SIGNATURES

Chief System Engineer: ___________________________ Date:__________
    Matt Johns

GMTO Director: ___________________________ Date:__________
    Patrick McCarthy

Project Manager: ___________________________ Date:__________
    Keith Raybould

Project Scientist: ___________________________ Date:__________
    Steve Shectman

Concurrence

SAC Chair: ___________________________ Date:__________
    Richard Kron
## REVISION LOG

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Affected</th>
<th>Engineering</th>
<th>Reason/ Initiation/ Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>4/12/2011</td>
<td>All</td>
<td>None</td>
<td>Initial Draft</td>
</tr>
<tr>
<td>1.1</td>
<td>4/22/2011</td>
<td>All</td>
<td>None</td>
<td>Draft.</td>
</tr>
<tr>
<td>1.2</td>
<td>5/2/2011</td>
<td>All</td>
<td>None</td>
<td>Major revisions.</td>
</tr>
<tr>
<td>1.3</td>
<td>5/4/2011</td>
<td>All</td>
<td>None</td>
<td>More revisions</td>
</tr>
<tr>
<td>1.4</td>
<td>5/7/2011</td>
<td>All</td>
<td>None</td>
<td>More revisions</td>
</tr>
<tr>
<td>1.5</td>
<td>5/12/2011</td>
<td>All</td>
<td>None</td>
<td>Editing</td>
</tr>
<tr>
<td>2</td>
<td>5/13/2011</td>
<td>All</td>
<td>None</td>
<td>Incorporate comments</td>
</tr>
<tr>
<td>3</td>
<td>6/10/11</td>
<td>All</td>
<td>None</td>
<td>Incorporate comments from SAC discussion.</td>
</tr>
<tr>
<td>4</td>
<td>7/14/2011</td>
<td>Section 6 + several</td>
<td>None</td>
<td>Matt last Version</td>
</tr>
<tr>
<td>5</td>
<td>7/15/2011</td>
<td>None</td>
<td>Johns, Trancho, McCarthy</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>7/19/2011</td>
<td>Sections 3-11</td>
<td>None</td>
<td>Major revision and consolidation.</td>
</tr>
<tr>
<td>7</td>
<td>7/22/2011</td>
<td>Sections 4-11</td>
<td>None</td>
<td>Revisions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Table of Contents

**SIGNATURES** ................................................................................................................. 3  
**REVISION LOG** .............................................................................................................. 4  
Table of Contents ......................................................................................................... 5  
1 Introduction ........................................................................................................... 8  
1.1 Scope ..................................................................................................................... 9  
1.2 System Description ................................................................................................. 9  
1.3 Definition of Terms ............................................................................................... 9  
2 References ................................................................................................................. 9  
2.1 Definitions and Acronyms ..................................................................................... 9  
2.1.1 Definitions .................................................................................................... 9  
2.1.2 Acronyms ..................................................................................................... 9  
2.2 Project ................................................................................................................. 10  
3 High Level Science Goals ...................................................................................... 11  
3.1 Planets and Their Formation ................................................................................. 11  
3.1.1 Imaging of Extrasolar Planets ...................................................................... 11  
3.1.2 Radial Velocity Searches for Exoplanets Around Low Mass Stars ................. 12  
3.1.3 Structure and Dynamics of Proto-Planetary Debris Disks ................................. 12  
3.1.4 Star Formation and the Initial Mass Function ............................................... 12  
3.2 Stellar Populations and Chemical Evolution .......................................................... 12  
3.2.1 Imaging of Crowded Populations ................................................................ 12  
3.2.2 Chemistry of Halo Giants in Loca Group Galaxies ........................................ 13  
3.3 Assembly of Galaxies ........................................................................................... 13  
3.3.1 The Mass Evolution of Galaxies .................................................................. 13  
3.3.2 Chemical Evolution in Galaxies .................................................................. 13  
3.3.3 Tomography of the IGM .............................................................................. 14  
3.4 Black Holes .......................................................................................................... 14  
3.5 Dark Energy and the Accelerating Universe ........................................................... 14  
3.5.1 Baryon Oscillations at z>4 ........................................................................... 15  
3.5.2 SNe at z>1 .................................................................................................. 15  
3.6 First Light an Reionization .................................................................................... 15  
3.6.1 The Reiomization Era .................................................................................. 15  
3.6.2 First Light ................................................................................................... 16  
3.7 Summary of High Level Science Requirements ...................................................... 16  
3.8 Instrument Capabilities ......................................................................................... 17  
3.9 Scientific Operations ............................................................................................ 18  
4 General Conditions and Constraints ..................................................................... 19  
4.1 System Architecture ............................................................................................. 19  
4.2 General Conditions .............................................................................................. 20
11.2 Engineering Data................................................................................................ 49

Table of Figures
Figure 1. GMT Concept................................................................................................. 8

Table of Tables
Table 1. Acronyms ....................................................................................................... 9
Table 2. Project Documents ........................................................................................ 10
Table 3. Science Areas and Requirements ................................................................. 16
Table 4. Instrument Capabilities Matrix ....................................................................... 17
Table 5. Transmission of the ADC as a function of wavelength .................................. 27
Table 6. Image Size Sources ....................................................................................... 31
Table 7. Applicability of Image Size Specifications ................................................... 32
Table 8. Parameters for BG and FP Natural Seeing Image Specification Parameters .... 32
Table 9. Parameters for WF Natural Seeing Image Specification Parameters ............. 33
Table 10. Mirror System Throughput with Fresh Coatings (TBC) ............................... 35
Table 11. Acquisition Time .......................................................................................... 37
Table 12. Blind Pointing Accuracy .............................................................................. 37
1 Introduction

The Giant Magellan Telescope (GMT) is a 25-meter alt-azimuth telescope and one of the first of the next generation of Extremely Large Telescopes (ELTs). In operation it will be used to conduct a broad range of astronomical scientific research at visible and infrared wavelengths. The telescope will be located at Las Campanas Observatory in Chile. The telescope concept is shown in Figure 1.

![Figure 1. GMT Concept](image)

GMT is being designed and constructed and will be operated by the GMTO Corporation. The corporation has been formed by an international group of universities and research institutions and is registered in the US as a non-profit 401(c)(3) organization. The project is funded through contributions of the member organizations with a small amount of additional funding from the US National Science Foundation.

The GMT Project was created by the GMTO Board of Directors to design and construct the GMT Facility. The Project includes the telescope, telescope enclosure, on-site and off-site support buildings, site infrastructure, and science instruments. The Project will also be involved in operations planning.
The science goals and top-level requirements for the GMT Project have been developed by the GMT Scientific Advisory Committee and will provide the basis for the design, construction, and operation of the GMT facility subject to the approval by the GMTO Board.

1.1 Scope

This document summarizes the science goals that drive the design of GMT and describes a set of generalized instruments that address those goals. The top-level requirements for the GMT observatory that derive from the science goals are listed in the second half of the document. These requirements will flow down to System- and subsystem level requirement that regulate the design and operation of the observatory.

1.2 System Description

1.3 Definition of Terms

Throughout this document, the use of the term "Shall" denotes requirements that are mandatory and will be the subject of specific acceptance testing and compliance verification.
"Is" or "Will" indicate a statement of fact or provide information and are not subject to any acceptance testing or verification compliance by the supplier.
"Can", "May", or "Should" indicate recommendations and are not subject to any acceptance testing or compliance verification by the supplier. The supplier is free to offer alternative solutions.

2 References

2.1 Definitions and Acronyms

2.1.1 Definitions

2.1.2 Acronyms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC</td>
<td>Atmospheric Dispersion Corrector</td>
</tr>
<tr>
<td>AO</td>
<td>Adaptive Optics</td>
</tr>
</tbody>
</table>
### Table 2. Project Documents

<table>
<thead>
<tr>
<th>Reference #</th>
<th>Document Number</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD-1</td>
<td>GMT-SCI-DOC-00031</td>
<td>GMT Detailed Science Case (DSC)</td>
</tr>
<tr>
<td>RD-2</td>
<td>GMT-SE-REF-00009</td>
<td>GMT Glossary of Terms and Abbreviations</td>
</tr>
<tr>
<td>RD-3</td>
<td>GMT-SE-REF-00144</td>
<td>GMT Environmental Conditions</td>
</tr>
<tr>
<td>RD-4</td>
<td>GMT-SE-DOC-00145</td>
<td>GMT Natural Seeing Image Size Budgets</td>
</tr>
<tr>
<td>RD-5</td>
<td>GMT-PM-RVW-00146</td>
<td>GMT CoDR Report</td>
</tr>
<tr>
<td>RD-6</td>
<td>GMT-SCI-DOC-00034</td>
<td>GMT Operations Concept Document (OCD)</td>
</tr>
<tr>
<td>RD-7</td>
<td>GMT-SE-DOC-00147</td>
<td>GMT Site Characterization Report</td>
</tr>
</tbody>
</table>

---

2.2 Project

The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.
3 High Level Science Goals

The primary science goals for the GMT are described in RD[TBD]. In this chapter we define the quantitative requirements that these goals place on the telescope, site, adaptive optics and instruments. For the sake of brevity we restrict the scientific discussion to a bare minimum.

3.1 Planets and Their Formation

The key elements of our program to understand the properties and formation of extrasolar planetary systems include imaging extrasolar planets, detecting new low-mass systems via reflex motion studies of low mass stars, and exploring the link between disk and planet formation. Our own solar system provides our best laboratory for studies of low mass bodies and presents special requirements. Star and planet formation are intimately linked and our priorities in this area include understanding the origin of the IMF and probing the collapse of molecular clouds to stars and disks.

