OPERATIONS CONCEPT DOCUMENT (OCD)

TMT.OPS.MGT.07.002.CCR07

2009 March 26th

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1 INTRODUCTION

This is the TMT Observatory Operations Concept Document (OCD). It is one of the three systems engineering level requirement documents, the others being the Observatory Requirements Document (ORD), and the Observatory Architecture Document (OAD).

The three documents are the project's response to the science requirements encapsulated in the Science Requirements Document (SRD). The requirements in these documents flow down to requirements for the observatory subsystems.

As necessary, new requirements implied by the current document flow down into:

- TMT Observatory Requirements Document (ORD)
- TMT Observatory Architecture Document (OAD)

Site-specific implementation plans to fulfill these operational concepts are described in the TMT Operations Plan (TOP).

The requirements in this document are numbered in the form [REQ-X-Y-Z], where the placeholders X, Y and Z denote the level of the requirement, the document the requirement is associated with, and a unique number for the requirement. This numbering scheme allows for unambiguous reference to requirements.

1.1 PURPOSE

This document shall be used as guidance for the top level engineering function and performance requirements of the observatory.

The requirements documented in the OCD and the ORD are intended to fully describe the top-level engineering requirements and operational concepts to satisfy the criteria of the Science Requirements Document, and by reference, the Science Case for the Observatory. By this definition, the OCD will change in response to changes in the SRD, but will not require modification when changes are made to the Observatory Requirements Document (ORD), Observatory Architecture Document (OAD), or to the Sub-System Requirements Documents.

The OCD shall also be used as guidance for the design and implementation of TMT operations processes and staffing plan.

1.2 SCOPE

This document contains high-level site-independent operations concepts and requirements in the following areas:

- General
- Science operations
- Technical operations (also known as engineering and technical services)

Science operations concepts are grouped into a minimum cost *baseline service* model and a more expensive *enhanced service* model. The latter model is sometimes known as the full-service or national-facility model.

It is expected that each major TMT sub-system (e.g. AO systems, instruments, enclosure, APS) will have a separate operation concept document that describes operations, calibration, and maintenance processes.

1.3 APPLICABLE DOCUMENTS

Applicable documents contain information that shall be applied in the current document. Examples are higher level requirements documents, standards, rules and regulations.

AD01	Science-based Requirements Document v15	TMT.PSC.DRD.05.001
AD02		

1.4 REFERENCE DOCUMENTS

Reference documents contain information complementing, explaining, detailing, or otherwise supporting the information included in the current document.

RD01	Proposed Additions to SRD V14.5 Operations Requirements (Januzzi & Jensen, November 2004)	TMT.PSC.DRD.05.002
RD02	Science Motivated Specifications for Switching of Instruments and Observing Modes for the TMT V2.0 (Jensen, September 2004)	TMT.PSC.TEC.05.004
RD03	TMT Science Operations Models (Silva, December 2006)	TMT.OPS.COR.06.008
RD04	TMT Operations Plan (Silva)	TMT.OPS.MGT.06.002
RD05	On Maximizing TMT Mean Available Science Time (MAST) (Silva)	TMT.OPS.COR.06.003

1.5 CHANGE RECORD

Version	Date	Remarks
CCR7	2009 March 26	Updates as per Level 1 DRD Change History Document TMT.SEN.TEC.07.038.REL05
CCR6	2007 May 25	First release under change control (no change since Draft 5)

1.6 ABBREVIATIONS AND ACRONYMS

AIV	Assembly, Integration, and Verification
AIVC	Assembly, Integration, Verification, and Commissioning
AO	Adaptive Optics
AoD	Astronomer-on-Duty
CM	Corrective Maintenance
CMMS	Computer Maintenance Management System
CoDR	Conceptual Design Review
CSV	Commissioning & Science Verification
DDT	Director's Discretionary Time
DLIRAOS	Diffraction-Limited Infrared Adaptive Optics System
ELT	Extremely Large Telescope
ESO	European Southern Observatory
FDR	Final Design Review
FTE	Full-Time Equivalent
GO	General Observer
GTO	Guaranteed Time Observation
HVAC	Heating, Ventilation, and Air Conditioning
HW	Hardware
IFU	Integral Field Unit
IQ	Image Quality
IR	Infrared
ISM	International Staff Member
ISO	International Standards Organization
IT	Information Technology
LRU	Line Replaceable Unit
LSM	Local Staff Member
LTQ	Long-Term Queue
LTS	Long-Term Schedule
MDT	Mean Down-Time
MIS	Management Information System
MTBF	Mean Time Between Failures
MTBM	Mean Time Between Maintenance
MTS	Medium-Term Schedule
MTTC	Mean Time To Complete
MTTR	Mean Time To Repair

MTTRS	Mean Time To Return (to) Service
MTTS	Mean Time To Service
NFIRAOS	Narrow Field Infrared Adaptive Optics System
NRC	National Research Council of Canada
NSF	National Science Foundation
OB	Observation Block
OAD	Observatory Architecture Document
OCD	Operations Concept Document
ORD	Observatory Requirements Document
PEL	Program Execution Likelihood
PDM	Program & Data Management
PDR	Preliminary Design Review
PM	Preventive Maintenance
PRC	Program Review Committee
PSR	Pre-Shipment Review
QC	Quality Control
RAID	Redundant Array of Independent Disks
SD	Science Demonstration
STS	Short-Term Schedule
SW	Software
TBC	To Be Confirmed
TMT	Thirty Meter Telescope
TBD	To Be Determined
UPS	Uninterruptible Power Supply
VLT	Very Large Telescope
VO	Virtual Observatory

1.7 GLOSSARY

Early operations shall be defined as the period that starts when the first non-technical facilities are accepted and continues until the observatory has reached steady-state operations.

Early science operations are expected to begin during the first 12 months after the M1 has been fully populated and phased for the first time.

Steady-state (science) operations shall be defined as the period that starts 36 (TBC) months after the M1 has been fully populated and phased for the first time. The intervening time shall be considered sufficient for tuning the performance and operational procedures to the level necessary to meet the requirements in this section.

Night-time shall be defined as the time between the end of evening nautical twilight and the beginning of morning nautical twilight. At these points, the center of the sun is 12 degrees below the horizon. For a northern Chilean site, this time interval corresponds to roughly 10 hours per 24-hour period in the mean.

1.8 VERB CONVENTION

Shall is used whenever a statement expresses a convention that is binding. The verbs *should* and *may* express non-mandatory provisions. *Will* is used to express a declaration of purpose on the part of the design activity.

1.9 ACKNOWLEDGEMENTS

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2 FLOWDOWN FROM SCIENCE REQUIREMENTS DOCUMENT

In this section, anything from SRD v15 that has operational implications and/or that is a starting point for concepts in this document has been extracted and written here.

Extracts from Science Requirement Document

Reference: TMT SRD v15 (TMT.PSC.DRD.05.001.REL15)

2.1.1 General considerations – Based on current scientific interest and technology limitations, initially the telescope is expected to be used roughly 50% of the time for seeing-limited observations and 50% of the time with diffraction-limited observations (using AO). AO with laser beacons is also likely to be compromised by cirrus clouds, so otherwise useful nights may not be available for AO. As AO capabilities come to fruition, this percentage may change.

2.1.2.4 Throughput – Telescope night-time lost to servicing mirrors should be minimized.

2.1.2.5 Backgrounds and stray light – Provisions should be made for frequent cleaning of the mirrors to preserve their low emissivity and high reflectivity. Actual cleaning frequency will depend on site characteristics, but is likely to exceed 1/month.

2.1.3.1 Slewing and acquiring – The telescope shall be able to move from any point in the sky to any other in less than 5 minutes, and be ready to begin observing. This time includes time needed to rotate the instrument, rotate the dome, acquire a guide star, and set up the ADC and AO system.

2.1.4.3 Rapid access – Require ability to observe with any instrument, at night, in <10 minutes

2.4.1 Overall efficiency of AO modes – The AO systems should be available on 10-minute notice. Down time should be under 1%. Night-time calibration should need no more than 1% of the observing time. Overhead or duty cycle goal is TBD.

SRD V15 has empty sections for data handling (data archiving, data reduction pipelines) and night-time operations models (queue scheduling models, instrument switching requirement, PI mode observations). Concepts and requirements for these issues are included in this document.

3 MOTIVATIONS: OPERATIONS SUCCESS METRICS

The development of TMT Observatory operational concepts shall be motivated by several key measurable metrics of success.

