17 OPERATIONS MODEL

17.1 Introduction

This chapter describes the operating model for the Giant Magellan Telescope. The facility, including the telescopes, instruments, adaptive optics systems, and associated support systems, will be operated to maximize their scientific output. Several observing modes will be supported, including classical visiting PI mode, PI remote observing, campaign mode, queue-scheduled service observing, interrupt target of opportunity, and queue-scheduled synoptic observing. We will support all of these modes via flexible assisted observing. In this operations model, observatory personnel will operate the telescope, the instruments, and the adaptive optics system. Resident staff astronomers will ensure that the telescope and instruments are operated efficiently and will be responsible for real-time decisions regarding which instruments are used and which programs are executed.

The operation is composed of several parts: the US corporate office, the GMT operations center, the Chilean support base, on-site operations, and distributed support for instrumentation. Our model for on-site operations flows down from the GMT science requirements and these are derived from the GMT science case.

Our operations model allocates a total of 120 FTEs to these three groups, 34 of which are based in the US. The GMT observatory will support the continued development of instruments at a level sufficient to produce one facility instrument every 3-5 years. Adaptive optics development will be supported by the observatory staff in the US and Chile. In addition to instrumentation and AO, the GMT operations budget will support facility upgrades through its annual operations budget, at the level of 1% of projected capital cost.

Our projections for the manpower and capital requirements for GMT operations are informed by the partners' experience with large observatories in Chile, Arizona and Texas. The operating modes of the Magellan, MMT, and HET telescopes each have their own unique characteristics and while none are directly transferable in total to the operations of the GMT, all of the proposed GMT operating modes are in use at one or more of the above observatories to varying degrees. While our operations model derives from our science requirements, it draws heavily on Carnegie's deep knowledge of Chilean operations, UT Austin's experience with a fully queue-driven telescope, and the Arizona and Smithsonian experience in adaptive optics operations and long-term development programs.

Two principles guide our thinking regarding operations for the GMT. The first is that we must maximize the scientific return from the facility. The GMT is not only an enormous capital investment for its partner institutions; it may represent the global astronomical community's premier large aperture optical/IR telescope for many years. The second principle guiding our thinking is the need to minimize costs, while achieving our goal of maximizing the scientific return from both capital and operating costs.

Three modes of operation are adopted currently on large telescopes: traditional visitor principal investigator (PI) mode, queue-scheduled service mode, and remote observing. Most large observatories tend to emphasize one of the modes over the others. GMT and its instruments will be sufficiently complicated that even in visitor PI astronomer mode, a significant level of technical and observing support is likely to be required. In order to maximize the scientific return from the investment in GMT, and to provide the GMT scientific community with the greatest range of operations capabilities, the telescope will be run in a flexible assisted observing mode. Under flexible assisted observing, the staffing level is appropriate to run the telescope in full queue-scheduled mode, and so can accommodate any other modes in response to changing conditions and time-critical observations.

Flexible assisted observing allows the following modes of operation:

- Visitor PI on site, with time block-scheduled
- Visitor PI observing from a remote location, with time block-scheduled
- Campaign observing for a large project, with an expert team on site
- Queue-scheduled service observing by a Resident Astronomer
- Target of Opportunity pre-emption of queue- or block-scheduled time, for transient targets and in response to observing conditions (e.g. excellent seeing, excellent water vapor, poor transparency, etc.)
- Synoptic observations of time-critical targets, scheduled in advance

Flexible assisted observing requires an observing support staffing level appropriate for fully responsive queue operation: Resident Astronomers (RAs), Telescope Operators (TOs), Instrument Operator (IOs), and Adaptive Optics Operators (AOOs) with specialized understanding of the telescope and its instruments will be required. In particular we foresee the need for significant adaptive optics (AO) support on site. GMT observing time will be sufficiently valuable that observing time lost due to technical problems or inefficiencies must be minimized. Thus staff with technical expertise relevant to the telescope and its instruments must be on-duty at night. During nighttime operations, a Resident Astronomer, a Telescope Operator, an Instrument Operator, and, when appropriate, an AO operations team will be present, in addition to the visiting PI or team, if on-site. The night operations team will have back-up from a technical staff that will be on the site and on-call at night.