3.1.1 Imaging of Extrasolar Planets

Imaging of exoplanets, whether via reflected light or thermal emission, requires high-contrast on angular scales from < 10mas to roughly 5 arcsec. GMT imaging studies of exoplanets will address both systems discovered from reflex motion and transit surveys as well as searches for objects with M > 20MJ and 5 < a < 40 AU, a range of parameter space not probed by these two techniques. The later will be most readily detected via thermal radiation in the 3-10mm windows. At a benchmark distance of 500pc (e.g. Orion), the required angular scales are 10-100mas and contrast ratios of $10^4 - 10^6$ are required. Nulling interferometry may be the technique of choice for these studies. Known giant exoplanets have separations ranging from 0.04 to ~4AU, corresponding to angular scales from 2-200 mas. The GMT should be able to access systems with angular sizes greater than ~40 mas. Direct imaging via reflected light and low-resolution spectroscopy of known exoplanets will reveal much about their evolutionary histories and the compositions of their atmospheres. The required contrast ratios at ~1.5mm range from $\sim10^6$ to $10^8$.

3.1.2 Radial Velocity Searches for Exoplanets Around Low Mass Stars

Reflex motion studies of low-mass, late-type, parent stars require high-resolution spectroscopy in either the visible or near-IR. The high-resolution spectrograph should be able to reach stars with $V = 13.5$ in observations spanning no more than three hours with a velocity precision of better than 2m/s. A spectral resolution of $R=50,000$ over the 4000-9000A range of the spectrum is required.
3.1.3 Structure and Dynamics of Proto-Planetary Debris Disks

Spatially resolved spectroscopy to determine the constituents of disks, including finding the locations of water ice reservoirs, requires high spatial resolution and contrast. While we would like to resolve disk structure on the smallest scales possible, it is critical that we be able to probe the area of the snow-line, the demarcation between solid and liquid water. In A-F type stars this lies at several AU. With angular resolutions of 15-30mas in the near-infrared, the GMT will study planet-forming disks at a resolution of 3 AU in the nearest star-formation regions. Effective imaging will require a high-dynamic-range adaptive optics system coupled to a near-infrared imager and low-resolution spectrograph as well as a mid-IR imager/spectrometer.

3.1.4 Star Formation and the Initial Mass Function

To study nearby regions of star-formation at unprecedented sensitivity and spatial resolution, we require a near-IR imager and multi-object spectrograph operating at the diffraction limit from 1-2.5mm over 30-40" FOV, most likely requiring an LTAO or MCAO optimized imager/spectrograph. This same capability will be needed to probe the ratio of high to low mass stars in extreme regions of star formation in the Milky Way and local group. Studies of the dynamics and chemistry of young stars requires high-resolution spectroscopy, particularly in the 1-5mm region. Understanding the formation processes of individual protostars will also require high spatial resolution mid-IR imaging and modest resolution spectroscopy.

3.2 Stellar Populations and Chemical Evolution

The study of stellar populations and the evolution of the chemical elements require both high spatial and high spectral resolution capabilities. Photometric studies of crowded fields will require an AO imager operating at the shortest wavelength possible. Stellar abundance work requires high-resolution spectroscopy, primarily in the visible and UV.

3.2.1 Imaging of Crowded Populations

Photometry of crowded regions can reveal the star formation and abundance histories of populations as a function of environment. These studies require a diffraction-limited adaptive optics system that produces a stable point spread function with a well determined, and minimal, spatial variation pattern. The required fields of view range from a few arcsec to 30-60 arcsec depending on the application. Moderate to high Strehl ratios (> 60% at H) are highly desirable.
3.2.2 Chemistry of Halo Giants in Loca Group Galaxies

Chemical studies of luminous halo giants in the local group require access to a high dispersion spectrograph operating in the visible region of the spectrum. Red Giants in local group galaxies that are accessible from Chile have apparent magnitudes of \( R = 17-19 \). The visible high-resolution optical spectrograph will need to be able to obtain spectra of these stars with \( R = 50,000 \) and SNR > 10 per pixel in exposure times less than 20 hours. Access to the 1-2.5\( \mu \)m region with similar resolution will allow abundance determinations of additional elements and molecules.

3.3 Assembly of Galaxies

Our program for understanding how galaxies are put together has three components: tracking the mass evolution of galaxies, coupling this with the changing chemical composition of stellar and interstellar matter, and examining the interplay between galaxies and the intergalactic medium. In addition to these primarily wide-field applications, we need to explore the internal structure of galaxies, determine their total masses and the distribution of dark and luminous matter.

3.3.1 The Mass Evolution of Galaxies

Determination of the stellar mass in galaxies over a wide range of redshifts and luminosities will entail spectroscopy of large samples of faint galaxies. Sample sizes of a few thousands per bin (by redshift, luminosity, and morphological type) are required. Large fields (~ 100Mpc) or multiple site lines are needed to suppress the impact of large-scale structure. Final field sizes on the order of 2 square degrees are needed. Achieving this in a reasonable amount of observing time calls for a multi-object spectrometer with a wide-field of view. A field area of 150 sq. arcminutes would allow one to sample a 2 square degree field in 25 pointings. A large field would clearly be preferable; a smaller field quickly becomes less attractive. Deep visible and near-IR imaging over large fields is essential for photometric redshifts, stellar mass, reddening and age determinations. The imaging material may be provided by space missions or ground-based near-IR surveys with other facilities.

Spectroscopic redshifts for these objects are best determined in the visible with a MOS covering 100-300 targets. The visible MOS should have a field area of > 150 square arcminutes and a range of resolutions from \( R \sim 1500 \) for redshift determinations to \( R \sim 5000 \) for dynamical studies.

3.3.2 Chemical Evolution in Galaxies

Abundance determinations in faint galaxies require access to the nebular lines in the near-IR J, H and K windows. The near-IR MOS should have as large a field of
view as possible: a 5’ x 5’ is the smallest practical size for this work as it will accommodate ~ 15-30 galaxies in the appropriate redshift and apparent magnitude range. Larger fields are clearly desirable. The resolving power should be sufficient to allow one to work between the OH lines in the J and H windows, or R ~ 3000. Dynamical mass determinations from rotation in either the H alpha or [OII]3727 emission-lines should be possible with the same data. Finally, internal dynamical measurements for a sub-sample of objects will require IFU observations at either GLAO or diffraction-limited resolutions.

3.3.3 Tomography of the IGM

Understanding the link between galaxies and the heating and enrichment of the IGM requires denser sampling than is possible with present instruments. Spectroscopy at intermediate resolution (R ~ 10K) on targets as faint as R(Vega) ~ 24-24.5 is required to achieve sufficient sampling on the sky. This requires a fairly high spectral resolution mode for the visible MOS. Survey areas on the order of 2 square degrees are needed, just as in section 3.2.1. The IGM survey must be complemented by a redshift survey over the same volume. The visible MOS requirements given in 3.2.2 are adequate for this task, and these two programs could be combined into a single large program.

3.4 Black Holes

Our priorities for black hole science center on extending the BH mass-bulge sigma relation to higher and lower masses, and, where possible, to higher redshifts. This will require diffraction-limited spatially resolved spectroscopy of the central regions of galaxies and star clusters. This is likely best accomplished with an IFU coupled to an LTAO imaging system. An IFU with lenslets that somewhat undersample the diffraction limit at 1.5μm and fields of 3” x 3” are desired. A 100 x 100 lenslet array with a pitch of 25mas may be a good compromise between angular resolution and sensitivity. The IFU should operate in the 0.8-2.5μm range. This may be accomplished with a single set of detectors, or it may be best done with two systems with different optics and detectors. These IFUs should feed spectrometers with resolutions from R=3000 - 5000.

3.5 Dark Energy and the Accelerating Universe

Our dark energy program has three components: determining the angular scale of baryonic oscillations at z > 4, extending and solidifying the SNe Hubble diagram at z > 1, and redshift determinations of LISA sources. Follow-up of LISA sources does not place any demands on the telescope or instrument that are distinct from those arising from other programs and thus they are not discussed further.
3.5.1 Baryon Oscillations at z>4

Determination of the power-spectrum requires large redshift surveys covering comoving scales > 150 Mpc. Redshifts of samples of z > 4 galaxies will be obtained via the Ly$\alpha$ line in the red end of the visible spectrum. This program, like the survey programs in section 3.2.2 also needs as large a field of view as possible, as roughly 50 square degrees of sky must be surveyed. Intermediate resolution in the red is desirable as it will allow effective rejection of the OH sky emission and avoid adding aliases into the power spectrum.

3.5.2 SNe at z>1

Spectroscopy and light curve determinations for SNe at large redshifts are limited to a large extent by blending of the SNe and host galaxy spectra. An IFU, operating at either the GLAO or the diffraction limit, can maximize the contrast between SNe and their host galaxies. This will also allow the collection of host galaxy spectra simultaneously with the same spectral resolution. SNe spectroscopic studies will be coordinated with imaging campaigns, perhaps from LST, that discover the candidate objects. This will require some coordination in scheduling, but does not necessarily require that the SNe IFU spectroscopic capability be available at short notice. Late-time light curves, particularly in the near-IR, will require an instrument that is regularly accessible. This is likely to be a small field, possibly AO, imager located at one of the folded Gregorian stations.

Studies of the physical properties of SNe will require near-IR spectroscopy and polarimetry in the visible and near-IR. The near-IR spectra should have low spectral resolution (R ~ 500) and high sensitivity. This may best be achieved by observing at high dispersion (e.g. R ~ 5000) and then rebining the spectra after masking of the atmospheric OH emission. Polarimetry is often most effective in the spectral mode. A spectropolarimetric mode for the visible and IR faint object spectrometers is a goal.