3.1 SCIENTIFIC SUCCESS METRICS

3.1.1 Primary metric: number of high-impact science papers

The primary metric of scientific impact shall be **the number of high-impact science papers per unit time.**

Conceptually, a high-impact paper contains transformational and/or unique scientific results. Quantitatively, high-impact papers lie in the upper 1% of all refereed papers ranked by number of citations.

The TMT Observatory shall endeavor to maximize the production of high-impact science papers based on data obtained with the TMT. This metric shall be evaluated per unit time (i.e. one year, TBC) and over the entire observatory lifetime.

3.1.2 Secondary metrics

Several other secondary metrics of scientific impact shall also be measured:

- The mean number of citations per refereed paper based on data obtained with the TMT, measured per unit time (i.e. one year, TBC) and over the entire observatory lifetime.
- The absolute number of papers published per year based on data obtained with the TMT.
- Citation decay rate as a function of time (a measure of impact longevity)

3.2 TECHNICAL SUCCESS METRICS

To maximize scientific success as measured by the metrics above, the TMT Observatory shall strive for technical excellence as measured by the following technical success metrics.

3.2.1 Number of unique observatory capabilities

High-impact papers often result from exploiting unique observatory capabilities. Such capabilities can lie in the areas of hardware (e.g. largest M1 collecting area, best science detectors), software (e.g. very efficient target acquisition system), or process (e.g. being the first of a new generation).

Conversely, it is well recognized that observatories that do not add new capabilities over time quickly become scientifically irrelevant, often limiting the overall scientific return on the original capital investment.

By design, the TMT Observatory shall be first in its class in many areas at the start of operations.

To maintain its lead in as many areas as possible within available funding, the TMT Observatory shall execute a vigorous development program during the operations phase. In particular, this program shall endeavor to provide the TMT Observatory with a steady flow of new and unique instruments and AO systems commensurate with the evolving ambitions of the TMT user community.

3.2.2 Number of science integration hours per unit time

As the number of science integration hours decreases, so does the potential for transformational observations.

The following metrics are directly related to the number of available science integration hours per unit time:

- Number of night time hours consumed by technical and process operational overheads
- Number of night time hours required for technical maintenance and performance tuning

- Number of night time hours required for commissioning of new observatory capabilities
- Number of night time hours required for instrument calibration
- Number of night time hours consumed by technical faults

These quantities must be minimized – by design as well as by an efficient operational process and a comprehensive maintenance program. More specific requirements and goals are discussed in Section 5 (Technical Operations).

3.2.3 System performance per unit time

As system performance degrades, so does the scientific grasp of TMT and hence its potential for transformational observations.

The following technical metrics are indirectly related to the number of available science integration hours per unit time:

- Delivered image quality during seeing-limited and AO-assisted observations
- Total system throughput (photons per second delivered to science detector)
- Total system background (photons per second delivered to the science detector)

These quantities must be optimized – by design as well as by a comprehensive monitoring and maintenance program. More specific requirements and goals are discussed in Section 5 (Technical Operations).

3.2.4 User process efficiency per unit time

It is well known that many things contribute to user process efficiency but it is difficult to quantify and measure their impact directly. These things include:

- User preparation prior to observing run
- Easy-to-use and complete user interfaces
- High-quality user documentation in all areas
- Well-documented, self-documented science data
- Well-designed data processing software with good user documentation (both at cookbook and details level)
- Efficient user helpdesk process that delivers rapid turnaround support

These issues are discussed in more detail in Section 5 (Science Operations).

4 GENERAL CONSIDERATIONS

4.1 ENVIRONMENT, SAFETY AND HEALTH (ES&H)

It is imperative that a comprehensive environment, safety and health (ES&H) program following international standards be implemented during all phases of TMT Construction and Operations.

[REQ-1-OCD-1000] The TMT ES&H program has the specific objectives to prevent personnel injury or loss of life during all phases of the TMT project and TMT operations; to prevent environmental contamination during the construction, shakedown or operation of TMT; to prevent damage to equipment caused by accidents during all phases of the project; to comply with all national, state and local laws, rules and regulations.

[REQ-1-OCD-1005] During operations, the TMT ES&H program is the responsibility of the TMT Director. The Director has responsibility to insure that the TMT staff members identify specific ES&H issues and risks, and establish appropriate safeguards and procedures for addressing those risks. To accomplish detailed ES&H planning, documentation and surveillance, a TMT ES&H Officer shall be appointed. The ES&H Officer shall be responsible for all ES&H program activities and report to the Director on matters pertaining to the ES&H program.

[REQ-1-OCD-1010] Service providers will conduct many parts of TMT operations. These service providers must implement their own ES&H policies and procedures that will be subject to review and audit by the ES&H Officer and TMT operations personnel.

[REQ-1-OCD-1015] Partner institutions manage their own safety programs. Activities at partner institutions will be governed by these programs. However, TMT systems must be designed and fabricated to safety standards established by the TMT Observatory.

[REQ-1-OCD-1020] TMT hazard analysis and safety practices will be governed by the following order of precedence:

- Design for Minimum Risk: The primary means for mitigation of risk shall be to eliminate the hazard through design.
- Incorporate Safety Devices: Fixed, automatic or other protective devices shall be used in conjunction with the design features to attain an acceptable level of risk. Provisions shall be made for periodic functional checks as applicable.
- Provide Warning Devices: When neither design nor safety items can effectively eliminate or reduce hazards, devices shall be used to detect the condition, and to produce an adequate warning to alert personnel of a hazard. Devices may include audible or visual alarms, permanent signs or movable placards.
- Procedures and Training: Where it is impractical to substantially eliminate or reduce the hazard or where the condition of the hazard indicates additional emphasis, special operating procedures and training shall be used.

4.2 ENVIRONMENTAL IMPACT MITIGATION

[REQ-1-OCD-1100] TMT Observatory operations shall be compliant with all local and national environmental regulations, as well as international standards (e.g. ISO 14000 family). Consistent with the spirit of this requirement, the TMT Observatory will remain mindful of the unique and high environmental and historical value, as well as sheer natural beauty, of its sites.

[REQ-1-OCD-1105] An environmental impact statement and protection plan shall be prepared as part of the site selection process. The TMT Director shall monitor the compliance with the protection plan after the TMT Construction is completed.

[REQ-1-OCD-1110] Efforts shall be made to minimize the physical and visual impact of TMT Observatory in its environs by, e.g. keeping the footprint of facilities as small as possible consistent with safe and efficient operations, driving on graded roads only, walking on graded paths for everyday activity, exercising proper care with waste disposal, architecture and finish of facilities, etc.

[REQ-1-OCD-1115] The TMT Observatory shall also take measures to minimize the emission of all electromagnetic radiation that might interfere with either itself or possible nearby future astronomical facilities. In particular, the emission of visible light shall be minimized from all TMT facilities within sight of the summit. Care will be taken to prevent laser guide star (LGS) operations from interfering unduly with neighboring astronomical facilities.

[REQ-1-OCD-1120] During Construction and Operations, the TMT Project and Observatory (respectively) shall take the necessary measures to minimize the amount of site damage that would be difficult and/or expensive to remedy once the Observatory is decommissioned at the end of its lifetime. For example, pumping hazardous waste into the ground for storage or disposal purposes shall not be allowed.

[REQ-1-OCD-1125] Consideration shall be given to the use of energy sources other than fossil fuel.

4.3 COMMUNITY RELATIONS

[REQ-1-OCD-1200] TMT shall conduct a community relations program with the following components:

- Education
- Public outreach
- Local community relations
- Host country relations (if located outside of USA)

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4.4 OBSERVATORY PHYSICAL INFRASTRUCTURE COMPONENTS

For reference purposes, site-independent descriptions of the observatory physical infrastructure are provided in this section. Site-specific implementation details are provided in the *TMT Operations Plan* [RD04].

4.4.1 Summit Facility

[REQ-1-OCD-1300] The Summit Facility (or just summit) is currently envisioned to be the telescope, enclosure, optics coating and storage facility and any other supporting infrastructure that must be co-located with those three major components. All potential sites will have the same set of facilities, although the exact physical layout will be site dependent.

Discussion: the design and construction of the TMT Summit Facility is a TMT Project deliverable.

4.4.2 Support Facility

[REQ-1-OCD-1305] TMT shall establish a support facility within a two (2) hour drive of the summit. This facility will host a variety of technical support services including warehousing, technical workshops, vehicle maintenance, etc. For the more remote sites in northern Chile, it will also host a large enough dormitory facility to sleep and feed up to 100 people per day. A number of offices will be provided for on-duty personnel required to be close to the summit but not necessarily required to work there every day (e.g. software engineers).