The RAs will have responsibility for the scientific usage of the telescope, while the TOs will have responsibility for the safety of the telescope and personnel. On any given night, the telescope may be used in a mixture of block-scheduled time allocated to one or more programs and queue-scheduled time covering multiple programs. The RA has authority to preempt the queue or block-scheduled time as conditions or special targets require, optimizing the scientific output of the telescope. An accurate accounting of time and conditions will be required to record and track the use of the facility.

The total annual projected operations budget is \$29.1M in 2004 dollars. Allowing for a 10% contingency to cover unanticipated costs sets an upper bound on the current model of \$32.1M. This amounts to 6.3% of the projected capital cost of the telescope, associated support infrastructure, and the first generation of instruments. The annual recurring operating expense is projected to be $15.4M. The remaining $13.7M is directed towards instrumentation and facility upgrades and represents an expected annual average cost that may fluctuate from year-to-year.

The model presented here ensures adequate staffing to support any scheduled observing sequence, and to react to changing conditions and time critical opportunities. The staffing level is somewhat higher than at facilities such as Magellan and the MMT that are primarily used in a traditional visiting PI mode. We believe this is justified in the context of the large capital investment in the GMT facility and instruments. The incremental cost of adding sufficient staff for flexible assisted observing is modest compared to the overall cost of operating GMT. It is expected that the staffing plan discussed here will result in a very high level of responsiveness from the GMT staff to the needs of PIs, whether they are observing on site or remotely, or receiving data taken in queue-mode.

17.2 Science Requirements for Operations

The requirements placed on the operations by the need to meet the GMT science goals are detailed in Chapter 3, section 7. The telescope and its instruments must be operated in a manner that enables modes ranging from large surveys to time-critical and condition-critical observations.

Highlights of the science requirements that pertain to the operations model are:

- Ability to react to, and obtain observations under, conditions of excellent precipitable water vapor (PWV) in order to work in the thermal infrared. This is a particularly crucial requirement if a lower altitude site is selected.

- Ability to react to, and obtain observations under, conditions of excellent seeing in the optical.

- Ability to respond to transient targets of opportunity such as gamma ray bursts and supernovae.

- Ability to obtain synoptic observations of targets at preset times.

It is clear that a traditionally block-scheduled telescope cannot meet all of these requirements.

17.3 Observing Modes

The telescope will be able to operate in a variety of modes, which may be mixed during the night. Below we describe each of these modes.

17.3.1 Classical PI Observing

Individual investigators, or small teams of investigators are pre-assigned blocks observing time, often, but not exclusively, in integral contiguous nights. The observatory staff will prepare the scheduled instrument(s) and will operate the telescope and may operate the instruments during the assigned time. The guest observers are responsible for the scientific use of the telescope, for operating the instrument(s) if sufficiently experienced, and for obtaining their science observations and any associated calibrations.

Campaign Observing: In this mode teams of investigators are assigned a larger than normal block of observing time, or blocks of time. The may be assigned in an open-ended fashion – enough observing time may be dedicated to a program until it is complete irrespective of weather delays. It is expected that in this mode a team of highly skilled observers will be present at the telescope and the requirement on support from the mountain staff may be reduced compared to normal classical PI observing.

17.3.2 Remote PI Observing

Individual investigators, or small teams of investigators are pre-assigned blocks observing time, often in units smaller than a full night, but observe remotely using video conferencing and computer facilities. The remote observers are responsible for the scientific use of the telescope, with the nighttime support staff providing assistance as needed to execute the program. At this time effective remote observing in Chile from a US or European site requires a high bandwidth satellite link. We anticipate that at the time of GMT operations remote observing will be possible through the general mountain Internet service.