3.6 First Light an Reionization

Our priorities for exploring the Universe at very high redshifts have two components: exploring the detailed history of reionization and probing the first galaxies via emission-line spectroscopy of faint galaxies at z > 5.

3.6.1 The Reionization Era

The epoch of reionization is currently best probed by spectroscopy of Ly$\alpha$ absorption along sight-lines to luminous distant quasars. The number of z > 6 quasars known, and beyond the reach of 8-10m telescopes, should increase in the next decade. Effective spectroscopy of these objects requires intermediate resolution (R ~ 10-20K) in the red end of the visible spectrum and, eventually, into
the near-IR. As the surface density of these objects is tiny, small fields and single-object spectrometers are adequate.

### 3.6.2 First Light

Direct observation of the first galaxies is one of the prime science drivers for the next generation of telescopes, both from the ground and from orbit. Successful realization of this goal will require maximum sensitivity in the 0.7 - 2.5$\mu$m region of the spectrum. Spectroscopy is the highest priority in the 0.7-1.2$\mu$m region as it covers Lyman alpha at $6 < z < 9$. Moderate resolving powers (e.g. $R \sim 2000-4000$) are required to reduce the impact of the telluric OH emission. A field area greater than 50 square arcminutes is needed to yield more than 100 $z > 5$ candidate objects per exposure. Integration times are likely to be in the tens of hours, thus there is a premium placed on field area and multiplex factor.

Diffraction-limited imaging in the near-IR over modest fields will complement, and will in some cases exceed, the capabilities of JWST. An AO optimized imager coupled with an IFU operating in the near-IR without added thermal background is an important part of the instrument compliment needed for this science. A field of view of $\sim20'' \times 20''$ with 5 mas pixels would be well matched to the diffraction limit at Ks and would fill a 4k x 4k focal plane array. Narrow bandwidth searches for Lyman alpha in the darkest parts of the J-band can probe the $z \sim 10$ regime. This may be best carried out with very narrow filters in an imaging survey mode, with high resolution spectroscopy, or with OH suppression reimaging spectrographs.

### 3.7 Summary of High Level Science Requirements

The science requirements are summarized in terms of the primary wavelength ranges, techniques to be employed and AO modes, in Table 3. A more detailed breakdown of the requirements is given in Table 4-1.1 in the appendix. Not all of the requirements can be encoded into either table. Requirements on multiplexing, time critical observations, and requirements on observing conditions are examples of constraints that will impact instrument designs and priorities, but are not listed in Table 3.

<table>
<thead>
<tr>
<th>Science Area</th>
<th>Wavelengths</th>
<th>Techniques</th>
<th>AO Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planet and Star Formation</td>
<td>NIR &amp; MIR</td>
<td>High Contrast Imaging</td>
<td>NGAO, LTAO</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IFU Spectroscopy</td>
<td>Natural Seeing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High Res NIR spect</td>
<td>LTAO, Natural Seeing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>imaging &amp; Spect</td>
<td>LTAO</td>
</tr>
</tbody>
</table>
3.8 Instrument Capabilities

Table 4 summarizes the instrument capabilities required to carry out the high level science goals described earlier in this section. The implementation of these capabilities may extend several years after science operations begins, in accordance with Board policy for instrumentation development.

<table>
<thead>
<tr>
<th>Instrument Capability</th>
<th>λ Range (mm)</th>
<th>Resolution Spectral/ Spatial</th>
<th>Field of View</th>
<th>Observing Modes</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible Wide-Field Multi-Object Spectrograph</td>
<td>0.4-1.0</td>
<td>1500-3000 / seeing</td>
<td>60 sq. arcmin</td>
<td>MOS / fibers</td>
<td>spec only</td>
</tr>
<tr>
<td>Near-IR Wide-Field Multi-Object Spectrograph</td>
<td>1.0-2.5</td>
<td>1500-5000 / seeing, GLAO</td>
<td>30 sq. arcmin</td>
<td>MOS / fibers / Imager / GLAO</td>
<td>Primary: spectra</td>
</tr>
<tr>
<td>Visible Echelle</td>
<td>0.35-1.0</td>
<td>20K-100K / seeing</td>
<td>3&quot;</td>
<td>Single obj/ fibers</td>
<td>spec only</td>
</tr>
<tr>
<td>Near-IR Echelle</td>
<td>1.0-5.0</td>
<td>30K-60K / AO</td>
<td>10&quot;</td>
<td>Single obj / LTAO / NGSAO</td>
<td>spec only</td>
</tr>
<tr>
<td>Near-IR Integral Field Spectrograph</td>
<td>1.0-2.5</td>
<td>5000 / 0.01 - 0.03&quot;</td>
<td>2&quot;x2&quot; - 7&quot;x7&quot;</td>
<td>LTAO / Imager</td>
<td>Primary: spectra</td>
</tr>
<tr>
<td>Mid-IR High Contrast Imager</td>
<td>3.0-14.0</td>
<td>100-1000 / AO</td>
<td>30&quot;</td>
<td>LTAO / NGSAO / Imager</td>
<td>Primary: imaging / contrast: 10⁻⁵</td>
</tr>
</tbody>
</table>
3.9 Scientific Operations

During the operations phase the GMT will support a range of interaction channels for scientific users. These will be referred to as "operating modes" in this document. Astronomers may carry out their observations while at the summit or may interact remotely, either in real time or through service observing. The telescope schedule will be developed with an understanding of how each observer will execute their program. At this time it is difficult to commit to a rigid plan for supported operating modes. In Section 4.5 we discuss requirements and goals for this aspect of operations. We have taken the approach of setting an achievable baseline for operating modes while establishing a clear set of goals. The requirements generally call for the project to include, or not preclude, capabilities essential to the implementation of remote and service oriented operating modes.

The baseline plan will include, at a minimum, classical PI-directed on-site observing. Plans for supporting remote, service, and queue scheduled operating modes should be developed and costed. The decision to implement modes beyond on-site PI-directed observing shall be made as part of the construction plan and may be revisited as budgets allow.

The range and number of modes that are supported during any observing period will be specified by the GMTO Director in accordance with policies set by the Board. More than one mode may be supported and nights may be split between multiple modes (e.g. service and PI-directed).

We define the parameters of the different operating modes below.

**PI directed- on site.** In this mode the astronomer is on site and executes his/her observing program by operating one or more scientific instruments. Observatory staff operate the telescope, guiders and active optics systems. Visiting PI’s will be able to control instruments in real-time and specify the pointing of the telescope via interaction with the telescope operators.

**PI directed- remote.** In the remote operations mode the PI is off-site and interacts with the mountain staff and instruments via a real-time or nearly real-time link. Partial, compressed or full fidelity data should be available to the remote PI on a time-scale sufficient to allow decisions impacting the observing program to be made in near-real time.

**Service observing.** In the service mode the PI may or may not be present or connected at the time the observations are carried out. GMTO staff on the summit will execute approved observing programs, generally using phase II implementation plans developed by the PI using observatory supplied software.

**Queue scheduling.** Operating modes interact closely with the scheduling process. PI directed on-site observing programs are generally scheduled classically - some number of nights or fractional nights are preassigned to a program and cannot be transferred or rescheduled within a single scheduling cycle. In the queue
scheduling mode programs are drawn from a stack or "queue" in response to changing conditions on the summit. In principle this allows more efficient use of the telescope as programs can be matched to conditions. Queue scheduling is generally matched with service observing.

**Interrupt observations.** Some science programs require time-critical observations. These include predictable synoptic programs and targets of opportunity. Synoptic programs can be supported through remote operations, but are, in many cases, more efficiently supported through service observing. Target of opportunity observations that require short reaction have become important in recent years, primarily due to the short decay times of GRB afterglows and require queue scheduling.

TOO programs are likely to be more important in the future as large scale time-domain surveys come on line. Time-critical interrupt observations can be disruptive to other programs and costly to implement. The minimum response time for TOO observations will be set by the GMTO Director in accordance with policies set by the Board. In practice policies will need to consider if observing a TOO requires a reconfiguration of the telescope and instrument and whether a change in focus (e.g. folded port to/from straight Gregorian) is required.

4 General Conditions and Constraints

4.1 System Architecture

4.1-1 GMT description
SCI0951: The GMT shall be a diffraction-limited adaptive optics 25-meter class ground-based telescope optimized for fundamental scientific research at near-UV, optical and infrared wavelengths.

4.1-2 Site location
SCI0952: The GMT facility shall be located at Las Campanas Observatory, Chile, on a site that was selected on the basis of site testing conducted by the GMT Project and confirmed by the GMTO Board of Directors.

4.1-3 Enclosure
SCI0953: GMT shall be installed in an enclosure that will open up to allow observing at night and close down to protect the telescope at other times.
4.1-4 Summit Facilities
SCI0246: Facilities shall be provided on-site for maintaining and operating the telescope and associated subsystems including a lodge and commissary for staff and visitors.

4.1-5 Off-site facilities
SCI0245: A sea-level facility in Chile shall be provided to support observatory operations.

4.2 General Conditions

4.2-1 Governance
SCI0954: The design, construction, and operation of the GMT facility shall be governed by policies and procedures established by the GMTO Board of Directors acting on behalf of the GMTO Corporation.

4.2-2 Laws and regulation.
SCI0955: The GMT facility shall be constructed and operated in accordance with all applicable laws and regulations established by governmental agencies with local jurisdiction.

