16 PROJECT IMPLEMENTATION

16.1 Introduction

During the preliminary GMT phase, the project has developed the conceptual design for an optical/infrared telescope that addresses the science goals set forth in the National Academy of Sciences Decadal Survey for a Giant Segmented Mirror Telescope (GSMT). In the next phase of the project the GMT design will be developed to a state where it is ready for construction. Early prototyping and the fabrication of time-critical and highly developmental subsystems will also take place in this time. One of the pacing items for the project, primary mirror fabrication, is already under way. The strategy for meeting GMT's ambitious project schedule is to allow time-critical systems to proceed directly into construction following their preliminary design review as soon as functional and performance requirements and interfaces can be frozen and funding permits.

The transition between the conceptual design and design development phases will be marked with a review (CoDR), and the issuance of the GMT Project Book and Implementation Plan. During the Design Development Phase (DDP) preliminary designs will be completed for the various subsystems. Each subsystem will be reviewed in a preliminary design review (PDR) as it is ready. A GMT system preliminary design review will be held approximately 3.5 years into the DDP that will incorporate the results from the subsystem PDRs and review GMT as a whole. After the system review the major effort will be directed to preparing the designs and contract documents for the Construction Phase that follows. Planning for the commissioning and operation of the GMT Observatory will take place throughout the Design Development and Construction Phases.

To this point, the development of GMT has been conducted with a very small project staff using the scientific and engineering staff at the partner institutions and contracted engineering services. As the project moves into the Design Development Phase it will be organized on a formal and permanent basis with the establishment of the corporation that will be responsible for constructing and operating the facility and a Project Office and staff that will do the work. The GMT organization and the process by which the telescope will be built are described in this chapter.

16.2 The GMT Partners

The GMT Project is a collaboration between a group of leading US educational and research institutions. The members are: the Carnegie Institution of Washington, Harvard University, Massachusetts Institute of Technology, Smithsonian Astrophysical Observatory, Texas A&M University, the Australian National University, the University of Texas at Austin, the University of Arizona, and the University of Michigan. They include the institutions that developed and currently operate the two recently completed Magellan 6.5 m telescopes at Carnegie's Las Campanas Observatory in Chile. Collectively the group has a long history of building and operating forefront astronomical optical/infrared telescopes stretching back over a century. Recent projects in addition to the Magellan telescopes include the Multiple Mirror Telescope (MMT) and its conversion to a single 6.5 m primary; the Large Binocular Telescope (LBT)

currently nearing completion on Mount Graham, AZ; the recently completed the 10 m Hobby-Eberly Telescope (HET) at McDonald Observatory, Texas; and the 10 m Southern Africa Large Telescope (SALT).

At this time the GMT Project is open to additional participants and talks are currently under way with other prospective domestic and international partners.

16.3 Preliminary Phase

In March 2003 the initial members signed a Memorandum of Understanding initiating the conceptual design phase of the GMT. The MOU envisioned a two-year study program with a design review and implementation review at the end of that time. A Board of Directors with two representatives from each institution was established with responsibility for the conduct of the project during this phase and the Board appointed a Project Manager.

Funding for the project has been provided through contributions by the members. During the preliminary phase funding is not tied to the partners' intended shares in the telescope but will count towards those shares when the telescope goes into operation. Contributions may be in the form of cash and in-kind work. The Project Manager is responsible for developing the budget and authorizing and monitoring expenditures.

Carnegie provides office space for the Project Manager and management and administrative services during the preliminary phase of the project. The location of the permanent project office will be determined at the start of the DDP.

16.4 GMT Organization

16.4.1 GMT Agreement

Following the preliminary phase an agreement will be concluded between the GMT partners. The Agreement will establish the non-profit corporation that will own the GMT facility and be responsible for completing the design, constructing the observatory, and operating it for the benefit of the partners. The Agreement will define the overall governance of the project and specify among other things the following:

- Scope of the Project.
- Organizational and administrative structure.
- Responsibilities and duties of Officers, key project appointees and the Science Advisory Committee.
- Funding and budgeting process during construction and operations.
- How contributions to the capital and operations cost of the project translate into project shares and time on the telescope.
- How instruments are to be provided.

The description of the organizational structure in Section 16.4.2 reflects the current draft agreement but may change in the final version.

16.4.2 Organizational structure

The organizational structure of GMT is shown in Figure 16-1. The GMT Board will be the governing body of the GMT Corporation with overall responsibility for the financing, construction and operation of the GMT. All corporate authority to appoint officers, approve budgets, policies, procedures, and program plans, allocate telescope time, and raise funds for the construction and operation of the observatory within the terms of the GMT agreement will reside in the Board. One member will be selected to chair the Board. Key appointees by the Board will include the GMT President, the Director, the Project Manager, and the Project Scientist.

The GMT President will act as Chief Executive Officer of the GMT Corporation responsible for business, legal, public outreach and matters of partner relations. The President will be head of the GMT Corporate Office and will report to the Board through the Chair.