Discussion: the exact nature of the support facility depends on the actual site selected. The design and construction of the TMT Support Facility is a TMT Project deliverable.

4.4.3 Headquarters Facility

[REQ-1-OCD-1310] TMT shall have offices (hereafter known as the Headquarters Facility) for a variety for purposes including administration and business services, human resources management, local government interface management, and work space for TMT science operations staff performing off-site work.

[REQ-1-OCD-1315] The Headquarters Facility shall have a remote observing center.

[REQ-1-OCD-1320] The Headquarters Facility shall be located within the local host country and/or the host state (if TMT is located in the United States).

*Discussion: the TMT Headquarters Facility is **not** a TMT Project deliverable. Build, buy, or rent options should all be explored to find the most economically advantageous solution.*

4.4.4 TMT Operations Support Center

Discussion: as of December 2006, an operations support center is not considered to be part of the baseline TMT construction or operations plans.

*As a general principle, the number of staff whose work site is at or near the TMT Summit Facility should be minimized. Since four of the five TMT candidate sites are quite remote, the possibility of creating a TMT operations center in North America should be explored. Analogous to other projects (such as ALMA, Spitzer, or GALEX), this facility could also be called the **TMT Science Center**.*

Such a center could host a number of activities, including:

- *Remote observing center*
- *Administrative functions not needed near TMT or in the host country*
- *TMT instrumentation development office (see Section 6).*
- *Various science operations tasks, such as user support, data delivery and processing support, observation scheduling and execution support.*
- *Education and public outreach activities*

Given possible reductions in costs related to relocation, salary, and benefits, creating such a center could be quite cost effective. It also has significant psychological and socio-political value to have a highly visible TMT "face" in North America.

4.4.5 TMT Data Archive

Discussion: as of December 2006, a TMT data archive is not considered to be part of the baseline TMT construction or operations plans.

It can be argued that the science and engineering data produced by TMT will have a high enough value that they should be permanently archived. TMT has two options: build its own data center or form a partnership with an existing data center. Given the large amount of data center expertise that already exists within the TMT Partnership (e.g. at places like IPAC and CADC), the latter option seems more attractive and cost-effective at this time.

If a TMT Science Center is created, co-location with the Partner data center is an obvious scenario to explore.

5 SCIENCE OPERATIONS

5.1 BASELINE SERVICE MODEL

The baseline service model was discussed by the SAC in December 2006 and given their preliminary approval.

5.1.1 Time allocation

[REQ-1-OCD-2000] Proposal solicitation, review, and time allocation shall be executed by the various Partners supported by documentation and integration time calculation tools (TBD) provided by the Observatory. The amount of time that each Partner can allocate is TBD by the TMT Board.

Discussion: during the Construction phase, the TMT Observatory shall explore ways to make this process as efficient as possible for all parties through an appropriate, cost-effective, and mutually agreed upon use of information technology.

[REQ-1-OCD-2005] As required for individual instruments and AO systems, users must provide enough information to demonstrate that their observations are technically possible. In particular, a guide star list or a description for how to deal with the absence of known guide stars will be required.

[REQ-1-OCD-2010] Based on the output of the partner-based TAC processes, a master schedule shall be created and managed by the TMT Observatory. That schedule will be subject to some TBD review and approval process.

[REQ-1-OCD-2015] The TMT Board shall adopt TBD policies for Director's Discretionary Time (DDT) and observing time allocation for staff astronomers.

5.1.2 Observing modes

[REQ-1-OCD-2050] Only *classical observing* shall be supported. In this mode, individual users (or teams) are assigned specific blocks of time for their use. To maximize efficiency, the smallest block size shall be no shorter than one half night. During their assigned time, users can specify system configuration in near-real-time.

[REQ-1-OCD-2055] During early science operations, most users will be expected to travel to a TMT control center at or near the TMT summit facility.

[REQ-1-OCD-2060] During steady-state science operations, off-site classical observing (hereafter *remote observing)* support shall be provided under condition that only hardware and software systems certified by TMT shall be supported. It is expected that one or more remote observing rooms will be established by each TMT partner. Remote observing from random locations on the Internet shall not be supported except under truly exceptional circumstances.

Discussion: need to add concepts for target-of-opportunity handling (rapid response and normal) and time-domain investigation.

5.1.3 User support

[REQ-1-OCD-2100] During every night scheduled for general science operations, a support astronomer shall be on-duty. The support astronomer duty station shall vary depending on the exact situation but shall be one of the following: Summit Facility, Support Facility, or Headquarters.

[REQ-1-OCD-2105] The typical support astronomer work shift shall be 1500 – 2400 TMT local time. The primary duty of this support astronomer shall be to ensure that the TMT system is ready for operation, properly configured, and performing within nominal, published ranges. These tasks shall be conducted in partnership with the on-duty system operators. Secondary duties of the support astronomer shall include: help classical observer(s) prepare for their planned observations, acquire whatever calibration data is needed to monitor system performance, and review current system performance metrics.

[REQ-1-OCD-2110] Due to the complexity of the TMT system, two (2) system operators are required each night at the summit facility (at least in the early years). All system operators will be trained to operate the telescope, instrument, AO, and laser guide star systems. Their nominal work shift will be sunset to sunrise. However, it may prove more optimal to have one operator start earlier to perform pre-sunset startup and calibration procedures. This issue requires further analysis.

[REQ-1-OCD-2115] The TMT Observatory shall implement a Web portal for the purposes of organizing all information the observatory wishes to present to its user community. Links from this portal shall include:

- User-level documentation for (e.g.) instruments, AO systems, etc.
- Observation preparation support center
- System status report
- Site conditions report: current and forecast
- Site conditions statistics
- System quality control parameter statistics
- Sky almanac generator
- Help desk access

[REQ-1-OCD-2120] As deemed necessary after further operations requirements development, the TMT Web portal shall be the gateway to a myTMT area that contains information tailored to a specific user. Access to that area shall required user authentication.

[REQ-1-OCD-2125] The TMT Observatory shall develop and maintain an electronic user helpdesk with the primary goal of helping users prepare and execute observations. Assistance with data calibration problems will be handled on a best-effort basis. This helpdesk system shall include:

- A method for submitting questions to the TMT Observatory
- A system for managing and responding to questions submitted by users
- A Web-based, user-driven but staff monitored forum (discussion group) section
- A Frequently Asked Questions (FAQ) area

Discussion: it is anticipated that this helpdesk will have the format of an open forum message board with persistent message threads so that users can try to find and search old dialogues before asking (or re-asking) questions. Exact implementation details are TBD but are anticipated to involve inexpensive (or free) open source solutions widely available on the Internet.

[REQ-1-OCD-2130] For each instrument, the TMT Observatory shall provide the following items (as appropriate for a particular instrument/AO system combination):

- Instrument handbook (see discussion below)
- Integration time calculators for all major modes
- Instrument and/or AO system configuration tools as appropriate (e.g. multi-object mask definition tools)
- Guide star definition tools
- Data processing applications (TBD)

[REQ-1-OCD-2135] The TMT Observatory shall be responsible for keeping this documentation and these tools up-to-date as TMT systems evolve.

5.1.4 Instrument Handbook

[REQ-1-OCD-2200] All TMT instruments shall be delivered with an Instrument Handbook. These are handbooks for TMT users – they are not intended to be technical operation and maintenance manuals. Information about associated AO systems will be included as appropriate.

[REQ-1-OCD-2205] An initial draft of the instrument handbook shall be delivered at the time of the instrument PDR. Revised drafts shall be delivered at the time of instrument FDR and Pre-Shipment Review (PSR). It is expected that the handbook will be completed during the commissioning phase and then delivered to TMT. After that final delivery from the instrument team, the assigned TMT Instrument Scientist shall be responsible for reviewing and revising the handbook on a regular basis.