4.2-3 Code Compliance.
SCI0956: The GMT facility shall designed and constructed in accordance with all applicable building and safety codes as dictated by the GMTO Corporation.

4.2-4 Safety
SCI0957: Procedures shall be established and enforced to insure the safety of the GMT facility, equipment and personnel at all times.

4.3 Time Periods

4.3-1 Lifetime
SCI0985: The GMT Observatory shall be designed for a 50 year lifetime assuming routine maintenance of the telescope and facilities and periodic upgrades of field replaceable components and subsystems.

4.3-2 Operations
SCI0986: The GMT Observatory shall be in operation every day of the year.
4.3- 3 Observing Time Allocation
SCI0987: Observing time on GMT shall be allocated following procedures set by the GMTO Board.

4.3- 4 Down Time
SCI0988: Observing Time lost during routine operations due to equipment failure or other causes not attributable to weather conditions, scheduled maintenance or other programmed interruptions shall not exceed 5% (TBC) [goal 3%] of the time available for science observations.
Time that would otherwise be lost to environmental conditions will not be counted as downtime.

4.3- 5 Maintenance Time Scheduling
SCI0989: Maintenance Time shall be scheduled to the extent possible to minimize the adverse impact on science operations in accordance with procedures approved by the GMTO Board.
Maintenance Time is defined as nights or partial nights scheduled for routine maintenance operations that preclude science operation (e.g. mirror recoating, mounting and check out of a science instrument, night time testing and recalibration of telescope systems, etc.). Maintenance Time and Commissioning Time are included as Engineering Time in the GMTO Founders’ Agreement.

4.3- 6 Maintenance Time
SCI0990: Once normal (steady state) operations are underway, total maintenance time shall not exceed 60 nights per year [goal: 36 nights/year] (TBC).

4.3- 7 Commissioning Time
SCI0991: Telescope time shall be allocated as needed for commissioning new facility science instruments, AO system components, and other capabilities following procedures established by the GMTO Board.
Commissioning time will be approved by the GMTO Board of Directors upon the recommendation of the GMTO Director as part of the authorization process for new instruments.

4.3- 8 Transition Period
SCI0992: The GMTO Board of Directors shall approve a plan prepared by the GMTO Director for the allocation of telescope time between maintenance activities, commissioning, and science operations during the transition period following the commissioning of the telescope, first generation instruments and AO system until normal (steady-state) operations are achieved.
4.4 Environmental

Environment conditions and statistics for the GMT site are described in documents RD-3 and RD-7.

4.4-1 Operating Conditions
SCI0993: GMT shall be designed to operate for normal observing as defined in Section 5 over the range of environmental conditions specified in RD-3.

4.4-2 Meteorological Survival Conditions
SCI0994: The GMT facility shall be designed to survive with inconsequential damage the extreme weather conditions specified in RD-3 with the enclosure and buildings closed up and secured.

4.4-3 Operational Level Earthquake
SCI0995: The GMT facility shall be designed to survive with minimum consequential damage and return to operations within 7 days a maximum operational level earthquake (OLE) with a 200 year mean return period as defined in RD-3.

4.4-4 Survival Level Earthquake (SLE)
SCI0996: The GMT facility shall be designed to survive without major structural failure a maximum survival level earthquake (SLE) with a 500 year mean return period as defined in RD-3.

4.4-5 Environmental Monitoring
SCI0998: Environmental data shall be collected and displayed on operator consoles in real time during observatory operations and stored in the Engineering Data System.

4.4-6 Environmental Data
SCI0999: Environmental Data shall include temperatures and humidity inside the enclosure, external weather data (wind speed/direction, humidity, temperature, barometric pressure), nighttime seeing from MASS/DIMM measurements, dust, and cloud cover/opacity.

4.4-7 Environmental Statistics
SCI1000: Statistics of the Environmental Data shall be compiled and made available to users by the Observatory.
4.5 Operating Modes

An operating mode is the process by which science data are acquired with the telescope. It defines the way observations are sequenced and the roles of the GMTO technical and scientific staff, the Principal Investigator’s team, and other stakeholders in the process. The observing modes of GMT are described in section 3.9 of this document.

4.5-1 PI Directed - On-Site
SCI1001: Classical on-site PI-directed operations shall not be precluded by hardware and software control systems associated with the telescope and instruments. Visiting PI’s shall be able to control instruments in real-time and shall be able to specify the attitude of the telescope via interaction with the telescope operators.

4.5-2 PI-Directed - Remote
SCI1002: Communications capabilities needed to support remote observing shall be provided.

4.5-3 Service Observing
SCI1003: The observatory control system shall allow observations to be carried out by on-site professional support staff in accordance with instructions from the PI.

4.5-4 Queue Scheduling
SCI1004: Implementation of queue scheduling should not be precluded by the observatory control system or other systems.

4.5-5 Interrupt Observations
SCI1005: The observatory control system should not preclude interrupt observing or changes between instruments on the upper platform during the night.

5 Telescope

5.1 Observing Modes

GMT will be designed for nighttime observing in natural seeing conditions and using adaptive optics (AO) to correct image blur caused by the atmosphere.
5.1- 1 Nighttime Operation  
SCI1006: GMT shall be designed for night time observing.

5.1- 2 Natural Seeing Observations  
SCI1007: GMT shall provide an observing mode that uses natural guide stars for tracking and corrects for telescope shake and optical misalignments and aberrations but does not correct for atmospheric or enclosure seeing.

5.1- 3 Natural Guide Star AO (NGSAO)  
SCI1008: GMT shall provide an NGSAO observing mode to achieve high-Strehl, high-contrast diffraction limited images for targets with sufficiently bright, near-by reference stars (possibly the science target itself). See Section 6 for requirements.

5.1- 4 Laser Tomography AO (LTAO)  
SCI1009: GMT shall provide a high-Strehl, high sky coverage capability to achieve diffraction-limited images over a large fraction of the observable sky. See Section 6 for requirements.

5.1- 5 Ground Layer AO (GLAO)  
SCI1010: GMT shall provide an AO enhanced observing mode to achieve moderate image quality improvement over moderately wide fields of view by correction of low altitude atmospheric turbulence effects. See Section 6 for requirements.

5.2 Optics

5.2.1 Optical Design and Layout  
The GMT optical system is based on an aplanatic Gregorian design with concave primary and secondary mirrors. The Gregorian configuration is driven, in part, by the desire for effective ground-layer conjugation of the adaptive secondary mirror, an important consideration for Ground-layer adaptive optics. In addition, the Gregorian configuration has the advantage that the secondary mirror segments, being concave, will be easier to manufacture and test. The concave focal surface in the Gregorian design also is optimal for the design of refractive collimators in reimaging spectrographs.  
The aplanatic optical prescription is coma-free off-axis to first order. The primary and secondary mirrors are specified as segmented. Separate secondary mirror assemblies may be provided for commissioning, optimizing different observing modes, and as a back-up.
Some baffling of stray light will be provided by the telescope structure but science instruments will be required to be internally baffled.

5.2.1-1 Gregorian Prescription
SCI1011: The GMT shall be designed with an aplanatic Gregorian optical prescription for a primary mirror radius of curvature of 36 meters and a final focal length of 207 m (+/- 2%).

5.2.1-2 Primary Mirror Type
SCI1012: The GMT shall be designed around a segmented primary mirror consisting of seven 8.4 meter mirrors produced by the University of Arizona Steward Observatory Mirror Laboratory (SOML) in a hexagonal configuration.

5.2.1-3 Secondary Mirror
SCI1013: The secondary mirror(s) shall consist of seven segments conjugated 1:1 with the primary mirror segments.

5.2.1-4 Collecting Area
SCI1014: The optical system shall provide a total effective collecting area of approximately 368 m² assuming a 3.2 m circular secondary mirror obscuration. This is equivalent to a 21.9 m circular filled aperture with the same central obscuration.

5.2.1-5 Angular Resolution
SCI1015: The diffraction limited angular resolution of the GMT optical design at a wavelength of 1.65 microns with adaptive optics shall be no worse than 15 milliarcseconds FWHM.

5.2.1-6 Bare Gregorian (BG) Science Field of View
SCI1016: The unobstructed science field of view for the bare Gregorian configuration (primary and secondary mirrors but no corrector) shall be 8 arcminutes [goal 10 arcminutes] (TBC) in diameter. The BG field of view usable for science is limited by field aberrations in the two-mirror optical system. The polychromatic (350 nm – 2.4 micron) 80% enclosed energy diameter is 0.07” at the edge of a 6’ diameter field, 0.13” for an 8’ field, and 0.19” for a 10’ field. An uncorrected field of view up to 20’ is accessible with possible vignetting by other optics (wavefront/guide sensors, GLAO pick-off mirror, etc).
5.2.1- 7 Technical Field of View
SCI1017: A unobstructed Technical Field of View of 20 arcminutes [Goal: 24 arcminutes] shall provide a patrol area for guiders, wavefront sensors, etc., outside of the science field.

5.2.1- 8 Guider Patrol Field
SCI1018: The patrol field within the Technical Field of View shall be sized such that the probability of acquiring suitably bright guide and wavefront sensor stars for natural seeing operation is not less than 99% [TBC].

5.2.1- 9 BG Wavelength Range
SCI1019: The operating wavelength range for the BG configuration shall be 320 nm to 25 microns.

5.2.1- 10 Focal Stations
SCI1020: GMT shall provide multiple focal stations at which instruments can be mounted: 1) Direct Gregorian Port (DG), 2) Folded Ports (FP), and 3) Gravity Invariant Station (GIS).
These are specified in subsequent sections.