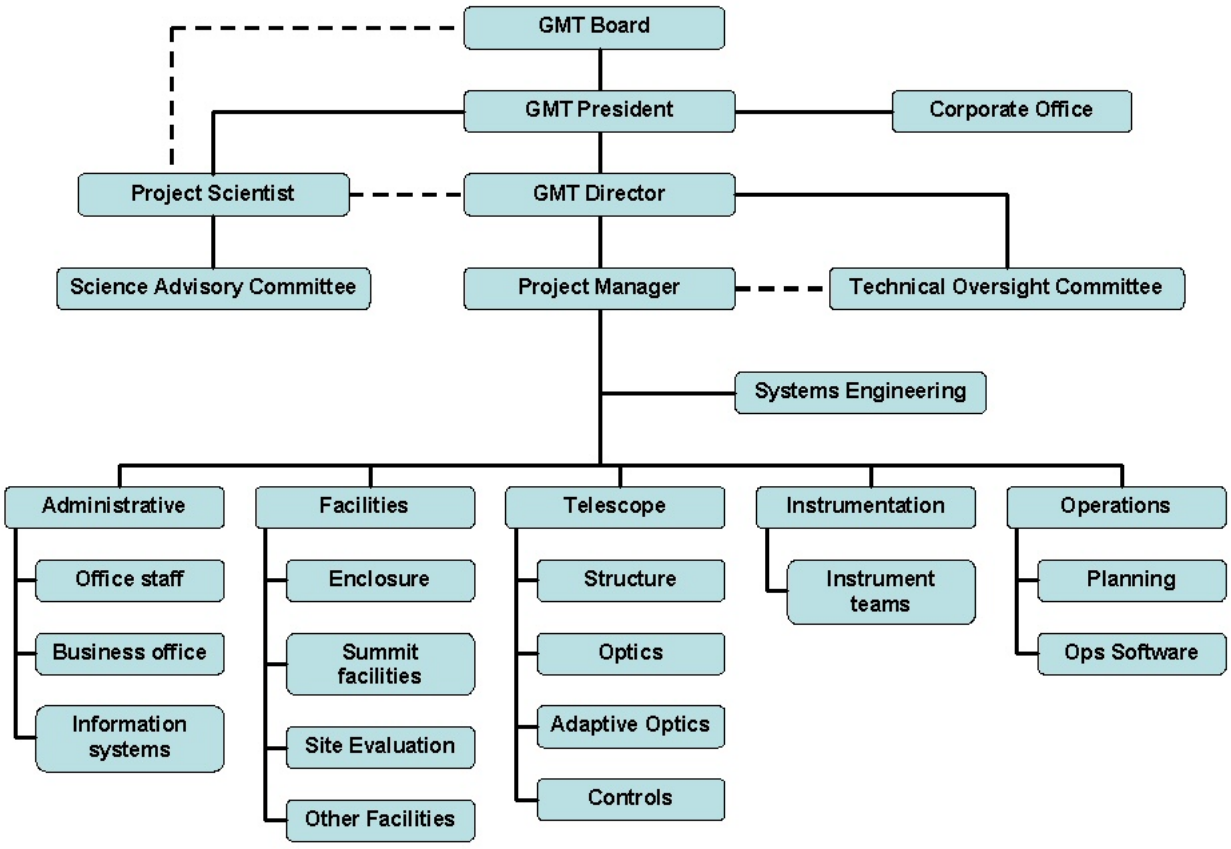


Figure 16-1. GMT Organization. Solid lines show reporting lines. Dashed lines are advisory channels.

During construction the Director will be responsible for ensuring that the GMT is constructed in a manner that meets the scientific goals of the Corporation with responsibility for the conduct of the Project through construction. The Director reports to the GMT President. He/she will be responsible for the interfaces between the Science Advisory Committee, the Project, and the Technical Oversight Committee. During operations the Director will have responsibility for the operation of the observatory following construction and for developing annual and long range program plans for review by the Science Advisory Committee and approval by the Board.

The Science Advisory Committee (SAC) advises the Board and the Project on scientific and technical issues. The SAC is chaired by the Project Scientist who advises the project through the Director. The SAC is responsible for ensuring that the telescope performance is consistent with the scientific objectives of GMT through verification of the design and compliance reports from the Project. SAC members and the Project Scientist will participate in major project reviews. The Project Scientist is independent of Project management and reports directly to the GMT President.

The Technical Oversight Committee (TOC) advises the Project on technical issues. The TOC is an outgrowth of the Project Scientists Working Group from the Conceptual Design Phase and reports to the Director. Members of the TOC will be tasked with acting as advisors to the section managers (see below).

The Project Manager will be responsible for assembling and managing the GMT Project Office. He/she will hire and oversee the technical and administrative staff responsible for the planning, design, and construction of the GMT facility. He/she will prepare the annual budget request and assist the Director in developing annual and long-range program plans for the Project.

16.4.3 Project Office

The GMT Project Office will consist of six sections:

- Administrative Section. This includes office staff, the business office with accounting, purchasing, contracts and human resources, and information systems. Some functions of the Administrative Section will be shared with the Corporate Office.

- Systems Engineering Section. Systems Engineering has system-wide responsibility for the performance of GMT as described in section 16.6 below.

- Facilities Section. Facilities is responsible for the enclosure and associated buildings and infrastructure at the summit, the lodge, the sea-level and US headquarters buildings, and site testing.

- Telescope Section. This section is responsible for the GMT structure, optics and controls, and adaptive optics systems.

- Instrumentation Section. This section is responsible for instrument development.

- Operations Section. This section is responsible for operations planning.

Each section will be headed by a section manager who will report directly to the Project Manager. Subgroups within the section will report to the section manager. The positions will be filled at the start of the Design Development Phase.

