanent” Chilean hires or ones “borrowed” from related organizations such as the NRAO itself. The sponsoring organization, the NRAO, should confine its involvement with the MMA to financial, logistic, and technical support as well as general, observatory-wide policies such as access to and scheduling of the MMA.

2.2.2. Salaries and benefits

As far as possible, employee salaries and benefits should be uniform among all MMA employees. By the time the MMA moves into full operation, we expect that Chilean professional salaries will be competitive with a world market. These salaries would include job classifications and the salary steps within them. Exceptions would be temporary employees “borrowed” from other organizations. These employees probably would have continuing financial commitments at home. “Benefits” would include medical insurance, pension contributions, educational allowances, housing, and travel allowances where appropriate. Such benefits as well as work rules should be in strict accordance with Chilean law regardless of the eventual diplomatic or international status of the MMA organization.

2.2.3. Contracting support services

As is customary in the Chilean mining industry, the MMA should contract for commercial services when they are available. For example, Chile has several large companies that provide food service to remote locations. The employer need only supply a kitchen and dining room, and specify the variety and quality of the food to be served. This situation also applies to medical services, housekeeping services, payroll, and vehicle leasing and maintenance. The MMA should actually hire only those employees unavailable or inappropriate to obtain from commercial service companies, such as management and administrative personnel, support scientists, engineers, programmers, and mechanics. Not only is this system flexible and cost-effective through competition, but it also frees the MMA management to focus on topics and workers essential to the MMA operations.

Contracting for services is already common practice for the NRAO. Much of the Charlottesville, and all of the Socorro and Tucson facilities are situated on university campuses. They contract with the host universities for housekeeping, building maintenance, telephone, and other services where possible or appropriate. Kitt Peak National Observation (KPNO) provide Arizona Operations with food and telephone services on Kitt Peak. As a unit, the NRAO contracts for all of its payroll services.

3. STAFFING

3.1. Sistema de Turno employment for the MMA and its Operations Center

To operate the MMA in Chile, *all* consultants recommend a rotating shift system known in Chile as the “Sistema de Turno” for staffing the operations center and the maintenance of the MMA itself. In Chile the Turno system is used by all international observatories and most mining operations. It complies with Chilean labor laws. Typically, it consists of one week “on” and one week “off” in a manner to provide 80 to 88 work hours over a two week period. Variations are common. A construction project in a remote area east of Iquique operates on a two week “on” and a 10 days “off” system. Customarily, the employer provides room, board and transportation to and from an urban assembly point.

A Turno-like system is not new to the NRAO. Telescope operators on Kitt Peak, Arizona, work according to a similar system, called the “Fixed Salary, Fluctuating Work Week” or Regulation 778.114 of the US Labor Department. Despite the extra work required to calculate payroll and vacations, the Kitt Peak employees are enthusiastic about their work schedule. It affords them continuity for projects, family, and occasional second jobs during their “off” time.

An effective Turno system must be appropriate to the operation of the MMA. This system is not appropriate for management people who need to be continually available. It is also inappropriate for employees responsible for creating new systems or equipment. However, it works well for “interchangeable” personnel like telescope operators and maintenance people who must be available seven days a week, 24 hours a day. There is extra cost involved. Statistics show that it requires about 2.4 employees for every Turno position to ensure overlap and continuity.

Given the difficulties of staffing a location like San Pedro de Atacama, the Turno system may prove to be the only practical solution.

To accommodate a Turno system, the MMA would need to provide dormitories at its operations center near San Pedro de Atacama. Our advisors recommend that the dormitories be sized so that each Turno-

employee could have the same room and the same bed each visit. In this way, that employee could leave personal effects in the room and could decorate the room to suit his or her preferences.

The MMA should establish pickup points for Turno employees only in Calama, at first. Region II has a network of modern, commercial buses linking its cities. Some of these buses serve San Pedro de Atacama more than once daily and, of these, a few continue on the Paso de Jama road into Argentina. The principle would be that commuting employees need to get themselves to the collection point by the most appropriate means and at their own expense.

Professional employees would either live in San Pedro and take substantial holidays as compensation for long hours on the job, or commute from elsewhere in Chile with some of the commuting time being considered working time. The VLA used a similar system for many years to transport employees from Socorro to the Plains of San Augustin..