17.3.3 Queue Scheduled Service Observing

As opposed to the classical PI mode, in the queue mode hours of observing time are assigned to particular programs or targets and the observations are executed by the observatory staff under appropriate lunar, weather and calendar conditions. Queue-scheduled mode provides the greatest flexibility, but makes the largest demands on staffing. Detailed bookkeeping both pre- and post-observation ensures that each institution receives its appropriate share of telescope time.

17.3.4 Synoptic and Time-Critical Observations

These observations must be carried out at precisely specified times to be successful. Some astronomical phenomena (e.g. eclipsing binaries; stellar occultations) occur at well-determined intervals, others simply must be monitored regularly (e.g. variable gravitationally lensed sources). These observing programs are easily accommodated in a queue system, but they may also be interspersed with classical modes which require that the observatory staff carry out the time-critical observations during otherwise block-scheduled nights. Significant science opportunities are enabled by this flexibility.

17.3.5 Targets of Opportunity and Rare Condition Programs

Some astronomical phenomena must be observed when they happen. Only very short notice is often given for the required observations. At present these include supernovae, gamma ray bursts, and gravitational micro-lenses; it is highly likely that other classes of transient objects will be discovered in new time-domain experiments planned for the coming decade. The other class of observation that requires intervention by the Resident Astronomer into the block or queue-scheduled time involves rare conditions. Periods of excellent precipitable water vapor or superb seeing in the optical are sufficiently valuable that they must be utilized fully, when they occur. This may involve pre-emption of the already scheduled observations, and it will be the responsibility of the RA to initiate such changes to the observing plan. Observation of these targets of opportunity will require an interrupt mode and service observing by the local staff, and is accommodated naturally in the staffing plan for GMT.

All of these observing modes can be accommodated with a staffing plan that allows for flexible scheduling and expert night time support beyond the classical level of the telescope operator. We propose to operate the GMT in a flexible assisted observing mode. In this style of operation, time is scheduled in blocks that comprise a mix of classical PI science and queue service observing. PI's or observing teams will travel to the telescope for assigned classical or campaign time and they will be assisted by telescope operators, instrument operators, and, where needed, resident astronomers. Special modes, such as adaptive optics, will require additional support. Classically scheduled time can be interrupted at any time, either for targets of opportunity, synoptic service observing, because conditions are no longer appropriate for the scheduled program, or because they are optimal for highly condition-sensitive programs. Note that the total fraction of the time allocated to pre-emptive observations will have to be limited so as not to impact overall efficiency. At HET for example, the fraction of time allocated to high priority interrupt programs is 15%, based on experience with running a fully queue-scheduled telescope.

17.4 Night Operations Personnel

Expert judgment will be required on-site to determine that the telescope is being used effectively. This judgment will be the purview of the Resident Astronomer (RA). RAs are PhD-level astronomers. The RA will be responsible for ensuring that observers make efficient use of the telescope, instruments, and observing conditions. The RA will have final say in all real-time nighttime decisions regarding which observing programs are implemented, which instruments are ready for use, and the observing modes that may be employed. The RA will endeavor to see that the observing program approved by the Director is completed within his or her shift on the mountain and will communicate the status of completed and pending programs to the RA on the next shift. In addition, the RA will provide rapid and thorough feedback to the PIs of programs that are observed in queue mode so as to ensure the most effective scientific use of the time. The planning and reporting functions of the RAs, in addition to actually taking a significant fraction of the observations, require a staffing level sufficient to cover the night time hours plus daytime activities for those RAs not on night shift. The RA is always present at the telescope, irrespective of which mode is scheduled for the night. If they are not needed to take data actively they will perform other tasks related to reporting and other duties. Experience (at the HET for example) has shown that five RAs, with one of them acting as overall lead for nighttime operations, is a sustainable level that covers the duties and allows a fraction of their time to be devoted to personal research. Attracting the best candidates for these positions, and retaining them, is crucial to the successful operation of the GMT. Experience has shown that the ability to carry out a program of personal research is a valuable factor in recruiting.