16.5 Project Phases

GMT development has been organized in four phases: conceptual design ("Preliminary Phase"), design development, construction, and commissioning. The activities that take place in those phases are listed in Table 16-1.

There will be some overlap between the phases. As time-critical systems complete their Preliminary and Critical design reviews they will proceed to construction as funding permits. There will be a corresponding overlap in the budgets for those phases. This arrangement puts a high premium on Systems Engineering to insure that systems that mature at different times are compatible in the final assembly.

The transition from construction and commissioning into science operations as instruments come on-line will likewise involve shared use of the telescope over a potentially extended period of time. Instrument development and commissioning will be a continuing activity of the GMT observatory. The policies and procedures for instrumenting GMT will be established in the Design Development Phase with Board approval.

Table 16-1. GMT Project Phases

Phase A: "Conceptual Design" *143 Weeks*

- Prepare Science Case - Science Working Group (SWG)
- Draft Top-Level Scientific Requirements
- Execute Memorandum of Understanding with Stakeholders
- Assemble Design Teams
- Develop Conceptual Design
  - Identify Major Technical and Cost Risks
  - Conduct Feasibility Studies
  - Draft Instrumentation Plan
- Design, Construct & Deploy Site Testing Stations — Begin Testing
- Prepare Draft Phase B/C Implementation Plan
  - Organization/Management Plan
  - WBS, Budget, & Schedule
- Conduct Conceptual Design Review (CoDR)
- Submit Implementation Plan to Stakeholders — Revise Plan as Necessary
- Start Primary Mirror Production

Phase B: "Design Development" *193 Weeks*

- Obtain Design Phase Approval
- Establish Organizational Structure
  - Corporation & Laws of Governance
  - Board of Directors
  - Science Advisory Committee
  - Appoint Project Manager/Project Scientist/Business Manager
- Establish Project Office
- Hire Key Project Staff
- Construct Additional Site Test Stations (as identified) — Continue Test Program
- Assemble High-Level Technical Specifications & Error Budgets
- Down-Select First-Generation Instrument Complement
- Assign Work Packages
- Prototype High-Risk/Long Lead-Time Systems
  - Primary Mirror Supports
  - AO System Components
- Complete Site Selection
- Prepare Detailed Phase C/D Implementation Plan — Update WBS, Budget, & Schedule
- Conduct Preliminary Design Review(s)
- Submit Implementation Plan & PDR Results to Shareholders
  - Revise Plan
  - "Freeze" High-Level Technical Specifications & Error Budgets

Phase C: "Construction" *286 Weeks*

- Obtain Approval to Proceed with Construction
- Prepare & Let Design/Fabrication Contracts
  - Assign Construction Management Staff
  - Contract Monitoring
  - Conduct Reviews (Design, Source Inspections, Acceptance)
- Start On-Site Construction
- Construct Base Operations Facility
- Begin Second Generation Instrument Studies
- Assemble & Test Telescope, Subsystems, & Instruments On-Site
- Prepare for Commissioning/Operations
  - Update Commissioning/Operations Plan
  - Assemble Commissioning/Operations Staff

Phase D: "Commissioning/Operations" *78 Weeks*

- Commission the Telescope and Instruments
  - Train Operations Staff
  - Characterize System Performance
  - Conduct Acceptance Reviews
- Phase-in Science Operations

16.6 Systems Engineering

The GMT is a complex assembly of highly interacting systems. Managing that complexity and successfully achieving the functional and performance goals of the project in an efficient manner is the purpose of Systems Engineering.

The responsibilities of Systems Engineering include:

- Provide documented traceability from top level functional and performance requirements through subsystem specifications down to the component level.
- Document and maintain the specification of the overall system configuration and manage change requests.
- Install and maintain the document system.
- Define and maintain well-defined interfaces between subsystems.
- Establish design requirements for defined subsystems and manage change requests.
- Establish procedures and plans for quality assurance and compliance verification.
- Provide standards for engineering software packages to ensure commonality between the Project and contractors.
- Participate in trade studies that investigate performance versus other factors such as schedule, cost, ease of use, reliability, etc.
- Conduct integrated modeling of the performance of telescope systems that span multiple disciplines: structures, optics, controls.
- As requested, advise the oversight committees on technical issues involving Systems Engineering.

16.6.1 Systems Engineering Management

The Systems Engineering Manager will work with the managers and technical staff of the other sections to accomplish the Systems Engineering objectives. The SE Manager will be supported by a small staff and will report to the Project Manager. Most of the engineering effort will take place within the sections themselves.

The SE Manager will coordinate with the Project Manager in areas affecting the performance of the telescope and associated systems. He/she will contribute to the PM's monthly and quarterly reports. The SE Manager will attend engineering meetings and reviews conducted by the sections and will support them in the interpretation of system requirements and the error budgets.

The SE Manager will work with the Project Manager and section managers to develop and periodically update the work breakdown structure for the project.

16.6.2 Document Management

GMT documents are currently stored in a web-based archive accessible to the engineering groups, oversight committees and management. The system is adequate for this purpose but lacks some of the features required for a full document management system. Specifically, it does not provide automated mechanisms for document approval or configuration control in response to change requests. During the organizing stage of the Design Development Phase the Document Management System will be upgraded to provide these capabilities.

Documents will continue to be web based making them available to engineering groups and contractors outside the project office. Protection in the form of access restrictions will be included for proprietary and procurement sensitive information.

