MMA Project Book, Chapter 16

Site Development

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5 Oct 98: Added new information regarding generating electric power in San Pedro de Atacama and the depth of potable water beneath the surface of San Pedro de Atacama.

SUMMARY

This chapter describes the characteristics of the four Chilean sites to be associated with the operation of the MMA and lists the construction items needed to make each site functional. These sites are the instrument site at Llano de Chajnantor at an elevation of 5,000 m (16,400 ft) in the Andes mountains near 23° S latitude, the principal support site near the village of San Pedro de Atacama at an elevation of 2,425 m (7,960 ft), a business office near the sea port of Antofagasta, and a business office in the capital of Chile, Santiago. We also consider the NRAO support facilities in the United States.

1. INTRODUCTION

Site development and operations are closely linked (see Chapter 18). The physical development of an observatory affects how it operates. Yet, we need to know how an observatory will operate to build an effective physical plant. The plan for site development described below is a consequence of our present ideas for operations in Chile. This plan will surely evolve as we gain experience operating in Chile. Moreover, the Chilean custom of using high-quality prefabricated buildings in remote areas will allow us to easily make substantive changes in the physical plant as we discover what works and what does not.

2. CONCEPT

Large, sophisticated optical observatories have operated in remote areas of Chile for decades. Indeed, perhaps the most sophisticated observatory of all, the Very Large Telescope (VLT) of the European Southern Observatory (ESO) is now under construction at a remote site approximately 96 km (60 miles) south of Antofagasta. Our development plan results from inspections of these observatories, extensive discussions with their directors past and present, and our own experience operating radio telescopes in the United States for forty years. To succeed with the MMA, we will need to be flexible and creative.

A principal feature of the MMA operation will be remote or "service" observing. The local operations staff will make observations for astronomers. During these observations, these astronomers will be able to oversee the observing via an Internet connection and, when necessary, modify the instructions. This mode is now common for the NRAO's VLA and 12-m telescopes. This situation is similar at many other astronomical observatories. There will be exceptions, of course, especially during the early years of operations. Data will be transported to the astronomers probably in the form of magnetic tapes.

The MMA "site" in Chile will involve several locations. The observing site is the location of the instrument itself, the Llano de Chajnantor in the Andes mountains. The nearby village of San Pedro de Atacama will serve initially as the construction office and, with a scope that may change with time, the local operations center. During construction and operations, the MMA will need a business office near the port of Antofagasta. It will receive

ocean, air, and overland shipments, export material to and from the telescope and local operating site, make local purchases, and interact with the regional authorities. The MMA will require an office in Santiago because Chile's head Foreign Office is the only place to process shipping documents associated with duty-free imports, no matter which Chilean port is used. Finally, the MMA will rely heavily upon the sophisticated resources of the NRAO sites in the United States. Each of these Chilean sites will need to be developed. Each of these sites will evolve differently because of changing requirements as the MMA moves from construction through interim operations into normal operations.

2.1 Llano de Chajnantor.

The telescope site lies at an elevation of 5,000 m (16,400 ft) in Region II of Chile, at a latitude of 23° S. Geologically, the site is a "bench" on the western side of the Andes range, with excellent drainage and a line-of-sight to a nearby community.

Logistically, this site has three important advantages: easy access, proximity to developed communities, and a gas pipeline. It lies near an international highway (Camino de Paso de Jama or International Route 27) connecting Chile with Argentina and now being paved. It lies within a 1-hour drive (approximately 55 km or 34 miles) east of the tourist village of San Pedro de Atacama (population 1,000); within a 2-hour drive (approximately 180 km or 110 miles) southeast of the mining support city of Calama (population 120,000) serviced daily by major Chilean airlines; and within a 5-hour drive (approximately 390 km or 240 miles) east of the port city of Antofagasta (population 300,000) also serviced daily by Chilean airlines. Finally, a new high-pressure gas line will pass by the periphery of the site, providing reliable and inexpensive energy to power gas-turbine electric generators.

Additionally, Chilean telephone companies are now installing broadband, fiber-optic cables and modern switching systems to link Chilean cities to accommodate the rapidly expanding economy. We can easily connect the MMA at Llano de Chajnantor into this network either by fiber-optic cable or state-of-the-art microwave links.

To make this site viable for the MMA, we will need to improve an 18-km (11-mile) existing mining road (with switchbacks) connecting the Paso de Jama highway with the site. It is likely that we might also want to improve an existing, straighter, 32-km (20-mile) mining road connecting the site to the Paso de Jama highway via the eastern side of the nearby hills Cerro Toco, Cerro Chascon, and Cerro Chajnantor.