Telescope operators (TO) will be responsible for the safe and effective operation of the telescope, and will have the final say in questions that affect the safety of personnel or the integrity of the facility. In principle, a minimum contingent of three TOs is sufficient to cover the nighttime hours, but in reality it is found that four to five are needed to cover the inevitable periods of sick leave and vacations, particularly in the winter months. Extra hours beyond the nighttime requirements are spent in support of daytime operations where operation of the telescope and instrumentation may be required. It is also highly beneficial to have the telescope checked out in the late afternoon prior to the arrival of the night TO for their shift. As a result, we recommend a minimum staff of four TOs for GMT.

The instrument suite envisaged for GMT will have a range of deployable smaller instruments (particularly IR ones capable of exploiting periods of excellent atmospheric stability or low water vapor), along with a number of larger instruments mounted at the straight Gregorian focus. It is expected that only one of these large instruments will be mounted at any time (although this is under debate), with the schedule synchronized with the phase of the moon or scientific drivers. Each of these instruments is highly complex, and it is essential that they are well maintained and that problems can be diagnosed and fixed quickly.

Instrument Operators (IO) will be responsible for the preparation of instruments for nighttime operation, and in some cases for the actual operation of one or more of the suite of instruments. Their primary role will be to ensure that the instruments are operated in an efficient and safe manner, and to diagnose problems should they occur. They will understand and be able to run all facility instruments available on GMT, and each will specialize in one large Gregorian instrument. Since the Gregorian instruments will be scheduled in blocks of time, the schedules of the IOs will be synchronized with the instrument changes. Four IOs will be needed to provide full support, as for the TOs. When not on nighttime duty, the IOs will engage in programs of preventative maintenance and other ongoing activities related to the instruments.

The adaptive optics systems are expected to be a very specialized set of equipment, requiring an additional staff of AO Operators (AOO), and a Laser Engineer (LE). Laser AO systems are currently not a standard facility on any telescope, so it is difficult to project the level of support needed at GMT. AO systems currently require teams of technical personnel to operate so assuming that a single operator will be sufficient is potentially unrealistic. We adopt a realistic projection that a staff of six AOOs and one LE will be sufficient to run the system between them. There may be periods when AO is not used, but it is certainly possible that AO observations would be made every night, as synoptic and other high-priority observations pre-empt the basic schedule. It is possible that a larger AO staff will be needed, probably not fewer personnel. Experience in the coming several years with AO systems in Arizona and elsewhere will guide this aspect of the staffing plan.

Some members of the Chilean operations base technical staff will need to be on call at the site during the night in case of technical problems. We do not expect to fix most classes of problem with instruments in real time, but diagnosis of instrument problems and any technical problems with the telescope that impact science need to be dealt with immediately.

17.5 Day Operations Personnel and Technical Support Staff

17.5.1 Chile Operations

A significant staff is needed in Chile to run and maintain the facility. We group the staff into four costs centers: administration, mountain operations, technical operations, and observing support.

17.5.1.1 Chilean administration

This group includes the Site Director and associate Site Director, a business manager and a small staff supporting purchasing, accounting, and the Chilean Support Base building and grounds. A total of 17 FTEs are included in this group.

17.5.2 Mountain Operations

This group includes the mountain superintendent, the site manager, associate site manager, and the mountain crew. The mountain crew maintains the roads, power and water infrastructure, lodging, etc. A total of 22 FTEs are assigned to this group. Many of the positions are among the least costly.

17.5.3 Technical Operations

The technical group is responsible for maintaining the telescope, associated facilities, and instruments. This includes electronic, mechanical, and software engineers and technicians, instrument scientists, and an optical engineer. The total number of FTEs in this group is 29.