16.6.3 Software Standards

Standard formats and software packages will be required across the project. Contractors will also be required to submit their work in those formats. The software currently in use is:

Office and management software:	MS Word, MS Excel, MS Project, Adobe PDF
Presentation	MS PowerPoint
Optical design:	Zemax
CAD:	AutoCAD Inventor
Finite Element Analysis:	Algor, Ansys

The choice of CAD and FEA packages is currently under review. Additional software packages (e.g. Mathcad/Simulink) will be required for integrated modeling and AO modeling.

16.6.4 Configuration Control

Documents that define the configuration of the GMT facility, its performance and functional capabilities, and operation will be placed under configuration control. Procedures for entering documents into the system, responding to request for changes, the approval process, and communicating changes to affected groups will be developed by SE and approved by Project Management.

A Configuration Control Committee will be appointed by the Project Manager to review and approve change requests. The Systems Engineering manager will chair the committee.

16.6.5 Design Requirements Documents

Design Requirements Documents will be required for all major subsystems. These will provide a description of the system, specify functional and performance requirements, and identify interfaces. DRDs will be developed by the SE section working with the managers and technical staffs of the affected groups.

Systems Engineering will be responsible for defining subsystems and their interfaces to other subsystems and will maintain the DRDs under configuration control. Requests for clarification or change will be managed by the Systems Engineering Manager.

16.6.6 Interface Control Documents

Interfaces between subsystems will be fully specified with Interface Control Documents (ICD). They will control the mechanical, electrical, and communication protocol connections. The ICDs will be developed by the SE section working with the managers and technical staffs of the affected groups. The ICDs will be maintained in the Document Management System by Systems Engineering and be subject to configuration control.

16.6.7 Error Budget Management

Error budgets are a tool for allocating maximum permitted error amounts to the various sources that degrade telescope performance. These ensure that top-level performance requirements are achieved. The quantities that are controlled through error budgets include image size, wavefront error, throughput, and emissivity in the infrared. Top-down budgets start with the science technical requirements developed by the Science Working Group and approved by the GMT Board. Allocations are assigned to the high level subsystems and propagate down to lower levels in a pyramid structure. Bottom-up budgets start with analyses of performance at the lowest component level and propagate errors upward. Eventually the two types of budget will be reconciled in the final GMT preliminary design. The top-level, top-down, image error budget is presented in Chapter 12.

Systems Engineering will be responsible for managing the error budgets, including

- Specifying the breakdown of subsystems that define the pyramid structure.
- Defining terms and specifying how errors are computed and combined.
- Allocating amounts to the top-down budget.
- Maintaining the budgets under configuration control.
- Managing change requests.
- Final reconciling of the top-down and bottom-up budgets.

This work will be coordinated closely with the technical staffs of the engineering sections and will rely on those groups to provide the necessary engineering support to determine component, subsystem, and system performance in the bottom-up formalism.

16.6.8 Product Assurance

Systems Engineering will prepare guidelines for developing quality assurance and compliance verification plans and will work with the section managers to develop and execute the plans. The procedures and plans will be reviewed and approved by the Project Manager prior to going

into effect. Formal reviews will be conducted by the SE Manager and final reports will be submitted to the Project Manager for review and approval. The results will be summarized in reports to the SAC and made available to the Board. All major systems will be subject to these procedures.

16.6.9 Performance and Operations Modeling

16.6.9.1 Purpose

The performance of various systems of GMT will be modeled during the Design Development Phase (DDP). The purpose is two fold: (a) to provide estimates of the system performance and demonstrate that the telescope as designed can achieve the science objectives and (b), as tools, to guide the design and optimization for various components of the system. As such, it is an iterative process that will be repeated as designs mature and become more complete.

16.6.9.2 Wind disturbance

During the GMT conceptual design phase the effect of wind disturbance on the telescope structure was modeled. The method and results are described in Chapter 7. In brief, wind power spectra measured for various configurations of the Gemini South 8 meter telescope and enclosure were applied to the finite element model of the GMT mount. Linear optical sensitivity equations as functions of the primary mirror segment, secondary mirror, and focal plane displacements derived from Zemax ray tracing of the segmented primary optical system were incorporated in a dynamic response model to calculate image blur due to wind. Both locked- and free-rotor cases were modeled for the main drives.

The wind disturbance spectrum used in the conceptual design study was specific to conditions at the Pachon site and the geometry of the Gemini enclosure and telescope. Although the effects of open and closed configurations of wind vents in the sides of the enclosure were considered during the tests, a wind screen was not included. Applying the Gemini wind speed and pressure power spectra densities (PSDs) to GMT involved a number of assumptions. The GMT results, while encouraging, require additional modeling and verification during the DDP.

The tools for modeling wind effects on structure include wind and water tunnel flow and pressure measurements on scale models and the analytical methods of computational fluid dynamics (CFD). A series of CFD studies will be conducted during the DDP to map out the wind flow and pressure field starting with the external, far field flow, applying that to the enclosure structure, and finally looking at conditions within the telescope chamber. Spatial sampling will be chosen to achieve a high enough frequency cut-off for dynamic response modeling of the telescope structure. The inside wind PSDs will then be applied to the telescope structure in similar fashion to what was done during conceptual design to predict image degradation.

The results of the these studies will be used to guide refinements of the design of the telescope and enclosure structure. The results of the wind studies will also be extended to predict the thermal performance of the system. The CFD models will be verified with wind tunnel tests of a representative case.