5.2.2 Atmospheric Dispersion/Wide-Field Corrector (ADC)
The dual purpose of the Atmospheric Dispersion/Wide-field Corrector (ADC) is to increase the usable science field of the telescope from the roughly 8’ diameter provided by the base Gregorian primary-secondary mirror optical system to 20’ and also correct for atmospheric dispersion.
There is a complicated trade-off with a refractive ADC between the accuracy of correction that can be achieved, wavelength range, and the maximum amount of correction [Ref. RD-5, chapter 6]. The availability of broadband coatings (throughput) is also a consideration. The specifications in this section represent a compromise over the region of the sky with the highest image quality and wavelength range with highest dispersion.
The position or curvature of the ADC focal surface is not be required to be coincident with the bare Gregorian focus.

5.2.2- 1 Atmospheric Dispersion Corrector (ADC)
SCI1021: A corrector with atmospheric dispersion compensation (ADC) shall be provided for wide-field observations at the direct Gregorian (DG) focus.
5.2.2-2 ADC Field of View
SCI1022: The unvignetted field of view in the wide-field configuration shall be 20 arcminutes [Goal: 24 arcminutes] in diameter.

5.2.2-3 ADC Minimum Elevation Angle
SCI1023: The ADC will be optimized to correct atmospheric dispersion down to a minimum elevation angle of 40°. Below the minimum elevation angle images will be partially corrected by the correction at 40°.

5.2.2-4 ADC Wavelength Range
SCI1024: The wavelength range of the wide-field configuration shall be 380 nm to 1.0 micron [Goal: 350nm to 1.8 micron].

5.2.2-5 Residual Dispersion
SCI1025: The residual dispersion over the full wavelength range and from zenith to the minimum elevation angle shall be less than 0.2 arc-sec P-V over a 20 arcminute FOV. Note: the uncompensated dispersion is ~2.0 arcseconds p-v over the same FOV and wavelength range.

5.2.2-6 ADC Throughput
SCI1026: The throughput of the ADC shall not be less than the values in Table 5.

Table 5. Transmission of the ADC as a function of wavelength

<table>
<thead>
<tr>
<th>Wavelength range</th>
<th>Minimum Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

5.2.2-7 ADC Insertion/Removal
SCI1027: A mechanism shall be provided for inserting and removing the corrector into and out of the Gregorian beam.

5.2.2-8 Time to Insert/Remove ADC
SCI1028: The time to insert the ADC into its deployed position or move it to its stowed position with the telescope parked at the zenith shall be less than 10 minutes [Goal: 5 minutes].
5.2.3 Field Rotation

Rotation of the altitude and azimuth axes will cause the field of view to rotate about the optical axis at the telescope focus. A mechanism (Gregorian Instrument Rotator (GIR)) for compensating field rotation will be provided for DG and FP instruments on the Optical Support Structure (OSS).

5.2.3-1 Gregorian Instrument Rotator (GIR)

SCI1029: An Instrument Rotator shall be provided to compensate for field rotation due to the alt-azimuth motion of the telescope and deliver a non-rotating field of view to DG and FP science instruments mounted on the rotator.

5.2.3-2 Gravity Invariant Station (GIS) Field Rotation

SCI1030: Science instruments mounted at the GIS shall provide their own field de-rotation if required.

5.2.3-3 GIR Stationary Operation

SCI1033: The GIR shall include a mode of operation in which the GIR is moved to a fixed rotation angle and locked in position.

5.2.4 Direct Gregorian (DG) Port

The Direct Gregorian Port (DG) provides a high-throughput, low-background focus with the minimum number of reflections. The DG port may be configured in one of two ways. The Bare Gregorian (BG) configuration uses just the primary and secondary mirrors to form images at the Gregorian focus. The optical properties of the bare Gregorian focus (no ADC) are given in Section 5.2.1.

The Wide-field (WF) configuration uses the ADC/Corrector to provide a dispersion corrected field of 20 arcminutes. The optical properties of the Gregorian focus with the ADC are given in Section 5.2.2.

The focal planes in the BG and WF configurations will not be coincident. The ability to use both configurations with a single instrument is not specified as an option/requirement.

The exchange of two DG instruments will require physically moving both instruments and re-balancing the GIR. It is anticipated that this operation will be performed by the daytime crew and is not a nighttime operation. However, nighttime switching between folded port instruments and an already deployed DG instrument will be supported.

5.2.4-1 Bare Gregorian (BG) Operation

SCI1035: The DG port shall accommodate science instruments in the Bare Gregorian (BG) configuration consisting of the primary and secondary mirror.
5.2.4- 2 Gregorian Port ADC Operation
SCI1036: The DG port shall accommodate instruments that use the ADC in the WF configuration.

5.2.4- 3 Number of DG Instruments
SCI1037: At least three [Goal: 4] DG science instruments shall be accommodated within the GIR.

5.2.4- 4 Exchanging DG Instruments
SCI1038: A mechanism shall be provided for exchanging the on-board DG Instruments at the DG port.

5.2.4- 5 Time to Exchange DG Instruments
SCI1039: The time to exchange DG Instruments with the telescope parked at the zenith position shall not exceed 1.0 hour.
Note: This does not include time for instrument configuration and calibration.

5.2.5 Folded Ports (FPs)

A tertiary mirror will be used to direct the Gregorian beam to a set of Folded Ports (FP). The purpose of the Folded Ports (FPs) is to provide optimized foci for narrow-field instruments which operate at visible, IR and NIR wavelengths (400 nm to 25 microns) where adaptive optics is most effective. Narrow-field natural seeing instruments may also be mounted at these ports. The choice of wavelength range is motivated by the desire to use high reflectivity (e.g. silver) coatings for the tertiary mirror to minimize emissivity in the infrared.

FP AO instruments will include a sensor package ("AO front end") that picks off the light for wavelength and tip/tilt sensing and feeds the science beam of the instrument. The image size specifications in this section apply to the light delivered to the FP and do not include contributions from the instruments or AO front end.

The ability to switch instruments during the night will be required to adjust to changing weather/atmospheric conditions, recover from instrument failures, or for programmatic reasons. Switching between Folded Port instruments or between a Folded Port instrument and an already deployed Direct Gregorian instrument is assumed to require little more than the motion of a fold mirror and reconfiguration of guide probes, etc. and can be accomplished in a reasonable time with minimally acceptable loss of observing time. Insertion or retraction of the ADC [cf. Section 5.2.2] should also take place within the time allowed for port switching.
5.2.5-1 FP Feed
SCI1040: A fold mirror(s) ("tertiary mirror(s)"") shall redirect the Gregorian (BG) beam to instruments at the FPs.
Note: a single steerable fold mirror or individual fold mirrors for each port will satisfy this requirement.

5.2.5-2 FP Instrument Count
SCI1041: GMT shall accommodate at least two (TBC) [goal: 3] Folded Port instruments at any time.

5.2.5-3 Time to Exchange FP Instruments
SCI1042: The time to re-direct the beam from one FP instrument to another shall not exceed 10 minutes [Goal: 5 minutes].

5.2.5-4 Time to Deploy Tertiary Mirror
SCI1043: The time to move the folded port pick-off mirror into or out of the beam with the telescope parked at the zenith position shall not exceed 20 minutes [Goal: 15 minutes].

5.2.5-5 FP Field of View
SCI1044: The unvignetted field of view delivered to the FP instruments shall be not less than 3 arcminutes [TBC] in diameter.

5.2.5-6 Tertiary Mirror Field of View
SCI1045: The reflective coating on the tertiary mirror(s) feeding the AO instruments shall be optimized for the wavelength range 400 nm (TBC) to 5.0 microns [goal: 400 nm to 25 microns].

5.2.6 Gravity Invariant Stations (GIS)
The gravity invariant instrument location is provided for instrument(s) that require the highest stability, for example those that measure precision radial velocities. The pick off of the Gregorian beam and optical feed to the GI instrument is provided by the instrument. Optical fibers, an optical relay or combination of both are possibilities.

5.2.6-1 Gravity Invariant Station (GIS)
SCI1046: GMT shall provide a gravity invariant instrument location on the telescope structure for mounting an instrument with high stability requirements.
5.2.6- 2 GIS Feed
SCI1047: The optical relay/feed to the GIS shall be provided as part of an instrument that uses that port.

5.3 Natural Seeing Image Quality

Image size budgets are essential tools for controlling the various factors in the telescope and enclosure that degrade imaging performance. The elements that enter into the budgets include fabrication errors in the optics, misalignments and distortion due to the mounting of the optics in the telescope, tracking errors and vibration of the structure (e.g. wind shake), and thermal effects that contribute to image blur (e.g. “mirror seeing”). Image blur caused by the atmosphere (“atmospheric seeing” and “dome seeing”) is not part of the image size budget but is a key factor in setting the cap on the total contributions from all other sources. Separate specifications for image quality apply to the Bare Gregorian (BG), Wide-Field (WF), and Folded Port (FP) configurations. The image size specification for each configuration is set such that the telescope sources of error contribute no more than approximately 7% to the overall image blur in median seeing and 10% in 25th quartile seeing.

The image size specifications apply under the conditions defined in the tables below on nights usable for observing when environmental conditions fall within the operating conditions specified in section 4 and clear sky with minimal or no cirrus. Image quality is expected to degrade slowly for observing in conditions outside of those specified but still within the GMT operational limits specified in Section 4. In general, the limiting values for wind speed for specifying performance are set by thermal considerations at low wind speeds and wind shake at the high end. Pointing the telescope away from the wind direction will permit operation at higher wind speeds while still achieving the image size specification.