Gas Atacama, an international consortium planning the gas pipeline between gas-rich northern Argentina and energy-thirsty northern Chile, has agreed to route the pipeline near but not across the MMA site. They will provide a gas tap at a place of our choosing, to allow us to site a gas turbine electric generating plant to power the MMA itself and the site support facilities. Energy provided to the site in this form should be reliable, inexpensive, and visually unobtrusive compared with the option of a high-voltage transmission line between Calama and the Llano de Chajnantor.

Potable water is a more difficult but solvable problem for the site. The Atacama desert receives little moisture, although higher elevations in the Andes mountains receive more because of the cooler temperatures associated with their altitude and their proximity to the wetter, eastern side of the range. The small, known accumulations of water on the western slopes of the Andes have already been committed to providing water for desert communities. For example, Antofagasta's water is piped about 320 km (200 miles) from the Andes to the coast. However, Andes water also collects into underground aquifers in the valley (Salar de Atacama) where San Pedro de Atacama lies. The new 4-star Explora Hotel in San Pedro de Atacama found good water approximately 180 m (590 ft) below the surface, accessed through a well. The simplest way to supply the MMA site would be to process this water through a treatment plant at the MMA support facility near San Pedro de Atacama and truck the water to the site as needed.

Alternatively, it may be possible to drill a well at the MMA site itself. Environmentally, it would be prudent to use this water sparingly at the site by installing low-water toilets and reprocessing grey water, if any. In effect, European Southern Observatory now does this to supply their VLT site at Cerro Paranal, approximately 96 km (60 miles) south of Antofagasta.

2.2 Operations Support

The remaining locations in Chile will serve to support operation of the MMA. Their functional aspects will change as the MMA moves from construction into operations and, correspondingly, so will the site characteristics. Largely, these changes will depend upon the individual preferences of the first few Chilean hires, on the Chilean economy at the time of their hiring, on the cash flow from the funding agencies, and what we learn is necessary to support the array.

2.2.1 San Pedro de Atacama

Initially, this village will surely be the center of construction operations. It is the closest community to the MMA site. Built to support its tourist industry, its few modern hotels could house temporary visitors to the construction operations. The highway connecting it with Calama is excellent. The runway of its small airport has just been paved and, possibly, commercial feeder flights may begin to use it in support of the tourist trade.

Land needed for the operations center and for off-site private housing may have limited availability. San Pedro de Atacama is a village of privately-owned land surrounded by government or "fiscal" land. Chilean law prevents foreign nationals from owning land within 100 km of an international border. The MMA should plan to lease fiscal land directly from the government or through an intermediary like the University of Chile or the Catholic University. Discussions so far indicate there will be no insurmountable problems in this regard.

The extent of the MMA development in San Pedro de Atacama will depend upon how construction proceeds. We are planning to send antennas to Antofagasta, Chile, by ship and to San Pedro de Atacama by road in the largest practical modules, so that a minimum of assembly will be required. If possible, we will assemble the antennas at the 2,425 m (7,960 ft) altitude of San Pedro, equip the antennas with cabling and electronics, and truck the completed antennas to the much higher-altitude MMA site. Such an operation would require a 2-storey assembly building, a machine shop, an electronics workshop, offices, a library, dormitories, a dining facility, a water treatment plant, and some recreational facilities like tennis courts and a swimming pool. The extent of these facilities will depend upon how quickly we procure the antennas, that is, ultimately upon the cash flow from the funding agencies.

The MMA should plan to generate its own electric power in San Pedro de Atacama. At this time, the village provides electric power by a generator operated only during the early evening hours. There is no electric power during the day. The better hotels generate their own electricity. The GasAtacama pipeline will run a few kilometers east of the village. They have agreed to install a separate side tap to provide natural gas to the MMA operations support facility (OSF) near the village. Still to be decided is whether to generate electric power at the tap and bring it to the OSF by high voltage lines, or to install approximately 3 kilometers of 6 inch gas pipe between the tap and the OSF to allow electric power to be generated at the MMA support facilities. Economic and aesthetic considerations will influence this decision.

After three antennas have been delivered to the site, limited observing can and should begin to test the array and to produce astronomical data. Such operations will require high-level support staff like computer programmers, electronics engineers, and support scientists generally unavailable

locally. These employees, although temporary, may insist upon bringing their families to Chile and require the MMA project to provide family housing as well, some of which will surely be in San Pedro de Atacama.