16.6.9.3 Drive Performance

The results of the wind disturbance modeling (Section 16.6.9.2) will be applied to a controls model of the main axis drives to estimate the low-frequency (<4Hz) tracking errors for the telescope in both open loop and guided operation.

16.6.9.4 Fast-steering secondary mirror (FSM) performance

The largest contributing modes to image blur due to wind shake of the mount occur in the frequency range around 8-10 Hz. They are manifested primarily as tip-tilt errors in the wavefront from the seven subapertures of the telescope that produce image wander, de-stacking of the images in the focal plane and, to a lesser degree, higher order aberrations such as coma. In general, image motion between subapertures is highly correlated indicating that vibration of the secondary truss and top frame is the principal cause. The uncorrelated motion is caused by random motions of the primary segments.

The initial dynamic response modeling indicates that the image size delivered by GMT should meet the natural seeing image error budget without fast correction except when the telescope is pointing into high winds (>9 m/s) without wind screen protection. This needs to be confirmed with additional modeling (Section 16.6.9.1) in the DDP with more realistic input for the wind disturbance.

The 8^{+} Hz vibration is above the lowest fundamental modes of the telescope structure and not correctable with the telescope main drives. For this purpose a fast tip-tilt capability is provided for the individual segments of the Fast-steering Secondary Mirror (FSM) and Adaptive Secondary Mirror (ASM).

The PSD of induced vibrations at the nodes of the secondary mirror segments from the wind disturbance analysis (Section 16.6.9.2) will be combined with a model of the FSM tip-tilt support system and controls and the optical sensitivity equations to model the disturbance correction.

16.6.9.5 AO Performance

Adaptive optics operates at much higher frequencies than the normal telescope tracking and active optics systems. Control frequencies are in the 100-200 Hz range and the adaptive secondary mirror operates with millisecond response times. The performance for the various AO modes will be estimated using models of the atmospheric wavefront distortion combined with simulations of the deformable secondary mirror (ASM), wavefront sensors, and the reconstructor and control elements. The simulations will include wind shake of the telescope mount in addition to atmospheric effects.

16.6.9.6 Observing Scenarios

Representative observing scenarios will be modeled during development of the detailed operations and staffing plans. These design reference missions will assume a specific science objective and instrument complement simulated to run in the flexible assisted observing mode described in the GMT operations plan (Chapter 17).

16.7 Implementation Plan

16.7.1 Work breakdown structure (WBS)

The various tasks of the GMT project will be organized into a work break down structure (WBS). Working with the section managers, the Project Manager will be responsible for defining the WBS tasks and assigning tasks to sections. The WBS will include allocation of resources and costs. Tasks will be broken down in sufficient detail to allow tracking of the project on a monthly basis. Costs will be tracked with earned value reporting.

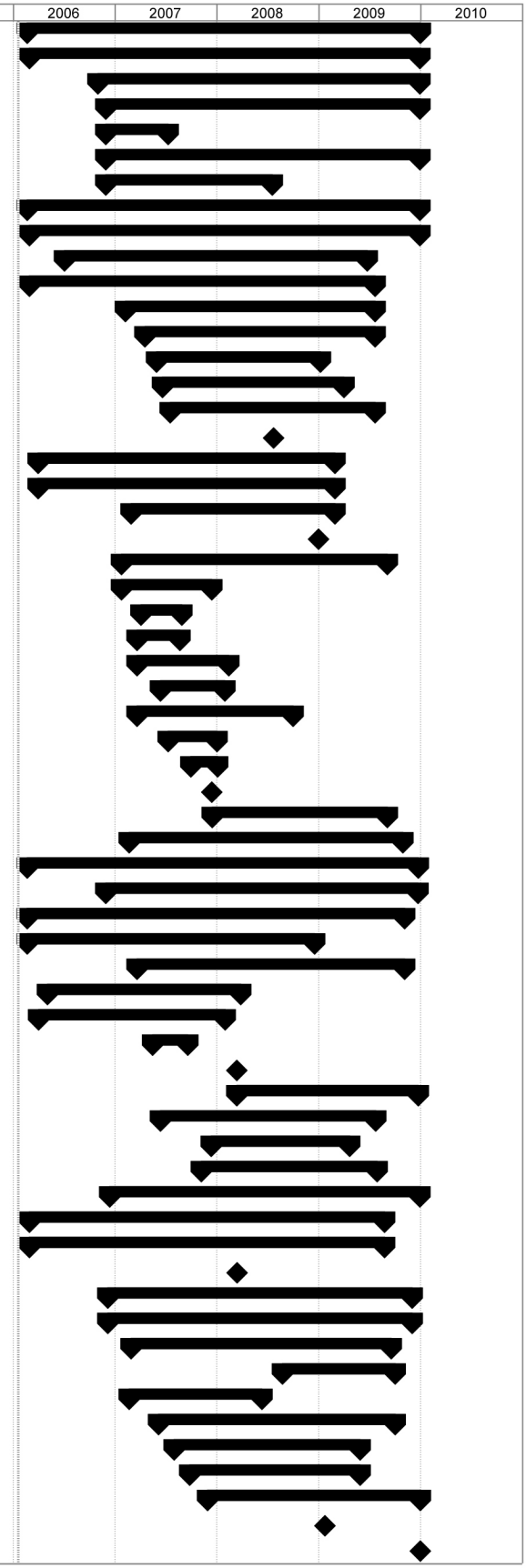
Project Management will maintain the master WBS for the Project. Section managers are responsible for monthly updates of the section of the WBS for which they are responsible. A Project Coordinator will incorporate the section updates into the master WBS. Monthly meetings will be held with the Project Manager, Project Coordinator and section managers to review progress and identify problems. Critical path tasks will be duly noted. A summary of the meetings will be transmitted to the Director.