17.5.4 Observing Support

The observing support group consists of telescope and instrument operators, resident astronomers, and an AO support group. The latter includes a laser engineer responsible for supporting the Na D laser beacon system. A total of 20 FTEs allows this group to cover operations on every scheduled observing night as well as engineering nights.

17.5.5 US Operations

The US operations staff consists of a technical group and a small observing support group.

17.5.5.1 US Technical Support

The US technical group supports the development of adaptive optics and the maintenance of the optical performance of the telescope. A total of 17 FTEs are allocated to this group.

17.5.5.2 US Observer Support

The US observer support group is responsible for scheduling the telescope, coordinating scheduling and observing with the Chilean operation and maintaining records and documentation relating to observations planned and carried out. A total of four FTEs are allocated to this group.

17.6 Personnel Requirements

Successful operation of the telescope and its support facilities will require close coordination between different segments of the observatory staff. For the present discussion these groups are organized as: the US corporate office, the US operations center, the Chilean support base, and on-site operations support. Below we outline the role of each group and their personnel needs and annual operating budgets. All budget figures are in 2004 US dollars.

17.6.1 The US Corporate Office

The administrative officers of the GMT Corporation are defined by the partnership agreement. These include the President (a half-time position, per the draft agreement), the Director, the Associate Director for Science (Project Scientist), a Business Manager, and a small administrative staff. The position of Project Scientist during the development and construction phase evolves into the Associate Director for Science position in the operations phase. A business manager and a small administrative staff support the senior administrators. The President is responsible for all legal and contractual obligations involving the GMT Corporation and managing the annual construction and operations budget, as set by the GMT Board of Directors. The budget for the corporate office includes the salaries for each of these positions as well as the cost of insurance, legal fees, and travel. The projected budget for the corporate office at the start of operations is shown in Table A4 and is estimated to be $1.8M, including the costs of insurance for the GMT facility and office space.

17.6.2 The US Operations Center

The US Operations Center includes administrative, technical, and observer support for the GMT. Administrative staff includes the business/HR manager, accounting, purchasing/receiving, and administrative personnel. Effective use of the telescope will require ongoing engineering and technical support at the level that cannot be sustained in Chile. As shown in Table A1, the US operations center will have a technical group with a group lead, an Adaptive Optics group comprising seven engineers/scientists, and will employ a chief optical scientist and seven other electronic, mechanical and software engineers and technicians. Adaptive optics will be a crucial aspect of GMT operations, one that we expect to require continued development beyond first light of the telescope. The US Operations Center will be the base for the group responsible for the ongoing development of AO capability. The other important function of the US Operations center will be to provide observer support. It is expected that the Resident Astronomers will provide the primary point of contact for PIs, once observations are approved, but there are significant tasks to coordinate the observing program between the partner institutions, and provide documentation. A staff of three is needed for these functions. Personnel expenses associated with the US Operations Center are shown in Table A1, and total $3.1M. Additional costs include office space rental and travel costs as shown in Table A1.

17.6.3 The Chilean Support Base

All Chilean operations personnel are summarized in Table A2. Logistical and administrative support for on-site operations will be centered at a sea level or intermediate elevation office in a significant population center. The Site Director and Associate Site Director and a subset of the technical staff that supports instrumentation will be located at the support base. The Chilean support base will have a significant administrative staff, including accountants, bookkeepers, purchasing and shipping/receiving staff. Building and grounds staff could be shared with another facility if the operations center is co-located, but the assumption is that a support base for GMT is established separate from any existing facility.

A significant technical group is based at the Chilean support base. These personnel will travel to the site but will also establish technical facilities at the support base to assist with activities such as instrumentation commissioning and maintenance. The technical group at the base will typically be the more highly qualified individuals among the technical support. As detailed in Table A2, a total of 15 personnel provide technical support from the Chilean Center base.