[REQ-1-OCD-2210] These handbooks shall contain information necessary for users to prepare observing proposals as well as to prepare and execute observations, including:

- An overview of instrument capabilities
- A technical description of the instrument
- A description of nominal performance (i.e. limiting magnitudes, etc.) for all major modes
- Descriptions of standard observation sequences and workflows
- Descriptions of available observing support tools (including user cookbooks as appropriate)
- An observing cookbook

[REQ-1-OCD-2215] These handbooks shall also contain the **instrument calibration plan**, consisting of the following information:

- A description of what calibration data to obtain and at what interval (with examples of valid calibration data)
- A description of how to remove the atmospheric, system, and instrument signatures from science observations using the calibration data described above (i.e. how to calibrate or process the data)

Discussion: fundamentally, this calibration plan information is required so that users can process their data into scientifically useful data products. However, this information is also crucial as guidance to the development of data reduction software (as discussed elsewhere in this document). Initial calibration plans shall be verified and revised during instrument commissioning.

[REQ-1-OCD-2220] Individual users may need to obtain additional calibration data. If so, they must request sufficient time for these calibrations as part of their original observing proposal. Time required to obtain such additional calibration data will be charged to the relevant users. However, as with standard calibration data, these additional calibration data shall be considered public information.

[REQ-1-OCD-2225] Instrument handbooks shall also contain a description of **quality control parameters** (e.g. readnoise, photometric zeropoint, fixed dark current patterns, spectral/spatial resolution, etc.) that shall be measured to establish and monitor system performance. These descriptions shall include prescriptions for what data are needed to measure each parameter and what equation (algorithm) is used to measure the parameter as well as when and how often each parameter shall be measured. It is anticipated that many of these measurements can be made based on data obtained during the day. Measuring QC parameters shall be the foundation of the system performance monitoring process described below.

5.1.5 User interfaces

[REQ-1-OCD-2250] User interfaces shall be developed for the following user classes:

- **System operator** – any on-duty TMT staff person who is responsible for controlling and monitoring the TMT Observatory system on behalf of other system users (e.g. visiting scientists, technical teams, etc.)

- **Classical (on-site) observer** – anyone executing science observations and/or acquiring associated calibration data in near-real-time while physically present at a TMT Observatory facility
- **Remote (off-site) observer** – anyone executing science observations and/or acquiring associated calibration data in near-real-time while physically present at a TMT Observatory approved remote observing facility

[REQ-1-OCD-2255] Graphical user interfaces (GUIs) shall be the default interface for all normal scientific and technical operations. All high-level interfaces shall have the same look-and-feel.

[REQ-1-OCD-2260] It shall be a high-level goal to keep all operator and observer interfaces as simple as possible. In particular, the number of windows (widgets) that must be accessed must be minimized.

[REQ-1-OCD-2265] In the default mode, observers shall only enter high-level observation description parameters (e.g. target/field coordinates, instrument configuration, desired dither patterns, etc). Such descriptions shall be tailored to each major mode of every science instruments.

[REQ-1-OCD-2270] Observers shall not be able to modify low-level technical settings (e.g. dome ventilation configuration, detector voltages, AO system control parameters, etc).

[REQ-1-OCD-2275] The TMT target acquisition sequence shall be highly automated to maximize efficiency and satisfy the 5-minute requirement established by the TMT SRD [AD01]. Automated target acquisition sequences shall be tailored to the each major mode of every TMT science instrument.

[REQ-1-OCD-2280] For the purposes of proposal and observation preparation, the following tools shall be provided:

- Instrument simulators (TBC)
- Exposure time calculators (including overheads)
- Multi-object mask definition tool (as needed)
- AO simulator support (as needed)

[REQ-1-OCD-2285] The system operator shall be provided with a master alarm monitor that shows TMT sub-system status in a clear manner. The minimal solution shall be a screen showing a red (alarm) or green (operational) bar for each major sub-system.

5.1.6 System performance monitoring

Discussion: this is sometimes called data quality assurance.

[REQ-1-OCD-2300] The TMT Observatory shall monitor system performance for the following purposes:

- To provide regular reports to future users for planning purposes and previous users for analysis purposes
- To detect sudden changes in performance to enable timely corrective actions
- To detect gradual changes in performance to enable timely corrective actions

[REQ-1-OCD-2305] System performance information shall be updated regularly (daily when appropriate, TBD) and made publicly available through the TMT Web portal.

Discussion: a more detailed discussion can be found in Section 6.3 (System Performance Monitoring Requirements).

5.1.7 Data management

[REQ-1-OCD-2350] All TMT science instruments shall produce data with the meta-data necessary for later organization (“find all science data associated with this science observation”), classification (“identify the type of science data, e.g. environmental conditions, instrument, instrument mode, etc.”), and association (“identify calibration data and processing algorithm needed to process these science data”).

[REQ-1-OCD-2355] All TMT science instruments shall produce data and meta-data compliant with the then-current FITS and Virtual Observatory standards. Meta-data information shall include:

- Information about observing program
- Target information
- System configuration at time of observation (telescope, AO system, instrument, detector)
- Environmental conditions at time of observation

Discussion: more precise meta-data requirements are still TBD.

[REQ-1-OCD-2360] All science data produced by TMT shall be captured and stored indefinitely.

Discussion: science data volume is expected to grow by about 150 TB per year (see Appendix A.3).

[REQ-1-OCD-2365] The TMT Observatory shall not maintain a long-term (“permanent”) science data archive, either independently or in partnership with an existing data center. Data produced by TMT shall have sufficient meta-data that a long-term data archive can be implemented later as desire and resources permit.

[REQ-1-OCD-2370] All TMT sub-systems (including instruments) are required to produce TBD status and diagnostic telemetry for the purposes of performance monitoring and failure analysis. A TBD subset of these data shall be captured and stored locally for at least one (1) year. This subset shall include both low-level (e.g. hydrostatic bearing pressures) and high-level (e.g. delivered image quality) information. Two copies shall be maintained with enough physical separation that one copy will survive in the event of a local catastrophe (e.g. fire). Survival requirements related to major earthquake survival are still TBD. The merits and costs of a permanent off-site copy shall be analyzed during the design phase.

[REQ-1-OCD-2375] It shall be possible to capture and store short (up to one minute, TBC) duration bursts of high-bandwidth (up to 200 Hz, TBC) engineering telemetry data.

[REQ-1-OCD-2380] The engineering data archive shall be implemented in such a way that information can be found and extracted quickly. All information shall be time-stamped with high enough precision to allow accurate cross-referencing of parameters. Tools shall be provided for the efficient search, retrieval, and analysis. It is desirable that such tools be Web-based to allow their use from any Internet location after user authentication.

[REQ-1-OCD-2385] The TMT Observatory shall reserve the right to access and review all scientific and technical data submitted to or generated by the TMT system. Such reviews shall be necessary as needed to monitor system performance and/or diagnosis system problems.

5.1.8 Data processing

[REQ-1-OCD-2400] The TMT Observatory shall not process science and/or calibration data on a regular basis to a level suitable for scientific analysis.

[REQ-1-OCD-2405] Science and/or calibration data obtained at the TMT Observatory shall be processed for the following reasons:

- To confirm target acquisition before observation begins
- To assess data quality (e.g. signal-to-noise ratio, delivered image quality in science instrument focal plane) during observation and as part of observatory system performance monitoring program.
- To remove the atmospheric, system, PSF, and instrument signatures before science analysis can begin

[REQ-1-OCD-2410] Each instrument development team shall deliver data processing software modules (not pipelines) that satisfy all above cases in a manner appropriate for their instrument

[REQ-1-OCD-2415] These modules shall be aligned with the calibration plan and data processing cookbooks provided in each instrument handbook. These modules shall be granular enough that they can be reused in a variety of applications.

[REQ-1-OCD-2420] The performance and accuracy of these modules shall be verified during instrument commissioning and then delivered to the TMT Observatory.

[REQ-1-OCD-2425] Based on these delivered software modules, quick-look pipelines shall be developed as needed and resources permit to support target acquisition and on-line (quick-look) data quality assessment. More detailed requirements and use cases are TBD.

[REQ-1-OCD-2430] Data visualization requirements for operators and observers are TBD.

Discussion: examples of pre-analysis, instrument-dependent, science-independent processing steps include:

- *Dark correction*
- *Bias correction*
- *Pixel-to-pixel response ("flat-field") correction*
- *Non-linearity correction*
- *Wavelength dispersion determination (and possibly correction)*
- *Fringe correction*
- *Cosmic ray removal*
- *Extraction of individual spectra from IFU frames*
- *Reconstruction of IFU image*
- *Extraction of two-dimensional spectrograms from MOS frames*

Science-dependent data processing shall be the responsibility of the TMT user community. Examples of such data processing steps include:

- *Extraction of one-dimensional spectra from two-dimensional data*
- *Aperture definition for photometry or spectro-photometry*
- *Object classification*
- *Spectral line equivalent width measurements*

5.1.9 Site monitoring and weather forecasting

[REQ-1-OCD-2500] A site condition monitoring system shall be installed and maintained. For more details, see Section 6.3.6.