Summary reports of GMT progress will be presented to the Board at semi-annual meetings or as requested on the basis of the WBS status.

Common project management software will be used across the project for the WBS. This is Microsoft Project. Contractors, whose work feeds into the WBS, will be required to submit their reports in the same format.

Table 16-2 Design Development Phase work breakdown structure (WBS).

ID	Task Name
1	**GMT Design Development Phase**
2	**Project Office**
51	**Information systems**
54	**System Engineering**
55	**Implement System Engineering Controls**
60	**System engineering**
64	**CFD modeling**
70	**Telescope systems**
71	**Telescope systems engineering/management**
75	**Telescope structure**
79	**Main drives**
94	**Hydrostatic bearings**
109	**Instrument Platform**
120	**Counterweights**
132	**Mirror covers**
145	**Utility transfer system**
157	**Telecope structure PDR**
158	**Primary mirror segments**
159	**GMT1 Production**
176	**GMT2 Production**
181	**GMT3 Production**
183	**Primary mirror cell**
184	**Cell specification & interfaces**
189	**Calibration stand**
198	**Mirror supports controls**
203	**Triple-axis support**
209	**Single-axis support**
215	**Hardpoints**
224	**Static supports**
230	**Ventilation system**
237	**Primary mirror cell assembly Review**
238	**Prototype Cell Assembly**
258	**Telescope Conrol system**
267	**AO Systems**
268	**AO Systems management/engineering**
275	**Development**
276	**Adaptive Secondary Mirror (ASM) and Support Design Work**
346	**LGS Design Work**
433	**WFS Design Work (Switchyard Design Phasing Camera, LGS an**
471	**ExAO Design Work**
512	**Edge sensors**
518	**Adaptive optics PDRs complete**
519	**AO post PDR development**
521	**Fast-steering secondary mirror**
531	**Secondary mirror segment fabrication**
539	**Corrector/ADC**
549	**Instrumentation**
556	**Site Evaluation**
557	**Site monitoring**
564	Site selected
565	**Facilities**
566	**Facilities engineering management**
569	**Enclosure**
580	**Site & Support Facilities**
586	**Coating plant**
593	**Lodge**
601	**Sea-level facility**
610	**US headquarters**
619	**Operations Planning**
622	**GMT PDR**
623	**Start of Construction Phase**



An outline of the WBS for the Design Development Phase is shown in Table 16-2. The WBS currently includes initial estimates of resource allocation and costs (not shown). Tasks will be broken down into finer detail as the DDP progresses and decisions are made regarding which systems are developed in-house versus contracted out, detailed staffing plans, adjustments to project scope, instrument and site selection, and schedule adjustments. Funding and the ramp-up of the project staff will have major impacts on the WBS and schedule.

The WBS for the GMT construction phase will be developed during the DDP. A preliminary top-level version has been assembled to provide an estimate of the project cost (Initial Project Cost) and schedule to completion. The schedule is shown in section 16.7.9 below.

16.7.2 Staffing plan

GMT intends to complete the Design Development Phase of the project with a relatively small engineering staff, Table 16-3. Much of the engineering work and prototyping of systems will be contracted to groups outside the project office as separate work packages. This is already the case in several areas: (1) the primary mirror subsystem where a group already exists at U. Arizona, (2) AO development at U.A., (3) mechanical and structural engineering of the telescope mount by Paragon Engineering, and Simpson, Gumperz and Heger (SGH) and (4) the design and engineering of the enclosure and on-site facilities by M3 Engineering. Instrument development is also an activity that will be subcontracted to outside groups.

Some of this work will be taken back into the project as the staff ramps up. Other aspects will continue to be developed under contract. The breakdown of work packages will determined during the ramp-up period and staffing levels will be adjusted accordingly.

Table 16-3. GMT Design Development Phase Staff.

GMT Design Development Project Office Phase Staff		
Section	**Title**	**Number**
Project Office	Project Manager	1
	PM Assistant	1
	Project Coordinator	1
	Business/HR Manager	1
	Contracts Officer	1
	Purchasing Agent	1
	Accountant	1
	Receptionist	1
	Information Systems Administrator	1
Systems Engineering	Systems Engineering Manager	1
	Systems Engineer	1
	Modeler/programmer	1
	Document Administrator	1
Telescope	Telescope Systems Manager	1
	Optical Engineer	1
	Mechanical Engineer	1
	Controls Engineer	1
	Software Engineer	1
	AO Systems Manager	1
	AO Scientist	1
	AO Systems Engineer	1
Instrumentation	Instrumentation Manager	1
	Instrument Scientist	1
Facilities	Facilities Manager	1
	Site Test Scientist	1
	Site Test Operators	2
	Site Engineer	1
	Coatings Engineer	1
Operations	Operations Manager	1
Total:		**29**

16.7.3 Contracting Strategy

Major portions of the GMT Project will be conducted under contract to groups outside of the Project Office. These will include both commercial enterprises, groups within the partner institutions and, potentially, groups at non-member institutions. Contracts will be awarded in open competition or sole-source as conditions dictate. The decision on which contracting strategy is employed will depend, on a case by case basis, on a number of factors including (a) the expertise and capabilities of potential bidders, (b) unique capabilities that may exist in only one source, (c) the desirability of open competition whenever possible to achieve the best combination of cost, schedule and performance, and (d) any conditions imposed by the GMT partners through the GMT Agreement and Board directives.