Wavefront error budgets for the different modes of AO operation are developed in Section 6. The Science instruments will have their own internal error budgets.

The metric adopted for GMT natural seeing image size is 80% encircled energy with sources combining in RSS for the total. (The conversion factor from Gaussian full-width half maximum (FWHM) to 80% encircled energy ($\theta_{80}$) is 1.52.)

A detailed description of the terms and formalism for the natural seeing image size budgets is given in RD-4. The contributors to the budget are shown in Table 6. Note that dome seeing has been deleted from the image size budget as presented at CoDR. The contributions roll up to a top-level image size specification given below for each configuration.

<table>
<thead>
<tr>
<th>Sources</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical design</td>
<td>Diffraction limit for images produced by the optical design</td>
</tr>
</tbody>
</table>
assuming unphased subapertures.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical surfaces</td>
<td>Residual figure and support errors not fully compensated by the ACOS.</td>
</tr>
<tr>
<td>Active alignment</td>
<td>Residual low bandwidth alignment and focus errors not fully compensated by the active alignment system(s).</td>
</tr>
<tr>
<td>Wind disturbance</td>
<td>High bandwidth mirror figure, alignment, and focus errors caused by wind disturbance.</td>
</tr>
<tr>
<td>Thermal</td>
<td>Thermal distortion of optical components and &quot;mirror seeing&quot;</td>
</tr>
<tr>
<td>Tracking</td>
<td>Residual tracking errors in the drive system not corrected by fast-steering/tip-tilt mirrors, differential flexure between guide sensors and the instrument focal plane, and instrument rotator angle errors.</td>
</tr>
</tbody>
</table>

Image size specifications apply to nights usable for observing under the environmental conditions specified in Table 7.

Table 7. Applicability of Image Size Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind speed</td>
<td>3.6 to 9.8 m/s (25th to 75th percentile) [Goal: 3.6 to 9.8 m/s (10th to 90th percentile conditions) with some pointing restrictions]</td>
</tr>
<tr>
<td>Wind direction</td>
<td>All angles with respect to shutter opening</td>
</tr>
<tr>
<td>Temperature</td>
<td>+4°C to +17°C (5th to 95th percentile) [Goal: -10°C to +25°C]</td>
</tr>
<tr>
<td>Temperature rate of change</td>
<td>± 0.5°C/hr over 1 hour (~20th to ~90th percentile) [Goal: +/- 1.0°C/hr over 1 hour]</td>
</tr>
<tr>
<td>Time of night</td>
<td>Between evening and morning astronomical twilight</td>
</tr>
</tbody>
</table>

5.3-1 Bare Gregorian (BG) Natural Seeing Image Size

SCI1048: The telescope contribution to narrow field natural seeing stellar image size at the BG focus (excluding the effects of dome and atmospheric seeing) shall not exceed 0.30 [TBC] arcseconds 80% encircled energy diameter under the conditions specified in Table 8. [Goal: 0.25 arcseconds (TBC)]

Table 8. Parameters for BG and FP Natural Seeing Image Specification Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zenith distance</td>
<td>0°</td>
</tr>
<tr>
<td>Field diameter</td>
<td>0 arcmin (on-axis)</td>
</tr>
</tbody>
</table>
### 5.3- 2 Wide-Field (WF) Natural Seeing Image Size

SCI1053: The telescope contribution to wide field natural seeing stellar image size in the telescope focal plane (excluding the effects of dome and atmospheric seeing) shall not exceed 0.38 arcseconds (TBC) 80% encircled energy diameter for the conditions in Table 9. [Goal: 0.30 arcseconds (TBC)]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zenith distance</td>
<td>0°</td>
</tr>
<tr>
<td>Field diameter</td>
<td>20 arcmin</td>
</tr>
<tr>
<td>Wavelength</td>
<td>0.37 – 1.0 microns</td>
</tr>
<tr>
<td>Primary mirror</td>
<td>Segmented with active figure control</td>
</tr>
<tr>
<td>Secondary mirror</td>
<td>Segmented with fast steering correction</td>
</tr>
<tr>
<td>Corrector/ADC</td>
<td>Yes. ADC angle = 0° (no correction)</td>
</tr>
<tr>
<td>Subapertures</td>
<td>Not phased</td>
</tr>
</tbody>
</table>

### 5.3- 3 Folded Port (FP) Natural Seeing Image Size

SCI1049: The telescope contribution to narrow field natural seeing stellar image size delivered to Folded Port instruments or the AO front end (excluding the effects of dome and atmospheric seeing) shall not exceed 0.35 arcseconds [TBC] 80% encircled energy diameter under the conditions specified in Table 5.4.

### 5.3- 4 PSF Stability (TBC)

SCI1050: The normalized point spread function (PSF) delivered by the telescope to instruments in the field of view that rotates with the OSS shall remain constant over the span of a night to within [TBD Spec].

Note: Diffraction effects caused by the segmented pupil of GMT will rotate with the OSS.
5.3-5 Off-Zenith Image Size
SC11051: The natural seeing image size budget amounts for all BG, WF, and FP configurations shall be relaxed for off-zenith stellar objects by a factor of \( \cos^{-3/5} \) (zenith distance).

5.3-6 Active Correction
SC11052: The image quality shall be continuously monitored during observing and corrections applied to the alignment of the optical system, focus, and primary mirror segment figures to meet the image quality specifications for natural seeing images delivered to instruments and/or the AO front end.

5.4 Optical Coatings
High reflectivity, low emissivity mirror coatings that cover the operating spectral range are important for meeting the science objectives of GMT. Achieving and maintaining coating performance in service is a key project objective.

The baseline plan is to coat the primary and secondary mirror segments with aluminum providing spectral coverage from the atmospheric cut-off out to 25 microns. A coating system will be provided on site for the primary segments. The coating system will be capable of applying coatings to meet the baseline specifications and upgradeable for more advanced coatings (e.g. multilayer silver) in the future.

The secondary segments may be coated in the existing coating chambers at LCO or sent out to industry for more advanced coatings.

The tertiary mirror(s) for the Folded Ports will have coatings optimized for wavelengths longer than 400nm.

The ADC coatings will be optimized for use at visible wavelengths. There may be provisions for additional ADC elements optimized in the NIR.

Facilities will be provided on site for the cleaning and coating of the primary and secondary mirrors. Re-coating of the tertiary mirror(s) and ADC elements will be done off site.

A process will be provided for cleaning the primary mirrors in-situ. This will consist of periodic spraying with CO2 snow to remove particulate matter (dust) on an approximately weekly schedule and periodic washing between re-coatings of the surface off the telescope.

The tertiary mirror(s) and ADC will be removed from the telescope for cleaning.

Table 10 is the expected throughput of the GMT optical system, not including the ADC, as a function of wavelength for the baseline coatings. Values for freshly coated surfaces and expected degraded performance over time based on operational experience on other telescopes.
The total emissivity of the GMT optics is assumed to be 1.0 minus the throughput (transmission) values in Table 10. The emissivity will vary considerably depending on the condition (fresh vs. aged) of the coatings.

5.4- 1 Throughput with Fresh Coatings

SCI1054: The combined primary, secondary and tertiary optical trains shall meet or exceed the throughput requirements in Table 10 for freshly coated surfaces.

Note: These apply to fresh coatings within a 8.4m subaperture of the telescope.

5.4- 2 Minimum Throughput

SCI1055: The total throughput of the seven combined subapertures of the telescope in the BG and FP configurations shall be no more than 10% [Goal: 5%] lower than the fresh coating values shown in the Table 10.

This requirement will be met by a schedule of periodic cleaning and re-coating of the telescope mirrors. The specification does not include losses in the ADC (see below) or instruments. The specification is generally achievable in practice with high quality aluminum coatings. The goal represents the best achievable in each wavelength band for aluminum or multilayer silver. No one coating type satisfies the goal over the full range.

<table>
<thead>
<tr>
<th>Table 10. Mirror System Throughput with Fresh Coatings (TBC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wavelength (μm)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Emittance (%)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

5.4- 3 Scattering

SCI1057: TBD
5.4-4 BG Emissivity
SCI1058: The BG telescope contribution to emissivity with freshly coated primary and secondary mirrors shall not exceed 5.9% [Goal: 4.0%] at wavelengths greater than 2.2 microns. [TBC]

5.4-5 FP Emissivity
SCI1059: The FP telescope contribution to emissivity with freshly coated primary, secondary, and tertiary mirrors shall not exceed 8.7% [Goal: 5.4%] at wavelengths greater than 2.2 microns. [TBC]

5.4-6 Coating Maintenance
SCI1060: Facilities and procedures shall be provided for cleaning and/or recoating optical surfaces as required to meet throughput and emissivity specifications during operations.

5.4-7 Coating System Upgradeable
SCI1061: The on-site mirror coating system shall be designed to be upgradeable in the future for advanced low emissivity coatings.

5.4-8 In-Situ Primary Mirror Segment Cleaning
SCI1062: Equipment and procedures shall be established for in telescope cleaning of the primary mirror segments to promote high throughput, low emissivity, and low scattering while at the same time minimizing the frequency at which segments need to be removed from the telescope for re-coating.

5.5 Pointing and Tracking

5.5.1 Pointing
The requirements in this section relate to the ability of the telescope to point at targets on the sky relying solely on the telescope encoders and look-up tables.

5.5.1-1 Sky Coverage
SCI1063: The GMT structure shall permit unvignetted science observations on the sky visible from the site throughout the full 360° range in azimuth angle and elevation angles from 30° [Goal: 25°] to 89.0° [Goal: 89.5°].
5.5.1- 2 Set-Up Time

SCI1064: The time to initialize the telescope from a cold start with the telescope from its stow configuration in the park position shall not exceed 40 minutes [goal: 20 minutes].