[REQ-1-OCD-2505] The development of TMT specific weather forecasting tools is **not** anticipated as publicly available weather service and satellite imagery are expected to be sufficient for the currently foreseen needs of the observatory.

5.2 ENHANCED SERVICE MODEL

Discussion: this entire section still needs significant cleanup.

As enhancements to the baseline services described above, more sophisticated services shall be added as desire, time, and budget allow. A complete set of such services is often called the *full-service*, *end-to-end*, *Gemini/VLT/HST style*, or *national facility* model.

Modular implementation of enhanced services within a coherent end-to-end architecture shall be a high-level design requirement. By implication, care shall be taking during the TMT design and implementation stages to provide the "hooks" need to implement basic and enhanced services within a common framework.

5.2.1 Time allocation

[REQ-1-OCD-2550] To support enhanced services, the time allocation process must:

- Capture relative scientific ranking within partner communities
- Capture TBD additional program description information

[REQ-1-OCD-2555] To support enhanced services, the observatory scheduling process must manage and track assignment of nights to specific activities and assignment of time to targets at specific celestial coordinates.

Discussion: for effective queue observing, it is important not to allocate too much time to the same location on the sky (e.g. the Hubble Deep Field North or South).

5.2.2 Observing modes

[REQ-1-OCD-2600] To optimize the match between varying atmospheric conditions and science observations, the TMT Observatory shall support *queue observing*. In this mode, observatory staff shall execute observations based on well-defined execution sequences created remotely by the TMT scientific and technical user community well in advance of execution.

[REQ-1-OCD-2605] Queue observations shall be executed via a dynamic scheduling process designed to ensure a high degree of completion for the highest ranked science proposals as well as to maximize the overall scientific return. To this end, the goal will be to execute the observation with highest scientific rank that matches the current atmospheric conditions and system configuration.

[REQ-1-OCD-2610] All other things being equal, programs closer to completion shall be given priority.

[REQ-1-OCD-2615] Queue observing time shall be allocated in hours and shall be over-subscribed to ensure a continuous supply of observations to execute.

[REQ-1-OCD-2620] The description of an individual, potential queue observation shall be known as an *observation block* (OB). Each OB will contain all the information necessary to configure the TMT system for observation execution, e.g. target coordinates, requested guide stars, instrument configuration, etc. Each OB also contains all the user-specified information necessary for scheduling, i.e. atmospheric conditions, lunar phase, time-window restrictions, etc.

[REQ-1-OCD-2625] When submitted to the observatory, each OB shall be verified to be executable and compliant with standard TMT procedures using a TBD combination of automated tools and manual review. Users will be allowed to modify unexecuted OBs. A complete OB description and lifecycle shall be described in a different document.

Discussion: queue observing process model (schematic):

- *User submits observing proposal*
- *Proposal reviewed – accepted or rejected*
- *Accepted projects submit observation blocks and associated supporting material (e.g. mask descriptions).*
- *Descriptions are reviewed and validated by staff (with software support). Iterate with users as necessary to resolve problems.*
- *Validated observation descriptions are accepted into the queue for possible execution.*

- *Based on scientific ranking, system configuration required, and current observations conditions, validated observation descriptions are selected from the queue for execution. If a problem occurs during execution, users are contacted.*
- *Assess data quality. If problem detected, decide whether or not to repeat observation.*
- *Deliver data to user.*

Requirements for productive and efficient queue observing:

- *Personnel trained in efficient use of instrument (mostly in regard to target acquistition)*
- *Personnel to support queue observers during observation preparation*
- *Personnel to perform data quality assurance and data management*
- *Stable system (telescope, instruments, tools) under configuration control*
- *Instrument calibration plans*
- *Data quality assurance process and tools*
- *Data capture, description, and delivery process and tools*
- *Software tools for:*
    - *Observation planning (e.g. exposure time calculators)*
    - *Observation description and submission*
    - *Observation description validation*
    - *Observation management and execution*

These requirements shall be further elucidated in a later version of this document.

[REQ-1-OCD-2630] Per the discussion of classical observing above, it is already assumed that one (1) staff scientist will be present per night to assist users. If queue observing nights are scheduled, the staff scientist on duty executes observations from the queue rather than supports an on-site user.

5.2.3 User Support

[REQ-1-OCD-2700] In addition to the baseline user support services, the following additional direct and indirect support services will be needed as follows:

- Provide user support during observation preparation
- Review and validate submitted observation descriptions
- Provide user support for execution problem analysis and resolution
- Execute data quality assurance process
- Execute enhanced calibration data acquisition process (see below)
- Deliver data to users.

[REQ-1-OCD-2705] The TMT science operations staff shall be large enough to support the additional workload associated with an efficient queue observing program. A complete analysis of the staffing plan necessary to support queue observing shall be provide in the *TMT Operations Plan (TOP)* [RD04].

5.2.4 Instrument Handbook

Discussion: this section will contain queue observing specific updates to the handbook requirements.

5.2.5 User interfaces

[REQ-1-OCD-2800] It is desirable that all user observing tools have same or similar user interfaces to maximize user efficiency.

Discussion: in a later version of this document, requirements and additional discussion will be provided about proposal preparation, observation preparation, and queue management tools.

5.2.6 System performance monitoring

Discussion: at this time, no additions relative to baseline model are anticipated.

5.2.7 Data management

[REQ-1-OCD-2900] All TMT science observations shall be systematically archived with TBD sufficient meta-data.

[REQ-1-OCD-2905] The TMT Observatory shall ensure that enough calibration data is obtained to met TBD *minimal* standards for data calibration in the context of a scientifically useful archive. These *minimal* calibration datasets may or may not be sufficient for some (or many) individual science programs. It shall be the responsibility of the individual users (or teams) to review the on-going calibration program and decide whether or not to obtain additional calibration data tailored to their specific needs as part of their own observing programs.

[REQ-1-OCD-2910] Rather than build an independent data center, the TMT Observatory shall form a partnership with an existing data center to store TMT data permanently. With this partner, TMT will define data structures and meta-data content that will allow data archiving and (eventually) service to Virtual Observatory.

[REQ-1-OCD-2915] All archive data shall be accessible to the worldwide community after the expiration of a proprietary period of 12 months [TBC] from the delivery to the PI. The TMT Director may grant extensions to this period if well justified on scientific grounds.

5.2.8 Data processing

[REQ-1-OCD-2950] The TMT Observatory shall take the data processing modules (typically) produced by instrument development teams and create observatory-based data processing pipelines[1]. These pipelines shall be used for quick-look reductions during observing, system performance monitoring, and (where useful) calibrated science products.

Discussion: successful implementation of such pipelines requires both software tools and a controlled operational process.[2]

5.2.9 Site monitoring and weather forecasting

Discussion: no additions relative to Baseline Service Model anticipated.

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[1] A **pipeline** is simply a set of data processing modules strung together and run with a situation dependent set of input parameters and datasets. It is common practice for users to build their own pipelines using some scripting language (e.g. shell code, Python, IDL macros).

[2] For a more complete discussion, see Silva & Peron (2004): http://www.eso.org/observing/dfo/quality/publ/Messenger/pipelines-mess118.pdf

6 TECHNICAL OPERATIONS

6.1 SYSTEM MAINTAINABILITY REQUIREMENTS

6.1.1 General

[REQ-1-OCD-3000] All TMT sub-systems shall be designed for maintainability, including use of standard components where possible, standardization on metric hardware, etc.

[REQ-1-OCD-3005] All TMT sub-systems shall be delivered with maintenance manuals, as-built drawings and comprehensive component parts lists.

[REQ-1-OCD-3010] In cases where sub-system components are custom fabricated, operational spares should be produced when the original components are fabricated, if appropriate.

6.1.2 Maintenance activity support systems requirements

[REQ-1-OCD-3015] In support of all maintenance activity, the TMT Observatory shall implement the following systems:

- Comprehensive problem reporting, tracking, and management system
- Work order driven preventive maintenance support system (usually known as CMMS for Computerized Maintenance Management System).
- Warehouse inventory and property control
- Document control center

[REQ-1-OCD-3020] For the purposes of monitoring technical performance, a TBD set of automatic reports based on engineering telemetry shall be generated on a daily basis. More detailed requirements are TBD.