17.6.4 On-Site Operations

The nightly operation and daily maintenance of the telescope and instruments are carried out by the on-site operations staff. The nighttime mountain staff consists of telescope operators, instrument and AO operators, and resident astronomers. The day crew is composed of instrument specialists, telescope specialists and electronic and software technicians. The daily operation is supported by the mountain crew (e.g. cooks, plumber, electrician). In order to maintain the flexible assisted observing capability discussed above, there must be a telescope operator, a resident astronomer, an instrument operator, and two AO operators present during nighttime hours. This will require four telescope operators, four instrument operators, six AO operators (on the assumption that two will typically be needed to run the system as is currently the case with the University of Arizona systems), a laser engineer, and five resident astronomers. Operations experience in full queue mode at the HET indicates that when vacation, sick leave etc. is taken into account, four people are the minimum to fulfill the tasks of each job category without causing burn-out. The extra resident astronomer above this number is to allow for the significant planning and bookkeeping tasks associated with the RA positions, and to ensure that there is sufficient time for them to interact significantly with PIs about their programs. One of the RAs will coordinate and lead nighttime operations.

17.7 Instrumentation and Facility Upgrades

A first generation of instruments will be provided as part of the capital construction cost of the telescope. Additional instruments will be designed and built with the ongoing support from the operations budget. A typical instrument will take 5-7 years to complete and is likely to cost $5-30M depending on its size and complexity. We anticipate that it will be necessary to support two or more instrument efforts at any time. For the purpose of budget planning we expect that each instrument team will require support for a Project Manager, two PhD scientists, an optical designer/engineer, two mechanical engineers and technicians, two electrical engineers and technicians, and a software person. We baseline a typical instrument cost at 55% loaded salaries and 45% hardware. Instruments will be built outside the GMT operations office and will likely be led by the GMT partner institutions. We assume that the instrument costs will include overhead at 75% indirect rate on salaries and none on capital. This IDC level is typical for salaries and in most cases large capital items are free of overhead.

In addition to a stream of new instrumentation, the telescope and related facilities will require continued investment to maintain state-of-the-art performance. These upgrades may include advances in optical coatings, increased laser power for adaptive optics, or improvements to the telescope mount and drive. We have budgeted an annual cost of $5M for facility upgrades, or 1% of the GMT capital cost. Expenditures in this area may occur at irregular intervals and it would be desirable to have steady annual contributions that may be held until they are needed, or sufficient funds are accumulated for particular capital improvement projects.

17.8 Estimation of Operating Costs

We lay out our estimation of the costs for operating the GMT and related facilities in spread sheets presented in the Appendix (Tables A1 to A4). The costs are separated into three cost centers: operations, instrumentation and facility upgrades, and U.S. administration. Personnel are attributed to one of the four centers defined above: US corporate office, US operations center, Chilean support base, and mountain operations.

17.8.1 Cost basis

Salaries are computed on the basis of experience with the partners operations of 8m class facilities. We parameterize the cost of each FTE (salary plus benefits) as an integral of a unit base cost of $50K, including 30% fringe benefits. Chilean support positions range from 1 to 2 units, US hires range from 2 to 3, and in the case of the Director, reach 4 units. This approach is imprecise; a more refined model could be assembled using salary data from Las Campanas or Gemini South and typical US salaries in an intermediate cost city. However, for the current estimates, this approach has sufficient precision, and is probably conservative.

17.8.2 Capital Costs in Support of Operations

The cost of operations in Chile and the US contains components other than salaries and benefits. We estimate these general expenses (spare parts, supplies, travel etc) from experience with the Magellan operations. The annual general expenses in Chile and the US amount to $17K and $20K per FTE, respectively, for support of the two 6.5m telescopes. We compute these expenses for GMT using the 86 FTEs in Chile and the 28 FTEs in the US operations group. This total is listed as “General Expenses” in Table 17-1.