As operation increases and construction wanes, the character of the work and of the support staff in San Pedro will change. Those remaining will tend to be "permanent" MMA employees, largely Chilean nationals, who will operate and maintain the array. Buildings suitable for construction will become unnecessary, and they should be removed. On the other hand, additional office and laboratory space will be required. Given the widespread use of high-quality prefabricated buildings in the Chilean mining industry, the MMA should also use such buildings in San Pedro de Atacama. Prefabricated buildings make it easy to change the physical plant to adapt to its changing function.

Eventually, MMA operations should become routine, very much like those of NRAO's VLA. Only a small staff may be required in San Pedro de Atacama, and most of the support staff could be moved to a Chilean city with more amenities such as Antofagasta where employee recruitment and retention will be easier. At this stage, the physical plant in San Pedro could be further reduced if prefabricated buildings are used.

Whatever the evolution of MMA operations based in San Pedro de Atacama, the MMA management needs to be sensitive to the character of the village. It is an international tourist destination because of its 16th century architecture, its geothermal areas, its pre-Columbian archeological sites, its indigenous Atacamañan residents, and its unique charisma. The village itself has strict architectural codes. Our location with respect to the village and the architecture of our buildings will affect our being accepted as desirable members of the community.

2.2.2 Antofagasta

In Region II, Antofagasta is *the* important city. It is the economic and administrative capital of the region. It is an international port. It has several commercial flights each day. It has at least one English-language international school. It has two small universities, and, it is the largest city in Region II. The MMA organization will need to have a small office there to receive and ship goods, to buy supplies unavailable in Calama or San Pedro de Atacama, and on occasion to represent the interests of the MMA to the regional government.

As the MMA moves from construction into full operations, the role of the Antofagasta office could expand substantially. Because of the limited amenities in San Pedro de Atacama itself, most long-term MMA families will choose to live elsewhere. To support this expanded presence, the Antofagasta office would need to grow considerably.

2.2.3 Santiago

Chile is a country of about 14 million inhabitants. About 50% live in the Santiago-Valparaiso area, and five million live in Santiago itself. Santiago's environs while smog-impaired during part of the year are exceedingly pleasant. It is an international city with lots of amenities. It has foreign-language schools that can prepare students adequately for admission to foreign universities, such as scoring well on the US SAT and achievement examinations, or the German Arbitur exam, or the French Baccalauréat exam. Two of its universities, the University of Chile and the Catholic University are among the best in South America. Most substantive Chilean companies maintain offices there. It is the entry point for most international flights. It is where you have to be to make and maintain important political and economic connections. Chileans and foreigners enjoy living there. Simply put, it is the capital of Chile.

The MMA operations will need a representative in Santiago. Shipping documents for duty-free imports can be processed only by the Foreign Office in Santiago. Specific goods are more available in Santiago than elsewhere in Chile. Visitors to the MMA will arrive first in Santiago.

What is in question is the *extent* to which the MMA will need facilities in Santiago. Unlike the Cerro Tololo International Observatory (CTIO), Carnegie Southern Observatory (CARSO), and the European Southern Observatory (ESO), the MMA is expected to operate primarily as a service telescope. Like the VLA, astronomers need not travel to the telescope to make excellent observations. Accordingly, no reception center will be required, no guest house will be required. When MMA staff and other visitors do come to Santiago, the large range of commercial hotels and restaurants in the city will suffice.

I believe that the MMA will need a small business office in the Vitacura or Providencia districts, staffed with one or two people. This staff will process customs documents, purchase and ship items unavailable in Region II, represent the MMA in governmental matters, and coordinate their activities with the CTIO and ESO offices now located there.

2.2.4 United States

The sophisticated support resources of the NRAO in the USA will be impossible to duplicate in Chile, owing principally to the diversity of the instrumentation routinely maintained in the USA. While the MMA management will maintain its equipment as much as possible in Chile, the ultimate support will be the NRAO facilities in the United States. I would expect technical development of new sophisticated equipment and software to occur in the United States, as well as the identification and correction of subtle flaws in hardware and software, and support of MMA users located in the US.

3. DEVELOPMENT DETAILS

3.1 Llano de Chajnantor

3.1.1 Peripheral development

3.1.1.1 Access road from Paso de Jama to the site, 18 km (11 miles) with a double-asphalt surface, 1.6 km (1 mile) of guard rails on the switchback turns.