6.2 SYSTEM AVAILABILITY AND OPERATIONAL EFFICIENCY REQUIREMENTS

Maximizing the number of night-time hours available for science observations during steady-state operations shall be a high-level technical performance requirement for the TMT Observatory.

6.2.1 Target acquisition and system configuration efficiency requirements

[REQ-1-OCD-3020] During steady-state science operations, the *TMT Science Requirements Document* [AD01] has established a science observation execution transition time requirement of at most five (5) minutes (without intervening calibration observations). Up to an additional five (5) minutes is allowed if moving the telescope beam to a different instrument is included.

[REQ-1-OCD-3025] To meet this transition time requirement, the TMT Observatory shall develop a target acquisition and system configuration process that satisfies the SRD requirement. This system shall be capable of achieving the SRD goal during classical and queue (TBC) operations.

[REQ-1-OCD-3030] For design and planning purposes, the TMT Project (and later TMT Observatory) shall develop a system-wide budget for target acquisition and system configuration during steady-state science operations.

6.2.2 Calibration efficiency requirements

[REQ-1-OCD-3035] During steady-state science operations, the amount of night time needed for acquiring calibration data shall be minimized.

T[REQ-1-OCD-3045] To meet the above requirement, care shall be taken during design and implementation to allow as many day time calibration activities as possible. In particular, attention shall be given to making instruments mechanically rigid so that calibration data taken during the day can be applied to science observations acquired at night.

[REQ-1-OCD-3050] Whenever possible, astronomical observations required for calibration purposes shall be executed between sunset and the end of nautical twilight.

Comment (L. Stepp, Feb 2007): (paraphrase) we may wish to establish guidelines for duration of day time calibrations in relation to the mean amount of technical work that is required per day and/or establish that such calibrations will not interfere with such technical work.

6.2.3 Scheduled system maintenance and performance tuning requirements

[REQ-1-OCD-3055] During steady-state operations, the TMT Observatory shall schedule no more than the equivalent of 24 (TBC) nights (240 hours assuming 10 hours per night in the mean) per 365-day year for scheduled system maintenance and performance tuning activities. Such activities include:

- M1 segment exchange activities (including telescope optics phasing and aligning).
- M2 and M3 re-coating events.
- Observation of astronomical objects for the purposes of revising pointing models, control system look-up tables, and active and/or adaptive system performance tuning.

Discussion: many such activities will not require using the entire night.

[REQ-1-OCD-3060] For tracking and analysis purposes, the TMT Observatory shall record descriptions and time required for all technical activity and provide a summary to the TMT Board at yearly intervals.

[REQ-1-OCD-3065] The requirement on scheduled night-time system maintenance and performance tuning activity does **not** include time for the integration and commissioning of new system capabilities (e.g. a new instrument, new process, etc).

[REQ-1-OCD-3070] For design and planning purposes, the TMT Project (and later TMT Observatory) shall develop a system-wide budget for night-time scheduled system maintenance and performance tuning activities.

[REQ-1-OCD-3075] Many system maintenance and performance tuning activities will require work during the daytime. For design and planning purposes, the TMT Project (and later TMT Observatory) shall develop a system-wide budget for daytime scheduled system maintenance and performance tuning activities including instrument calibration and preparations for night-time science operations.

6.2.4 Scheduled instrument commissioning time

[REQ-1-OCD-3080] In steady-state operations, the TMT Observatory shall schedule no more than 15 nights (TBC) per year for instrument commissioning. This assumes no more than one (1) new major instrument per year.

Discussion: at current observatories, most major instruments require 2 – 3 multi-night runs to reach truly operational status.

6.2.5 Unscheduled technical downtime requirements

[REQ-1-OCD-3085] In steady-state operations, the TMT Observatory shall have no more than 3% (TBC) unscheduled technical downtime between the end of evening nautical twilight and the start of morning nautical twilight during hours scheduled for science operations.

Discussion: if 320 nights (3200 hours) per year are scheduled for science operations, this requirement corresponds to 9.6 nights per year or 18 minutes per night.

[REQ-1-OCD-3090] All instruments declared to be operational are expected to have technical downtimes commensurate with the above system level requirement. The system level requirement is not met if one or more operational instruments are offline due to unscheduled technical problems.

Discussion: not all instruments will be declared operational every night. In particular, some maintenance procedures will require taking instruments off-line. Scheduled downtime will be publicly announced and taken into account when the observatory science operations schedule is constructed.

[REQ-1-OCD-3100] The TMT Observatory shall implement and maintain a comprehensive system-wide *predictive maintenance* program based on regular inspection and/or condition monitoring of all major sub-systems including enclosure, telescope, adaptive optics, and instrumentation. The goal is to detect and correct performance degradation and/or potential failures before these problems cause lost science time or significantly reduce system efficiency.

[REQ-1-OCD-3105] The TMT Observatory shall implement and maintain a comprehensive system-wide *preventive maintenance* program based on vendor recommendation. This program shall cover all major technical sub-systems including enclosure, telescope, adaptive optics, and instrumentation. The goal is to maintain system efficiency within specified ranges and maximize the time between failures.

[REQ-1-OCD-3110] The TMT Observatory shall maintain an on-site or near-site technical team (with associated technical infrastructure) to react to problems quickly. In general, it shall not be necessary to remove sub-systems from the observatory site for repair at off-site facilities.

[REQ-1-OCD-3115] During steady-state operations, the TMT Observatory shall not maintain an on-duty, night-time technical problem rapid reaction team. Key personnel may be placed on-call to respond to technical problems at the discretion of the TMT Director.

[REQ-1-OCD-3120] For tracking and analysis purposes, the TMT Observatory shall record the descriptions and time required to recover from each event. A summary of all such activity shall be provided to the TMT Board at yearly intervals.

6.2.6 Instrument availability

[REQ-1-OCD-3125] The TMT Observatory shall endeavor to keep at least four (4) science instruments (and their associated AO systems) operational within nominal and published performance ranges at all times so that any instrument can be used for science observations within 10 minutes.

Discussion: by design, all TMT science instruments shall be mounted on the telescope for long durations

Discussion: in practice, each instrument and associated AO system shall require scheduled downtime for maintenance at regular intervals.

[REQ-1-OCD-3130] TMT shall implement predictive and preventive maintenance plans for each instrument supported by adequate on-site staffing and equipment. By implication, it may be necessary to increment staff size for each new instrument. The necessity and magnitude of such an increment requirements are TBD and require further analysis.

[REQ-1-OCD-3135] It shall be possible to obtain simultaneous daytime calibrations for all operational instruments with independent light paths without interfering with each other. In the event that instruments share (e.g.) calibration units, it shall still be possible to obtain internal calibrations (e.g. detector bias frames) simultaneously from all instruments.

6.3 SYSTEM PERFORMANCE MONITORING REQUIREMENTS

It is not enough to maximize TMT Observatory availability – it is also required to monitor and maintain system performance in areas critical for science observations.

6.3.1 General requirements

[REQ-1-OCD-3140] TMT Observatory staff personnel shall monitor system and instrument performance on a regular (daily where appropriate) basis with the goal of detecting sudden as well as gradual performance changes. The primary activity shall be to measure and record the quality control parameters specified in the instrument handbook(s).

Discussion: sudden changes should be obvious – detecting long-term changes will require monitoring performance as a function of time.

[REQ-1-OCD-3145] The numeric output of this process shall be made available to all TMT staff and users via a Web interface. Minimal information to be provided includes the most recent measurements and the time series for the last month. It is desirable to provide an interface that allows staff and users to browse the QC database and plot any X against any Y (organized by time).

[REQ-1-OCD-3150] TMT Observatory staff personnel shall also monitor performance-related engineering parameters such as residual errors in segment edge sensors, current demand by major motors, internal temperatures of instruments, etc. For a TBD set of such parameters, normal ranges shall be defined. System operators shall be notified when these normal ranges are exceeded.

6.3.2 Instrument and AO system monitoring requirements

[REQ-1-OCD-3155] The TMT Observatory shall obtain a limited set of calibration data on a regular (daily where appropriate) basis for the purposes of instrument and AO system performance requirements. In general, these calibration data shall not be sufficient for the processing of all scientific observations or the creation of a science archive facility useful for a broad community.

I[REQ-1-OCD-3160]. It shall be the responsibility of individual users to ensure that calibration data appropriate and sufficient for their science observations are obtained.