3.2. Support offices in Antofagasta and Santiago

The Antofagasta and Santiago offices would not require a Turno system, nor would one be appropriate to their function. The Antofagasta office would process shipments in and out of the seaport and the airport, representing the MMA to the regional government when necessary, and purchasing supplies and services available in Antofagasta. The Santiago office would provide a similar role, with connections to the central rather than the regional government. For continuity, the same personnel should be available in these offices Monday through Friday. Each office might require only a small staff.

The role of these offices may change with experience. After 30 years of operating in Chile from La Serena, the CTIO has chosen to use only ports of entry near Santiago even though the city of La Serena is contiguous with the port of Coquimbo. The CTIO has found that the high traffic levels at the Valparaiso seaport and the Santiago International airports give the widest opportunities for shipping. Equally important, they have found that, in most cases, these ports are less expensive to use than the port of Coquimbo even though the Santiago goods must be trucked to and from La Serena. Because the Foreign Office in Santiago must process all papers for duty-free shipping regardless of which Chilean port is used, CTIO requires an Santiago representative.

An alternative scenario for the NRAO might be to withdraw all but essential operations support from San Pedro de Atacama to somewhere else in Chile just as the VLA operations has moved from the Plains of San Augustin to Socorro, use the Santiago ports of entry to ship and receive all international goods, and truck these goods overland from Santiago to Antofagasta and San Pedro de Atacama. In this case, the Santiago business office of the MMA would function similarly to CTIO's Santiago office.

4. OPERATIONS COSTS

This section discusses the cost of operating in Chile. Section A describes estimates of these costs in US dollars from data from different epochs; Section B, historical variations in the purchasing power of US dollars in Chile; and finally, Section C, the estimate for operations in Chile in terms of 1998 dollars.

4.1. Operating Expenses in Chile

There are several ways to estimate the operating costs of the MMA in Chile. One is to itemize and total all expected expenses; another, to total personnel salaries and benefits and divide by whatever fraction that is typical for similar operations in Chile; a third, to find a similar institution operating in Chile and

adopt its operating budget adjusted by the number of employees. While all of these will be in error because of the MMA's uniqueness, the latter two methods may be least in error because they include operating expenses which the NRAO can not foresee.

For similar institutions, the ratio of salaries and benefits to total budget tends to be the same. In 1995 the NRAO value was approximately 0.73. For CTIO, the value is 0.70. Both values reflect an exceptionally tight funding climate. Operating at lower ratios makes more funds available for repairs and improvements. Our consultants recommend a value of 0.6 for Chile, especially for the early years of operations.

Table 1: MMA Personnel in the United States and Chile		
Categories	Employees	Percent of Total
Scientists	9	8.8
Engineers and programmers	18	17.6
Supervisors	3	2.9
Clerical personnel	13	12.7
Technicians	44	43.1
Maintenance personnel	15	14.7
Totals:	102	100.0
Exempt employees	30	29.4
Non-exempt employees	72	70.6

In 1995 the NRAO estimated the personnel needed to support and operate the MMA in Chile. This estimate includes all MMA employees, that is, both in the United States and in Chile. Table 1 lists the categories. The estimate resulted from experience operating the VLA in New Mexico and from an analysis of the MMA requirements in Chile. The total includes additional employees to compensate for efficiency losses for the few employees working at the high-altitude MMA site on a daily basis. Salaries and benefits (31.5%) for these 102 employees total US\$4.3M in 1994 dollars. Dividing the NRAO estimate for salaries and benefits by 0.6 gives an estimate of US\$7.2M to operate the MMA in 1994 dollars.

The CTIO provides a good comparison for the MMA. In early 1995, the CTIO had 138 employees, of whom 20 were US hires and 118, Chilean hires. Salaried "exempt" positions were 29% of CTIO positions, which is what the NRAO model projects. The distribution of CTIO employee classifications corresponded well to the NRAO projections, subject to differences in job titles between the two observatories. CTIO salaries and benefits (33%) totaled US\$5M. Scaling to the 102 projected MMA employees gives US\$3.7M, and dividing by 0.6 predicts an operating budget for the MMA of US\$6.2M in approximately 1995 dollars.