This requirement includes initialization of the mirror support systems, power-on of the drive and bearing systems, configuration of guide/wavefront sensors, and zero-point initialization of the pointing model. These operations would typically take place prior to the end of astronomical twilight.

5.5.1- 3 Acquisition Time

SCI1065: The time to re-point the telescope between any two positions within the permitted range of azimuth and elevation and rotator angles, acquire guide starts, commence tracking, stack the subaperture images, commence active optics and deliver a science-ready image to the instrument shall not exceed the values in Table 11 as a function of offset angle in azimuth or elevation.

<table>
<thead>
<tr>
<th>Table 11. Acquisition Time</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Offset angle</th>
<th>Spec (TBC)</th>
<th>Goal (TBC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 degree</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>10 degrees</td>
<td>125</td>
<td>60</td>
</tr>
<tr>
<td>60 degrees</td>
<td>200</td>
<td>180</td>
</tr>
<tr>
<td>180 degrees</td>
<td>300</td>
<td>240</td>
</tr>
</tbody>
</table>

**Note:** For adaptive optics operation the acquisition time is the time to deliver images to the AO system front-end assembly.

5.5.1- 4 Blind Pointing Accuracy

SCI1066: GMT shall meet the blind pointing accuracy specifications in Table 12 over the full range of telescope azimuth and elevation angles.

<table>
<thead>
<tr>
<th>Table 12. Blind Pointing Accuracy</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification (TBC)</th>
<th>Goal (TBC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offsets ≤ 1°</td>
<td>≤ 0.5 arcsec rms</td>
<td>≤ 0.3 arcsec rms</td>
</tr>
</tbody>
</table>
## 5.5.2 Tracking and Guiding

GMT will provide two modes of tracking objects on the sky: unguided and guided. Tracking includes both motions of the azimuth and elevation axes and rotations of the GIR. Errors in the GIR rotation angle will show up as mis-registration of objects in the field of view and possibly as guide errors when using off-axis guide stars.

Unguided operation relies on the open-loop operation of the telescope drives and encoders using pointing look-up tables without reference to guide stars. The accuracy of unguided tracking is set by the blind pointing accuracy of GMT.

GMT will provide the ability to point the telescope using position reference stars (“guide stars”) of sufficient brightness located within the technical field of view centered on the science field. Guide sensors may be mounted on the telescope structure, within the science instruments or AO front end, or some combination of these.

Guided operation involves closing the azimuth, elevation, and rotator pointing servo loops around the observed position of star(s) in the field of view after applying the appropriate offsets. Multiple guide sensors will allow GIR rotation errors to be sensed and corrected. Guiding is the normal mode of GMT operation for science observations.

Offset guiding uses one or more reference stars (“guide stars”) offset from the center of the science FOV. On-axis guiding uses a guide star, possibly the target object itself, at the center of the FOV but is not sensitive to rotator error. On-axis and off-axis guiding with multiple sensors may be combined to satisfy the guiding requirements.

Tracking errors will contribute to image blur and are one component of the Image Size Budget. Pointing specifications may be relaxed for instruments with lower pointing accuracy requirements.

### 5.5.2-1 Guide Sensors

SCI1067: GMT shall provide optical position sensors to acquire and lock onto guide stars located inside the technical field of view and provide position feed-back for the telescope azimuth, elevation, and rotator drives and, if provided, fast tip/tilt system.

### 5.5.2-2 Closed-Loop Guiding

SCI1068: GMT shall provide the hardware and software for closed loop tracking of the telescope main axes and facility instrument rotator(s) (GIR) using position feedback from guide sensors.
5.5.2-3 Guide Sensors Patrolling
SCI1069: Off-axis guide sensors shall have the ability to patrol an area within the technical field of view to acquire guide stars.

5.5.2-4 Guide Sensor Sky Coverage
SCI1070: The number, sensitivity, and patrol field of guide sensors shall be chosen to provide a minimum 99% [Goal: 99.9%] probability of acquiring suitable guide stars for natural seeing operation at all permitted telescope azimuth, elevation, and GIR rotator angles. [TBC]

5.5.2-5 Sidereal Tracking
SCI1071: GMT shall be able to observe objects moving at the sidereal rate over the full permitted range of azimuth, elevation, and rotator angle using the guide sensors.

5.5.2-6 Non-Sidereal Tracking
SCI1072: GMT shall be able to observe objects moving at rates up to TBD arcseconds/sec relative to the sidereal rate over the full permitted range of azimuth, elevation, and rotator angle using the guide sensors.
This requirement includes objects and guide stars with different non-sidereal rates.

5.5.2-7 Time to Position Guide Sensor
SCI1073: The time to position off-axis guide sensors anywhere in their patrol area shall not exceed 60 seconds. [Goal: 30 seconds] (TBC)

5.5.2-8 Natural Seeing Pointing Accuracy with Guide Stars
SCI0997: The pointing error at the center of the science field delivered to the instrument focal plane for natural seeing operation shall be no greater than 0.20 arcsecond RMS [Goal: 0.10 arcsecond] relative to the guide star position(s) for all permitted telescope azimuth, elevation, and GIR rotator angles. [TBC]

5.5.2-9 AO Pointing Accuracy with Guide Stars
SCI1034: The pointing error at the center of the science field delivered to the instrument focal plane in NGSAO and LTAO modes shall be no greater than 0.070 arcsecond RMS [Goal: 0.020 arcsecond] relative to guide star (s) located within 90 arcseconds of the field center for all permitted telescope azimuth, elevation, and GIR rotator angles.
5.5.2-10 Offset Pointing Stability
SCI1032: The pointing stability at the center of the science field delivered to the instrument shall be constrained by the Image Size Budgets for natural seeing and AO observing modes.

5.5.2-11 Uninterrupted Observing
SCI1031: The GMT mount, instrument rotator(s) guider assemblies, and utility wraps shall be designed for continuous and uninterrupted tracking of any object through its full range of motion on the sky within the permitted range of elevation angle.

6 Adaptive Optics

6.1 General Specifications

6.1.1 Applicability of Specifications

6.1.1-1 Applicability of AO Specifications
SCI1077: The AO image quality specifications below apply in 50th percentile atmospheric conditions and with seasonal minimum sodium layer density as defined in [RD-3].

6.1.2 Throughput and Emissivity

6.1.2-1 AO Throughput
SCI1078: Components of the AO system, not including an adaptive secondary or tertiary mirror, shall have a throughput to the instrument(s) of no less than a 85% over the wavelength range 960 nm - 14 μm [900 nm - 25 μm goal].

Move to level 2. Add more general throughput to instrument requirement.

6.1.2-2 AO Emissivity
SCI1079: Components of the AO system, not including an adaptive secondary mirror or tertiary mirror, shall increase the thermal background of the telescope over the wavelength range 2.0 - 14 μm by no more than 30% of the telescope contribution, in all AO observing modes [2.0 - 25 μm goal].
Note: The ASM and tertiary mirror throughput and emissivity requirements are defined in the Telescope section.

6.1.3 Efficiency

6.1.3-1 AO Availability
SCI1080: The time to activate and deploy components of the AO system necessary for any observing mode (NGSAO, LTAO, or GLAO) shall be no more than 10 minutes [goal: 5 minutes].

Note: Constraints regarding the projection of high-power lasers may restrict LGS-AO availability to previously planned targets and observing periods.

6.2 NGSAO

6.2.1 Field of View

6.2.1-1 NGSAO Field of View
SCI1081: The NGSAO system shall deliver an unvignetted field of view no less than 60 arcseconds in diameter to the science instrument.

Note: This requirement is not intended to constrain the technical field of view necessary for AO guide star acquisition.

6.2.1-2 NGSAO Guide Stars
SCI1082: Any guide star within 60 arcseconds radius of the science target shall be accessible to the NGSAO system.

6.2.2 Image Quality

6.2.2-1 NGSAO Strehl Performance
SCI1083: The NGSAO system shall deliver an on-axis K band (2.20 \( \mu \text{m} \)) Strehl ratio of no less than 0.75, at the instrument focal plane, when using a \( V=8.0 \) G2V guide star [goal: 0.80 Strehl].

Note: Strehl ratio is defined with respect to the GMT pupil.
6.2.2- 2 NGSAO Contrast Performance
SCI1084: The NGSAO system, together with an appropriate coronagraphic instrument, shall deliver M band (4.75 μm) images with a contrast greater than 10^-6 at 77 mas (2λ/D) from a V=8.0 G2V guidestar, at the science focal plane.

6.2.2- 3 NGSAO Anisoplanatism
SCI1085: The field dependence of the NGSAO system image quality shall be limited by atmospheric anisoplanatism.

6.2.3 Efficency

6.2.3- 1 NGSAO Acquisition Time
SCI1086: The time required to deliver science-ready images to the instrument in the NGSAO observing mode shall not exceed 3 minutes after the delivery of seeing-limited, science-ready images by the telescope [goal: 2 minutes].

6.3 LTAO

6.3.1 Field of View

6.3.1- 1 LTAO Field of View
SCI1087: The LTAO system shall transmit an unvignetted science field of view no less than 60 arcseconds in diameter.

Note: This is not intended to constrain the technical field of view necessary for AO guide star acquisition.