3.1.1.2 Gas tap on GasAtacama high pressure gas line, connecting pipe to gas turbine generator

3.1.1.3 Fiber-optics link from site to San Pedro de Atacama, approximately 56 km (35 miles) , Or, broadband microwave link (E-1 links) from site to San Pedro de Atacama

3.1.1.4 Water well, if economically feasible

3.1.2 Actual site development

3.1.2.1 Gas Turbine generator, 2 MW minimum (rated to produce 4 MW at sea level).

3.1.2.2 Diesel or Gas emergency generators, 1 MW minimum at altitude, to power

cryogenics

3.1.2.3 Transformer station to switch between generators and alter voltages as required.

3.1.2.4 On-site roads, approximately 20 km, 7 m wide, compacted but unpaved, to connect pads with service buildings. (We need a specific layout to estimate this number accurately.)

3.1.2.5 Approximately 145 antenna pads, reinforced concrete, with signal and power connections.

3.1.2.6 Intra-pad signal (fiber-optic and coax) and power connections, approximately 20 km (12 miles). (We need a specific layout to estimate this number accurately.)

3.1.2.7 Water storage and distribution system to accommodate up to 20 workers.

3.1.2.8 Sewage disposal system.

3.1.2.9 Internal telephone system, data compatible

3.1.2.10 Internal power distribution system

3.1.2.11 Antenna barn with 3 bays, each 40 ft x 50 ft (6,000 ft^2 or 557 m^2), includes transporter repair station, perhaps with elevated partial pressure of oxygen

3.1.2.12 Warehouse, 1,000 ft^2 (93 m^2), prefab

3.1.2.13 Control building & first-aid station, 15,000 ft^2 (1,393 m^2), with elevated partial pressure of oxygen, prefab

3.1.2.14 Emergency dormitory, 2,000 ft^2 (186 m^2), with elevated partial pressure of oxygen, prefab

3.1.2.15 Generator building, 2,000 ft^2 (186 m^2), prefab (?)

3.2 San Pedro de Atacama

3.2.1 Peripheral development

3.2.1.1 Electrical generation plant, 500 kW maximum, powered by natural gas.

3.2.1.2 Either approximately 3 km of 6 inch gas pipe to connect OSF generators with the GasAtacama gas tap, or 3 km of high voltage lines to connect our generators at the gas tap to the OSF.

3.2.1.3 Well, probably 180 m (590 ft) deep based upon the experience of the new Explora Hotel

3.2.1.4 Water treatment/ recovery plant

3.2.1.5 Sewage treatment

3.2.2 Actual site development

3.2.2.1 Laboratory, auditorium, & library building(s), 12,000 ft^2 (1,115 m^2), prefab

3.2.2.2 Antenna barn for assembling antennas, 2,000 ft^2 (186 m^2), prefab. (This 2-storey structure may conflict with local zoning laws.)

3.2.2.3 Warehouse, 4,000 ft^2 (372 m^2), prefab

3.2.2.4 Control & first aid, building(s), 8,000 ft^2 (743 m^2), prefab

3.2.2.5 Welding, carpentry, mechanical shop, 3,000 ft^2 (279 m^2), prefab

3.2.2.6 Dormitory, 8,000 ft^2 (743 m^2), *masonry* for acoustic isolation

3.2.2.7 Recreational building (s), 8,000 ft^2 (743 m^2), prefab

3.2.2.8 Fiber-optics or microwave link terminal

3.2.2.9 Electric power distribution system

3.2.2.10 Telephone system, internal, data compatible

3.2.2.11 Sophisticated communications facilities such as LAN, facsimile, connection to Internet

3.2.2.12 Houses, 5 @ 2,000 ft^2 (186 m^2), prefab, perhaps scattered through community

3.2.2.13 Outdoor recreational facilities

3.2.2.14 Parking lot for 40 vehicles

3.2.2.15 Security wall, adobe

3.3 Antofagasta

3.3.1 Actual Site Development

3.3.1.1 Offices, 2,000 ft^2, with garage space for two vehicles, rented

3.3.1.2 Transit warehouse, 2,000 ft^2

3.3.1.3 Sophisticated communications facilities such as LAN, telephone, facsimile, and connection to Internet.

3.4 Santiago

3.4.1 Actual Site Development

3.4.1.1 Offices, 2,000 ft^2 with meeting room, with garage space for two vehicles, rented

3.4.1.2 Sophisticated communications facilities such as LAN, telephone, facsimile, and connection to Internet