Discussion: the following list is an example minimum calibration dataset:

- *Two (2) observations of photometric or spectrophotometric standard stars, one at start and one at end of night.*
- *Bias or dark frames (for optical or infrared detectors)*
- *Flat fields (as necessary depending on instrument configuration)*
- *Arc lamps (as necessary depending on observations from the night before)*
- *Reconstructed PSFs (as necessary for specific AO observations)*

[REQ-1-OCD-3165] Observations of astronomical objects necessary for performance monitoring shall not be charged to individual users. As much as possible, such observations will be limited to nautical twilight at the beginning and ending of each night.

[REQ-1-OCD-3170] These standard calibration data shall have no proprietary period and will be available to all users.

[REQ-1-OCD-3175] For the purposes of instrument configuration and calibration, it shall be possible to operate multiple instruments in parallel

6.3.3 Image quality monitoring

Discussion: the TMT Science Requirements Document [AD01] establishes various quantitative image quality requirements.

[REQ-1-OCD-3180] The TMT Observatory shall establish procedures for monitoring natural seeing external to the TMT enclosure. To that end, monitoring equipment shall be setup on the TMT summit, in both upwind and downwind locations (see Section 6.2.6).

[REQ-1-OCD-3185] The TMT Observatory shall establish procedures for monitoring delivered image quality in focal plane of the science instruments as well as at other TBD locations related to wave front sensors and guiding units. Image quality measurements shall be made on a daily basis and stored on a long-term basis.

[REQ-1-OCD-3190] It shall be possible to compare natural seeing and image quality measurements in an efficient and timely manner. To this end, all measurements shall be time-tagged in a similar manner and stored in the same TBD database.

[REQ-1-OCD-3200] Baseline image quality performance shall be established during TMT integration and verification.

[REQ-1-OCD-3205] Comparisons between natural seeing and image quality shall be assessed for unusual instantaneous deviations as well as for long-term trends. When either case of deviation emerges, the TMT Observatory shall take whatever measures are necessary to analyze the situation and return the system to nominal performance as quickly as possible.

Discussion: details of measurements and measurement intervals are TBD.

6.3.4 Telescope throughput requirements

Discussion: the TMT Science Requirements Document [AD01] has established requirements for total system reflectivity and emissivity.

[REQ-1-OCD-3210] During steady-state operations, the TMT Observatory shall not allow the actual mean net reflectivity to degrade by more than 10% (TBC) (in a relative sense) from the best-possible mean net reflectivity at any wavelength longer than XX microns. At shorter wavelengths, net reflectivity is allowed to degrade by up to 20% (TBC) (in a relative sense).

[REQ-1-OCD-3215] The TMT Observatory shall establish procedures to CO2 clean M1, M2, and M3 at TBD intervals (expected to be weekly or bi-weekly).

[REQ-1-OCD-3220] The interval between M2 and M3 recoating events shall be no less than 24 months (TBC), i.e. it shall be possible to met the mean net reflectivity requirement for at least 24 months based on M2 and M3 considerations alone. During the design phase, consideration shall be given to allowing M2 and M3 recoating to be completed within the same TBC window (goal: 5 days maximum).

Discussion: the M1 segment recoating and exchange cycle shall be driven by the following requirements:

- *Maximum allowed number of nights per year for scheduled maintenance (stated above).*
- *Maximum allowable degraded mean net reflectivity requirement (stated above).*
- *The dispersion in M1 segment reflectivity measured over all segments shall be less than TBD (to be established relative to overall requirements for high-contrast imaging using extreme adaptive optics techniques).*

6.3.5 System throughput monitoring

[REQ-1-OCD-3225] The TMT Observatory shall establish procedures for monitoring instrument mode specific total system (first optical surface to science detector) throughput (photons/sec). Appropriate measurements shall be made regularly (in some cases daily and/or nightly). Details of measurements and measurement intervals are TBD and shall be described in the individual instrument handbooks (see above).

Discussion: instrument mode specific performance shall be determined during the instrument commissioning phase.

[REQ-1-OCD-3230] During operations, system throughput measurements shall be reviewed daily for both instantaneous changes as well as long-term (e.g. last 3 months) trends.

[REQ-1-OCD-3235] When system throughput degradation is detected, the TMT Observatory shall take measures to identify the cause for this performance loss and make timely efforts to return the system to its baseline performance.

[REQ-1-OCD-3240] For design and planning purposes, it is suggested that the TMT Project (and later TMT Observatory) develop a system throughput budget for each instrument mode.

6.3.6 Site conditions monitoring

[REQ-1-OCD-3245] TMT shall monitor and record external site conditions from at least one position on the summit.

[REQ-1-OCD-3250] Site monitoring equipment shall be based on the current TMT site characterization equipment and measure such things as air temperature, wind speed, wind direction, etc. Instruments shall include: DIMM/MAST seeing monitor, IR cloud monitor ("all-sky camera"), and PWV monitor. A complete equipment inventory is TBD.

[REQ-1-OCD-3255] AO systems and on-board wavefront sensors shall provide TBD supplementary information about atmospheric conditions.

[REQ-1-OCD-3260] Site conditions data shall:

- Made available to the TMT system operators immediately (i.e. in near-real-time).
- Made available immediately to the community at large via the TMT Web portal.
- Stored permanently.

6.4 INSTRUMENT OPERATIONAL SUPPORT CONCEPTS

Discussion: the term instrument is used in the rest of this section for any integrated telescope+AO+instrument package used for scientific observations.

[REQ-1-OCD-3265] When an instrument development or upgrade project is initiated, an observatory-based instrument scientist shall be assigned to the project. This scientist represents the interests of observatory operations during the design, implementation, integration, and commissioning process.

[REQ-1-OCD-3270] Near the end of the implementation phase, a pre-shipment review (PSR) shall be held. This review should not be held until a successful outcome is foreseen. During this review, the instrument team shall demonstrate to the satisfaction of TMT operations staff that the instrument is technically ready to be packed and shipped to the observatory. The exact shipment decision criteria are instrument dependent and TBD but the generic goal is to fix all known technical problems before shipment.

[REQ-1-OCD-3275] When a new instrument arrives at the observatory, it is uncrated, assembled, and installed on the assigned TMT Nasmyth platform. TMT staff personnel shall execute this activity under the guidance of the instrument team. This phase is completed when basic electro-opto-mechanical integration has been completed and basic instrument control has been achieved.

[REQ-1-OCD-3280] The next phase is instrument commissioning. Ideally, this phase ends when all technical problems have been resolved, all instrument modes have been demonstrated to meet their technical requirements, all software tools and interfaces are complete and robust, all documentation has been completed, and the instrument is ready for scientific use by the general user community. At the start of this phase, instrument commissioning activity is executed by the instrument team with support from and participation of TMT personnel, especially the assigned Instrument Scientist. Through some TBD transition process, TMT staff personnel assume more and more commissioning responsibility as time progresses.

[REQ-1-OCD-3285] During the science operations phase, TMT has full responsibility for instrument maintenance and upgrades. As desired and appropriate, TMT may consult with the original instrument team in these matters. The assigned instrument scientist is responsible for monitoring and improving (as necessary and possible) instrument technical performance and operational efficiency.

6.5 SYSTEM INTERFACE REQUIREMENTS

Discussion: this section is intended to provide high-level guidance for developing and maintaining technical interfaces.

TO BE COMPLETED

6.5.1 Technical interface requirements

[REQ-1-OCD-3290] Technical interface requirements must be developed, including:

- Motion control (and controller) interface
- Command/control interface
- Data transport and archiving system interfaces
- Physical connectors
- Cabling
- Basic services for instruments (e.g. power, signal, coolant,…)
- Basic performance constraints for instruments (e.g. mass, heat dissipation in enclosure, vibration…)
- Future proofing

Discussion: many of these issues have software interface and communications implications.

6.5.2 Data interface requirements

[REQ-1-OCD-3300] TMT shall establish a data interface requirements to promote the standardization and configuration control of various data structures, including:

- All scientific and technical data products to be stored (temporarily or permanently)
- All scientific and technical data products to be delivered to the astronomical community
- All data structures used for inter-process communication including configuration, alarms, events, and status
- All data structures used to described requested observations

[REQ-1-OCD-3305] The data interface definitions shall cover data and file formats, naming conventions, meanings and physical units where applicable. Examples include, but are not limited to: FITS headers, data structures, XML structures, and instrument configuration descriptions.

[REQ-1-OCD-3310] Where applicable, TMT data structures shall be compatible with emerging Virtual Observatory (VO) standards and/or easily transformable into VO compliant data structures.