In all cases major work packages will be contracted in response to a request for proposal from the Project. The RFP will include a statement of work (SOW), technical specifications, a sample contract and GMT's general conditions for contracts. The statement of work will include a definition of the work, schedule requirements, a list of deliverables, and reporting and oversight requirements. In the case of competitive procurement, evaluation criteria and procedures will be provided with the RFP. The project will attempt to identify potential bidders for various major contracts prior to issuing an RFP to ensure a good response from qualified sources.

In their proposal, prospective contractors will be required to submit a technical section describing the work with a compliance matrix of requirements, a management section with WBS in a GMT compatible format and reporting commitments, a cost proposal with a schedule of payments based on milestones and a list of exceptions, if any, to the sample contract.

In general, fixed-price contracts will be preferred where the scope of work is well determined ahead of time and development costs are understood. This will not always be the case and other forms of contract (e.g. cost plus fee) will be considered. Management tools will be employed to constrain cost overruns including a process of regular reviews measuring progress against WBS earned value, scope adjustments where needed to remain in budget, and cost caps with prompt intervention by Project Management when problems arise.

A Contracts Officer will be employed to manage the contracting process and ensure that procedures are followed. He/she will be involved in administering contracts through to completion.

The partner institutions may undertake work packages to provide components of the facility or services as in-kind contributions counting towards the partner's share of the Project. Major work packages for in-kind credit will be required to follow the same contracting process as non-in-kind contracts, that is, proposals will be required in response to an RFP and will be judged, depending on whether they are sole source or competitive procurement, on the same basis. The GMT Board in consultation with the Director and Project Manager will have final approval over in-kind contributions to the project including selection of work packages available for credit, approval of contracts, and final granting of credit.

Science instruments for GMT will be provided by contracting with instrument development groups outside the GMT organization. The procedures for contracting and monitoring instrument work packages will be the same as for other contracts. Policies for which groups are eligible to submit proposals will be established by the GMT Board and may depend on the level of investment by the partners and outside sources.

The section managers will have direct responsibility for day-to-day monitoring of contracts within their section. On a monthly basis they will review outstanding contracts with the Project Manager who will summarize their findings in a report to the Director. Problems that arise will be promptly reported to the Project Manager who will, depending on the severity of the problem, bring it to the attention of the Director or, if not serious, resolve it with the section manager and contractor. Contractors will be required to submit monthly progress reports to the project and conduct quarterly progress reviews.

16.7.4 Risk Management

A project of the complexity of GMT involves substantial technical, schedule, and cost risk. The three are related and trade off against one another.

The Project will employ the following measures to reduce the overall risk:

- Provide well documented system specifications and controlled interfaces. This is discussed in Section 16.6.

- Exercise configuration control over the documents that define the facility (Section 16.6).

- Establish formal reporting procedures to document serious problems encountered that may affect performance, cost or schedule at any level of the project and bring the problems to the prompt attention of the responsible manager/group leader. The problem report will include an assessment of the impact of the problem, measures taken to solve it, who was notified and the final resolution. These will be regularly reviewed by the section managers and reported in summary to the Project Manager.

- Use established technology where it exists. In the case of GMT, this involves starting with an existing mirror technology and extending it for the off-axis nature of the mirrors. The other area where the project builds on existing technology is in the development of adaptive secondary mirrors.

- Use commercially available components if possible and industry standard solutions available from multiple sources where they exist.

- Model the system with simulations to demonstrate the ability to achieve the Project functional and performance specifications before designs are locked in (cf. Section 16.6.9).

- Prototype critical subsystems and components that require a significant development time and effort. The prime example for GMT is the production of the first off-axis 8.4 m

primary mirror segment that started during the conceptual design phase and will be completed near the end of Design Development. This effort will develop technology for producing the segments, demonstrate technical feasibility and establish the production pipeline and cost basis for this time-critical component before the start of construction.

Other systems that will be prototyped during Design Development Phase include the primary mirror supports and a full-up assembly of the primary mirror cell, an off-axis secondary mirror segment for the FSM, and AO components.

- Identify core requirements and capabilities of the facility and provide options that allow timely completion of the telescope with those capabilities, but not preclude eventual completion of the full baseline plan. Provide fall-back options that allow the project to proceed when technical problems or delays in funding slow down some parts of the project.

- Stage the assembly and commissioning process to avoid problems with installing and commissioning multiple, highly complex and possibly interacting systems simultaneously.

16.7.5 Cost Management

The GMT Agreement contains an Initial Project Cost that is the basis of the GMT budget (contained in a separate document). The cost estimates used to derive the budget come from a variety of sources:

- Actual quotes and contracts.
- Contracted cost studies.
- Catalog prices.
- Extrapolation from recent experience with existing systems and prototypes.
- Budget (ROM) estimates from contractors and vendors.
- Internal estimates of the materials costs and time required for various tasks.