6.3.2 Image Quality

Note on LTAO image quality requirements: The project understands that maximizing the sky coverage is important to the GMT’s scientific productivity. The following three requirements are challenging, but we believe that they are achievable within the current budget constraints. We will, during the preliminary design process, evaluate the potential cost of achieving the stated goals. Until
then, the requirements remain To Be Confirmed unless specific sky coverage values can be derived from the science case.

6.3.2-1 LTAO H Band Strehl
SCI1088: The LTAO system shall deliver an on-axis H band (1.65 μm) Strehl ratio of no less than 0.30 at the science focal plane, over at least 20% (TBC) of the sky at the galactic pole [goal: 50% at the galactic pole].

6.3.2-2 LTAO K Band Strehl
SCI1089: The LTAO system shall deliver an on-axis K band (2.20 μm) Strehl ratio of no less than 0.45 at the science focal plane, over at least 50% (TBC) of the sky at the galactic pole [goal: 90% at the galactic pole].

6.3.2-3 LTAO Ensquared Energy with High Sky Coverage
SCI1090: The LTAO system shall deliver an on-axis K band (2.2 μm) fractional ensquared energy in 50x50 mas of no less than 0.40 at the science focal plane over at least 50% (TBC) of the sky at the galactic pole [goal: 90% of the sky at the galactic pole].

6.3.2-4 LTAO Anisoplanatism
SCI1091: The field dependence of the LTAO system image quality shall be limited by atmospheric anisoplanatism.

6.3.3 Field Acquisition

6.3.3-1 LTAO Acquisition Time
SCI1092: In the LTAO observing mode, the time required to deliver science-ready images to the instrument shall not exceed 7 minutes after the delivery of seeing-limited, science-ready images by the telescope [Goal: 5 minutes].

6.4 GLAO

6.4.1 Field of View

6.4.1-1 GLAO Field of View
SCI1093: The GLAO systems shall transmit a field of view no less than 7.0 arcminutes in diameter.
6.4.2 Image Quality

6.4.2-1 GLAO K Band Performance
SCI1094: The GLAO systems shall deliver a K band (2.2 μm) point spread function with FWHM no greater than 0.25 arcseconds over at least 90% of the sky at the galactic pole.

6.4.2-2 GLAO PSF Uniformity
SCI1095: The PSF delivered by the GLAO system shall have a FWHM uniformity of better than 30% across the full science field.

6.4.3 Field Acquisition

6.4.3-1 GLAO Acquisition Time
SCI1096: In the GLAO observing mode, the time required to deliver science-ready images to the instrument shall not exceed 7 minutes after the delivery of seeing-limited, science-ready images by the telescope [Goal: 5 minutes]

7 Science Instruments

Instruments are classified as either “Facility” or “PI” instruments. We define Facility instruments as major science instruments that are provided to the observatory by GMTO, supported and maintained by GMT staff, and generally available to all GMT users for an extended period of time. All other instruments are considered to be PI instruments.

Instruments shall be selected and procured in a process approved by the GMTO Board. All instruments that are brought to the observatory require prior authorization under policies approved by the GMTO Board.

7.0-1 Facility Instruments
SCI1097: Facility Instruments shall be provided and supported by GMTO as integral parts of the observatory under guidelines established by the GMTO Board.

7.0-2 Instrument Availability
SCI1098: Facility Instruments shall be designed to be mounted on the telescope for extended periods of time, following guidelines established by GMTO.
7.0- 3 Standby Condition
SCI1099: Facility Instruments mounted on the GMT shall be maintained in a powered-up stand-by condition ready for use.
Exceptions: small instruments that can be rapidly deployed, instruments that cannot work through the lunar bright phase or instruments that are primarily used for infrequent synoptic observations may be exempted from this requirement.

7.0- 4 Instrument Lifetime
SCI1100: Facility Instruments shall have a design operational lifetime of 7 years [goal: 12 years] assuming routine maintenance.

7.0- 5 Instrument Spares
SCI1101: Sufficient spares for critical components shall be provided to meet the instrument design lifetime.

7.0- 6 PI Instruments
SCI1102: The observatory staff shall assist PI Instrument groups in mounting their instrument but shall not be responsible for servicing, maintaining or upgrading the instrument.

7.0- 7 Instrument Interface Specifications
SCI1103: Interface specifications for the available ports on GMT shall be provided by the project for both facility and PI instruments.

7.0- 8 Instrument Mounting
SCI1104: The GMT observatory shall provide a means for mounting and unmounting instruments on the telescope including equipment lifts, cranes, and access paths through the enclosure, Facility Building, and telescope. These activities will take place only during daytime.

7.0- 9 Handling Fixtures
SCI1105: Specialized handling fixtures and carts specific to an instrument shall be provided with the instrument.

7.0- 10 Flat- Field and Spectral Calibration System (TBC)
SCI1106: GMT shall provide a deployable system(s) to project continuum and spectral light sources with beam characteristics that mimic the light coming from astronomical sources for flat-field and wavelength calibration of visible and near IR (non-thermal IR) instruments.
The Calibration System may be attached to GMT or may be deployed from a fixed structure (e.g. the enclosure) separate from the telescope.

8 Enclosure

8.0-1 Enclosure
SCI1107: When closed, the enclosure shall provide weather and dust protection for the telescope and instrumentation under all expected conditions as specified in RD-7.

8.0-2 Shutters
SCI1108: The enclosure shall be equipped with doors that open up (“shutters”) and a rotation mechanism that together allow the telescope to observe all portions of the sky within the permitted altitude and azimuth observing range of the telescope without vignetting of the beam by enclosure structure.

8.0-3 Wind Protection
SCI1109: The enclosure shall be equipped with shutters and ventilation doors that are adjustable to allow wind-forced ventilation of the telescope chamber while at the same time minimizing wind shake of the telescope structure.

8.0-4 Dome Seeing
SCI1110: The enclosure shall be designed using best practices to minimize image blur (“dome seeing”) caused by an inhomogeneous air temperature distribution inside the enclosure and temperature differences with the outside ambient air.

8.0-5 Moon Light Shielding
SCI1111: The enclosure shall be designed, to the extent feasible, to shield the telescope and optics from direct moon light during observing.

8.0-6 Light Tight
SCI1112: The enclosure shall, to the extent practical, be sealed against light infiltration to allow instrument calibration to take place in the day with light sources mounted on the telescope at prime focus.

8.0-7 Service Access
SCI1113: The enclosure shall provide service access to the telescope and instrument areas in the structure.
9 Facility Infrastructure

9.0-1 Instrument Service
SCI1114: Facilities with class [TBD] clean lab space shall be provided on the summit for on-site final assembly, integration, installation, and routine service of science instruments and AO system components.

9.0-2 Instrument Storage
SCI1115: Dry storage space shall be provided at the observatory for the temporary storage of instruments and associated handling and support equipment. Storage space will be kept moderately clean but instruments will need covers, crates, etc. to keep clean.

9.0-3 Network Connections
SCI1116: Network connections shall be provided to support the specified Observing Modes and data transfer rates as required between the summit, sea-level facility, and user institutions.

10 Observing Support
Tools will be provided to assist staff and users in preparing and carrying out observing programs on GMT.

10.0-1 Phase I Proposal Tool
SCI1117: A web-based software tool shall be provided for preparing observing proposals.

10.0-2 Phase II Observing Plan Tool
SCI1118: Software tools shall be provided for preparing observing plans.

10.0-3 Observing Utilities
SCI1119: The GMT software systems shall provide tools to support the operation and observing modes of the telescope.

10.0-4 User Manuals/Guides
SCI1120: User guides and manuals shall be provided to assist users in planning and carrying out observing programs.
10.0- 5 Instrument Specialists
SCI1122: Instrument specialists shall be available at the observatory to assist GMT users.

10.0- 6 Telescope Operator
SCI1124: Telescope operator shall be available to operate the telescope.

10.0- 7 Logistics Support
SCI1125: The GMT Observatory shall provide logistics support to GMT users to coordinate travel and the shipment of equipment and supplies.

11 Data Products

11.1 Science Data

11.1- 1 Quick Look
SCI1126: “Quick look” data reduction software shall be provided for each facility instrument to allow near real time quality assessment of the science data.

11.1- 2 Data Formats
SCI1127: GMTO shall specify common data formats to capture a complete and transparent record of each observation and insure compatibility with the data archive and Virtual Astronomical Observatory (VAO) requirements.

11.1- 3 Data Pipeline
SCI1128: Each Facility Instrument shall be provided with a data pipe line for reducing the observations and archiving them in a standard format.

11.1- 4 Data Reduction
SCI1129: Observational data in the pipeline shall be reduced to remove the instrumental signature of the instrument, so that, at a minimum, data are flat-fielded, linearized, and wavelength calibrated.

11.1- 5 Data Archive
SCI1130: An archive with secure backup shall be provided for storing and retrieving science data acquired on GMT.
11.1-6 Archive Lifetime
SCI1131: The data archive shall be designed for the lifetime of the GMT Observatory.

11.1-7 Distribution
SCI1132: GMTO shall implement policies and procedures as approved by the GMTO Board for distributing data taken on the telescope including such items as access rights, proprietary periods, authorship of papers, formats, and support for distribution.

11.2 Engineering Data

11.2-1 Engineering Data
SCI1133: Subsystems critical to the functioning and performance of the GMT shall, wherever feasible, provide hardware and software controls for monitoring the health of the system and generating engineering data.

11.2-2 Engineering Data Management
SCI1134: An engineering data management system shall be provided to collect, store, retrieve and analyze engineering data.

11.2-3 Diagnostic Software
SCI1135: Software tools shall be provided for displaying instantaneous and long term trends in the performance of individual components/subsystems and to time correlate that information with data from other subsystems.