17.8.3 Facilities Costs

The GMT will bear some of the cost of maintaining infrastructure at the site. The cost of providing power, water, maintaining roads and buildings will likely scale with the number of FTEs in Chile, both on the site and at the operations center. We use experience with the Magellan operations to determine a per FTE annual infrastructure cost of $20K. The total facilities cost is determined from this rate and the total of 86 FTEs in Chile and is listed as “Facilities Cost” in Table 17-1.

17.8.4 Corporate and Administrative Costs

The annual costs of the corporate office are dominated by insurance for the telescope, instruments, and facility buildings and equipment. The projected annual cost for this segment of the budget is detailed in Table A4, and is estimated at $1.8M.

17.8.5 Operations Costs

As detailed in the Appendix and Table 17-1 we estimate the annual running cost of the facility, including both US and Chilean operations at $15.2M in 2004 dollars, or about 3% of the projected GMT capital cost. This is in addition to the Corporate Office costs. A question of interest is: what is the incremental expense of enabling the full flexible assisted observing model described in the introductory sections over a bare-bones operation model? If the number of telescope operators and resident astronomers are reduced to three, the minimum sustainable level, the instrument operator positions eliminated entirely, and the AO positions reduced to four, the operating cost is reduced by $1M to $14.2M, or 2.8% of capital. However, this level of support would seriously limit the flexibility of scheduling and would impact the scientific return at an unacceptable level. Experience at HET is that three TO/RA positions is not a sustainable level without burnout. The annual cost of the extra personnel to fully enable flexible assisted observing is only $1.0M, a very minor cost and only about 3% of the entire operating budget.

17.8.6 Instrumentation and Facility Improvements

The support of two instrument teams at a level sufficient to produce one facility class instrument every 5-7 years costs $8.7M in our estimate. Proper support of facility improvements in estimated at 1% of the capital cost or $5M per year, giving a total cost for the non-operational component of the annual budget of $13.7M. We consider this level of effort on new instrumentation and facility improvements to be the minimum needed to maintain the competitive edge of the GMT, and, at only 2.7% of the capital, it is far below the level sustained by Gemini, for example.

17.8.7 Contingency and Reserve

While we have attempted to be inclusive in our operations model and cost estimate, it is likely that there are costs that we have not foreseen. As with any long-range budget forecast there is some uncertainty and we have assigned an uncertainty of 10% to our total budget estimate. While it is possible that our budget has been overestimated, experience suggests that it is more likely that we have underestimated the costs. We include an unallocated reserve of $2.9M in our budget estimate to cover this uncertainty.

17.8.8 Total Annual Operations Cost

The sum of the components of the operations budget is estimated at $29.5M (see Table 17-1). With the 10% reserve/contingency applied, this reaches $32.4M, or 6.4% of the capital cost of the facility and the first generation of instruments. This is a similar fraction of capital as the current operating cost for the Magellan 6.5m telescopes (~6% including instruments), and is not substantially different from other 8-10m class operations (e.g. Keck: ~ 6%) that do not include a full scientific research staff in the operations budget.

Table 17-1 Summary of GMT Operations Expenses

Cost Center	Annual Cost $M	%Capital	Notes
Operations Personnel	9.9	2.0	See Tables A1 & A2
General Expenses	2.3	0.4	Tables A1 & A2
Facility Costs	1.8	0.4	Table A2
Instrumentation	8.7	1.7	Table A2
Facility Upgrades	5.0	1.0	Table A3
Corporate Office	1.8	0.4	Table A4
Total Projected Operations	**29.5**	**5.9**	
Reserve/contingency	2.9	0.6	
Total with reserve	**32.4**	**6.5**	

Note: A total GMT capital cost of $503M is assumed in the conversion.

17.9 Appendix

Notes on tables A1-A4: Unit salary is US$50,000 including fringe benefits (30%).