The basis year for estimating the project cost is 2004, the first fiscal year of the project and the year the first segment primary mirror contract was executed. Actual expenses over the life of the project are estimated assuming increases for inflation. The budget estimates will be updated as designs mature and planning progresses into greater detail and more sophisticated methods of cost estimating are applied.

A reserve of 20% will be applied to the Initial Project Budget. The reserve will be held by the Project Manager and allocated at his/her discretion in response to requests from section managers. Final approval of the budget and allocation of reserve funds rests with the GMT Board.

Costs for GMT will be tracked in spreadsheets linked to the WBS and budget and accounting system. Monthly budget meetings with section managers and quarterly financial reports will be used to monitor progress. Tracking of earned value through the WBS will identify problem areas

where the work is going over-budget. Those areas will be reported to the Director with suggestions from the Project Manager on how they might be resolved.

Details of the cost accounting system will be finalized once the GMT Agreement is in place and the Project Office is established.

16.7.6 Safety Program

The Project Manager is responsible for ensuring personnel and equipment safety during project development. This responsibility includes designing systems that are safe to operate under all conditions that are likely to be experienced on the site over the lifetime of the telescope. Safety requirements and procedures will be part of all design requirements documents and will be incorporated in an overall safety program.. The Project Manager will appoint a designated safety officer and safety committee that will hold periodic meetings with the section managers to ensure that procedures are being followed and to identify potential hazards. Minutes will be recorded and safety concerns will be documented and promptly reported to management. Project management will work to resolve the concerns and will respond to the committee and section managers in writing with measures taken to correct the problem and recommended follow up actions.

16.7.7 Project Meetings

Regularly scheduled project meetings will be conducted to keep team members and management informed of the work in progress and the schedule. These will include:

- Weekly meetings between the section managers and work groups.
- Bi-weekly meetings between the Director, Project Manager and the section managers.
- Quarterly meetings between the Director, Project Manager, Project Scientist, Science Advisory Committee, Technical Oversight Committee and section managers to review technical progress against the WBS and the budget.
- Meetings of the safety committee conducted by the designated safety officer every six months or more frequently as required by the applicable local state and/or federal regulations.

16.7.8 Reports

The progress of GMT will be documented in periodic reports issued by GMT to the appropriate governing bodies. On the Project level these will include:

- Monthly status reports of the technical progress of the project prepared by the Project Manager. These will incorporate summaries from the section managers including work by contractors.
- Quarterly financial reports to the President prepared by the Project Manager and the Director.

- Semi-annual status reports to the GMT Board summarizing the financial state and technical progress.
- Yearly budget requests to the Board prepared by the Director and Project Manager.
- Technical notes and reports issued by the Project.
- Reports from major project reviews including safety reviews.
- Verification and compliance test reports.

In addition, the sections will maintain their own internal reports and minutes from group meetings.

16.7.9 Schedule

The project master schedule is maintained by the Project Manager and linked to tasks in the WBS. Microsoft Project is the software currently being used for this. The schedule will be available to all members of the Project team and GMT organization and periodically updated to reflect the current status of the work and projected completion dates for the WBS tasks. Proposed changes in the top-level schedule will be reported to the GMT Board at regular Board Meetings for their review and approval.

The schedule will be developed and maintained with the assistance of the section managers who will be responsible for the detailed WBSs for their sections. Schedule problems that manifest themselves through the WBS will be flagged and brought to the attention of the Project Manager. Regular reviews of the schedule will take place as part of the quarterly review process. Tasks on or near the critical path will be noted. The project will endeavor to provide schedule slack where possible to reduce the likelihood of slips. Contractors will provide WBS updates for their portion of the work in project compatible format in time for inclusion in the quarterly reports by the section managers.

The detailed WBS and schedule for the construction and commissioning phases of GMT will be developed during design development. The preliminary top-level project schedule through completion is shown in Figure 16-2.

16.7.10 Commissioning Plan

The Director and Project Manager, working jointly with the section managers and in consultation with the SAC and TOC, will develop the commissioning plan and schedule for the GMT which will then be incorporated into the master project schedule. Each section will contribute its part to the plan. The commissioning plan will be reviewed by the SAC and forwarded to the Board for approval. The Project Manager will be responsible for assembling the WBS that goes with the plan and managing it.

Figure 16-2. GMT Schedule.

ID	Task Name
1	**Phase A: Conceptual Development**
2	Conceptual design studies
3	Start site testing
4	Conceptual Design Reviews
5	Submit Phase B/C implementation plan
6	**Phase B: Design Development**
7	Project office staffing
8	Assign work packages
9	Preliminary Design Phase
10	Site selection
11	Final Design development
12	**Phase C: Construction**
13	Issue construction contracts
14	Civil construction on site
15	Enclosure fabrication
16	Enclosure assembly on site
17	Occupy base facility
18	Telescope fabrication
19	Telescope Installation
20	Optics installation
21	**Phase D: Commissioning**
22	Telescope commissioning
23	Instrument commissioning
24	Start of science operations
25	**Primary mirror segment production**
26	Mirror #1- Prototype off-axis segment
27	Mirror #2 off-axis segment
28	Mirror #3 off-axis segment
29	Mirror #4 off-axis segment
30	Mirror #5 off-axis segment
31	Mirror #6 off-axis segment
32	Mirror #7 center segment
33	Mirror #8- spare off-axis segment