An accurate projection for the MMA in Chile involves additional factors. First, the MMA plans to contract for food and house-keeping services now provided in-house by CTIO employees. Second, the mix between temporary world-market and permanent Chilean hires may be different for the MMA than for

CTIO, especially during its early years. Third, the remoteness of the MMA operations center will require significantly higher salaries than observatories operating from cities like Santiago and La Serena. Geographic adjustments of 20 to 30% above Santiago salaries are common for Region II. Fourth, its remote location may require larger transportation budgets than CTIO's La Serena location. Finally, scaling the unusually tight CTIO budget may provide an unrealistically low estimate for operating costs. Considering the projections described above and these factors, we believe that US\$8M in 1995 dollars is a reasonable estimate for routine operations of the MMA in Chile.

In addition to the cost of routine operations in Chile, the MMA will have a continuing need to develop new instrumentation and software. These developments will provide additional scientific capabilities for the telescope as new technology becomes available. An annual investment of even 2% of the capital cost of the MMA would provide a budget of US\$4.5M for the development of equipment and software that should be considered as part of the annual operating costs. Furthermore, the power of the MMA will depend in part upon its real-time accessibility to astronomers worldwide. We estimate the cost of supporting this access—through the Internet and via satellite links—to be about US\$1M. Finally, the need for a shared rotation of the highest level staffing of the MMA between the operations center and NRAO facilities in the US to be about US\$0.5M per year.

4.2. Purchasing Power of US Dollars in Chile

The purchasing power of the US dollar in Chile is driven by market forces. These include how much Chilean banks are willing to pay for US dollars on the international market, how much Chileans are willing to pay for foreign-made goods, and the cost of living in Chile. At this writing, Chile has no national debt. Its economy is expanding. It has a favorable trade balance with the US and, consequently, more dollars than it needs.

Variations in the purchasing power of dollars in Chile also involves the relative price inflation of both countries. Consistent with economic practice, both countries track inflation through a variety of consumer and wholesale price indices. A principal US index —there are many — is the seasonally adjusted Consumer Price Index or “CPI”, published by the US Federal Reserve Data Bank (FRED) and available on the World Wide Web. For Chile, the approximate equivalent is the Índice de Precio de Consumador or “IPC”. Both indices are model dependent, they are calculated on the basis of a hypothetical “market basket” of a typical family that may or may not apply to the MMA situation.

Until recently, Chile has experienced high rates of inflation. It has become common practice for Chilean companies to write contracts, and in some cases pay salaries, in units of the Unidad de Fomento (promoted unit) or UF. The Chilean government adjusts the UF to compensate for variations in the internal buying power of the Chilean peso.

Specific exchange rates between the US dollar and the Chilean peso are the Dolar Acuerdo (agreed rate), the Dolar Informal (informal rate), and the Dolar Interbancario (interbank rate). The Dolar Acuerdo reflects the number of pesos per dollar in contracted transactions. The Dolar Interbancario applies to mercantile and financial transactions within the banking industry. The Dolar Informal is the rate that results from tourists and foreign companies exchanging pesos for dollars as needed.

Combining the IPC and CPI with the Dolar Informal rates experienced by AURA over the last several years, I believe that the buying power of the US dollar in Chile has fallen at an annual rate of about 6%. Over a longer period, the rate is closer to 8%.

Scaling budgets to future years is difficult. Despite more than thirty years of experience, CTIO has found it impossible to predict the variation in the buying power of the US dollar in Chile. Market forces affecting the dollar/peso exchange rate and the US and Chilean inflation rates are too complex to predict. The CTIO management recommends that projections be limited to only one year in the future. Last year, the dollar's purchasing power in Chile fell by approximately 8%.

4.3. Projecting MMA Operations costs in US dollars

Summing the cost estimates described in Section A above and adjusting these estimates to 1998 US dollars through considerations discussed in Section B, we estimate the annual cost of operating the MMA to be approximately US\$15M 1998 dollars.

Considering the expected impact of the MMA upon our understanding of the universe in which we live as well as the costs of the powerful and successful Hubble Space Telescope, we believe the cost/benefit ratio of operating the MMA will be remarkably reasonable.

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