Table A1 – GMT U.S. Operations Personnel

Position	**FTE**	**Units**	**FTE*Units**	**Cost $K**
Administration				
Business/HR manager	1	3	3	150
Purchasing	1	2	2	100
Senior Accountant	1	2	2	100
Assistant Accountant	1	1	1	50
Administrative Assistants/ Clerks	2	1	2	100
Purchasing & Receiving	1	1	1	50
Technical				
Group Lead	1	3	3	150
AO Engineering Team	7	3	21	1050
Optical Scientist	1	3	3	150
Electronic Engineering	1	2	2	100
Electronic Technician	1	2	2	100
Mechanical Engineering	1	2	2	100
Mechanical Tech.	1	2	2	100
Software Engineering	2	2	4	200
Scientific Support	1	2	2	100
Documentation	1	2	2	100
Observer Support				
Liaison	1	2	2	100
Scheduling & Coordination	1	2	2	100
Documentation & Recording	1	2	2	100
Outreach & Publicity	1	2	2	100
Personnel Total	28		62	3100
General Expense US				560
Total US Operations				**3660**

Table A2 - GMT Chilean Operations					
Position	FTE Center	FTE Site	Units	FTE*Units	Cost
Administration					
Site Director	1		3	3	150
Associate Site Director	1		2	2	100
Business Manager	1		2	2	100
Admin. Assistant	2		1	2	100
Purchasing & Receiving	2		1	2	100
Accounting	3		1	3	150
Building & Grounds	5		1	5	250
Mountain Operations					
Mountain Superintendent		1	2	2	100
Site manager		1	2	2	100
Assistant Site manager		1	1	1	50
Admin. Assistant		1	1	1	50
warehouse supervisor		1	1	1	50
Mountain crew		15	1	15	750
Paramedic & Safety		2	1	2	100
Technical Operations					
Group Lead	1		2	2	100
Electronic Engineer	1	2	2	6	300
Electronic Technician	1	2	1	3	150
Mechanical Engineer	1	2	2	6	300
Mechanical Technician	1	2	1	3	150
Optical Engineer	1		3	3	150
Software Engineer	1		2	2	100
Software Support		2	1	2	100
Computer Sys Admin	1		1	1	50
Instrument Scientists	4		2	8	400
Telescope Specialists		4	2	8	400
Document Manager	1		1	1	50
Data Archivist	2		1	2	100
Observing Support					
Resident Astronomers		5	3	15	750
Telescope Operators		4	2	8	400
Instrument Operators		4	2	8	400
Laser Engineer		1	3	3	150
AO Operations Support		6	2	12	600
Total Personnel Chile	30	56		136	6800
General Expenses Chile					1462
Facility Costs Chile					1720
Total Chile Operations					**9982**

Table A3 - GMT Instrumentation Development			
Instrumentation	FTEs	Units per FTE	Cost $K
Cost Per Group			
Project manager	1	3	150
Senior Scientists	2	3	300
Optical Engineering	1	3	150
Mechanical Engineering	2	3	300
Electronic Engineer	2	3	300
Software Engineer	1	3	150
Electronic Tech	2	2	200
Mechanical Tech	2	2	200
Salaries Total			1750
Other expenses			90
Capital @ 80% of salaries			1400
Overhead @ 75% on non-capital costs			1118
Total Cost Per Group			4357
Annual Cost for 2 groups			8715
Facility Upgrades			5000
Instrument and Facilities Total			**13715**

Table A4 – GMT Corporate Office and U.S. Administrative Personnel				
Position	Number FTE	Units	FTE* Units	Cost $K
President (half-time position)	1	3	3	150
Director	1	4	4	200
Assoc. Director for Science	1	3	3	150
Business Manager/Contracts Administrator	1	2	2	100
Administrative Assistants/ Clerks	2	1	2	100
Total personnel	6			700
Insurance				1000
Travel				50
Office expenses				60
US Corporate Total				**1810**