[REQ-1-OCD-3315] TMT shall create and maintain a Data Interface Control Document (Data ICD). [3] Preliminary versions of the DID document shall be delivered for the TMT preliminary and final design reviews.

[REQ-1-OCD-3320] Once released, the TMT DID document shall be under configuration control. The TMT Project (and later Observatory) shall establish a DID configuration control process.

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[3] Based conceptually on the ESO Data Interface Control document, as described in the ESO Data Interface Control document (GEN-SPE-ESO-19940-794/2.0), Appendix A, available on-line from http://archive.eso.org/DICB/.

[REQ-1-OCD-3325] TMT shall maintain a data definitions database containing all keywords, data structures, and formats under configuration control. This database shall be available for on-line for consultation by the community.

7 OBSERVATORY DEVELOPMENT CONCEPTS

Discussion: this section shall describe (or summarize) the TMT strategic vision for observatory development in key areas.

7.1 AO AND INSTRUMENT DEVELOPMENT

TO BE COMPLETED

7.2 SCIENCE OPERATIONS DEVELOPMENT

TO BE COMPLETED

7.3 FACILITY DEVELOPMENT

TO BE COMPLETED

A. APPENDICES

A.1 SCHEDULED NIGHT-TIME ACTIVITY

TO BE COMPLETED

This section shall tabulate all known night time technical activity with estimated durations per year.

Here is a preliminary list:

	Per Year	
	Hours	**Nights**
Total	523.5	55.1
Segment Exchange Impact	124.0	13.1
Commissioning Impact	190.0	20.0
Other	209.5	22.1
Assumed Hours Per Night	9.5	

		Duration (Hours)		
Task	**N Per Year**	**Per Event**	**Per Year**	**Assumptions**
Post segment exchange: alignment & phasing	31	3.0	93.0	246 segs/year, 8 segs/work-day
Post segment exchange: AO alignment	31	1.0	31.0	246 segs/year, 8 segs/work-day
M2 recoating	0.5	47.5	23.8	Five (5) nights every two (2) years
M3 recoating	0.5	47.5	23.8	Five (5) nights every two (2) years
Commissioning	20	9.5	190.0	Could be instrument, AO, new software, etc.
Pointing model maintenance	12	4.0	48.0	0.5 nights/month
Misc. technical work	12	9.5	114.0	NEEDS ANALYSIS

A.2 SCHEDULED DAY-TIME ACTIVITY

TO BE COMPLETED

This section shall tabulate all known day time technical activity with estimated durations per year.

Here is a preliminary list:

	Per Year	
	Hours	**Days**
Total	1747.0	218.4
Segment Exchange Impact	248.0	31.0
M2/M3 Recoating	40.0	5.0
Optics cleaning	312.0	39.0
Commissioning	160.0	20.0
Other	1339.0	167.4
Assumed Work Hours/Day	8.0	

		Duration (Hours)		
Task	**Days**	**Per Day**	**Per Year**	**Assumptions**
Optics handling				
M1 segment exchange	31	8.0	248.0	246 segs/year, 8 segs/work-day
M2 recoating	2.5	8.0	20.0	Five (5) days every two (2) years
M3 recoating	2.5	8.0	20.0	Five (5) days every two (2) years
M1 cleaning	26	4.0	104.0	0.5/day, bi-weekly
M2 cleaning	26	4.0	104.0	0.5/day, bi-weekly
M3 cleaning	26	4.0	104.0	0.5/day, bi-weekly
Science Operations				
Cal data acquisition	329	3.0	987.0	Every day except re-coating days
Commissioning				
New instrument	10	8.0	80.0	
New AO system	10	8.0	80.0	
Other	0	8.0	0.0	

A.3 ESTIMATED SYSTEM DATA RATE AND STORAGE REQUIREMENTS

For the purposes of communications design, an estimate of TMT data rates is required. Only data that requires transport to a central (“public”) database shall be considered. Sub-systems may have their own internal (“private”) data rate requirements.

Science data

Current TMT instrument concepts with estimated frame rates are summarized in the table below.

			Frames/Hr	
Instrument	**Nx**	**Ny**	**Mean**	**Peak**
HROS	8192	8192	5	25
IRIS	4096	4096	60	300
IRMOS	4096	4096	60	300
IRMS	2048	2048	60	300
MIRES	2048	2048	3600	18000
WFOS-OUV (2 barrel)	8192	4096	5	25
Generic (high-volume)	4096	4096	825	4125
Generic (low-volume)	4096	4096	80	400

Columns	
Nx	Number of pixels (x-direction)
Ny	Number of pixels (y-direction)
Frames/Hr: Mean	Estimate
Frames/Hr: Peak	Mean x 5

As illustrated in the table above, current TMT science instrument concepts can be separated into two categories: high-volume and low-volume. To estimate data rates, the following assumptions are made: one (1) 2-byte integer per pixel, 10 hours of science operations per day, 30% additional calibration data, 20% transmission overhead.

Under those assumptions, the required data rates and annual data storage volumes (2 copies) are:

- Low-volume: 0.01 GBit/s, 30 TByte per year
- High-volume: 0.1 GBit/s, 300 TByte per year

Technical data

All TMT sub-systems shall be required to transmit telemetry. The estimated total data storage per year ~75 TB (2 copies) (see table at left).

Number of Reporting Devices	20000
Mean Reporting Rate Per Sec	1
Record ID (bytes)	2
Record Value (bytes)	4
Number of Records Per Device	10
Mean Record Size (Bytes)	60
GBps	0.0012
Gbps	0.0096
Hours Per Day (mean)	24
GB Per Day	103.68
GB Per Year	37843.2
TB Per Year	37.8
TB Per Year (with copy)	75.7

AO systems are expected to contribute an additional 400 kB/sec or ~10 TB per year (2 copies) (C. Boyer, 2007, private communication).

The site conditions monitor systems will add two (2) GB per 24-hour period or ~ 1.5 TB per year (2 copies) (M. Schöck, 2007, private communication).

The total annual technical data storage requirement is ~ 90 TB per year.

A.4 MEAN AVAILABLE SCIENCE TIME (MAST)

TO BE COMPLETED

For a preliminary discussion, see Reference Document 4.

Under a set of conservative assumptions (see [RD04] for more details about categories), estimated net mean available science time (MAST) is:

		Fraction	
	Annual Hrs	**Possible MAST**	**Scheduled MAST**
Total Possible MAST Per Year (hours)	***3467.5***	***1.000***	***Not Applicable***
Scheduled Commissioning Time (hours)	173.4	0.050	Not Applicable
Scheduled Engineering Time (hours)	173.4	0.050	Not Applicable
Scheduled M1 Maintenance Recovery Time (hours)	150.0	0.043	Not Applicable
Total Scheduled MAST (hours)	***2970.8***	***0.857***	***1.000***
Weather Loss During Scheduled MAST (hours)	445.6	0.129	0.150
Process Overhead Time during Scheduled MAST (hours)	431.8	0.125	0.145
Observation Overhead Time during Scheduled MAST (hours)	414.1	0.119	0.139
Unscheduled Technical Loss during Scheduled MAST (hours)	126.3	0.036	0.043
Net Scheduled MAST (hours)	***1553.0***	***0.448***	***0.523***

The most optimistic set of assumptions leads to this result:

		Fraction	
	Annual Hrs	**Possible MAST**	**Scheduled MAST**
Total Possible MAST Per Year (hours)	***3467.5***	***1.000***	***Not Applicable***
Scheduled Commissioning Time (hours)	69.4	0.020	Not Applicable
Scheduled Engineering Time (hours)	69.4	0.020	Not Applicable
Scheduled M1 Maintenance Recovery Time (hours)	48.0	0.014	Not Applicable
Total Scheduled MAST (hours)	***3280.8***	***0.946***	***1.000***
Weather Loss During Scheduled MAST (hours)	393.7	0.114	0.120
Process Overhead Time during Scheduled MAST (hours)	336.1	0.097	0.102
Observation Overhead Time during Scheduled MAST (hours)	448.1	0.129	0.137
Unscheduled Technical Loss during Scheduled MAST (hours)	86.6	0.025	0.026
Net Scheduled MAST (hours)	***2016.4***	***0.582***	***0.615***

To paraphrase Section 3.2, the TMT Observatory is required to maximize the number of net scheduled MAST hours. The tables above list six items that are under direct TMT control, while weather is not (except in the limit that one parameter in TMT site selection is minimizing potential weather downtime). A TMT Observatory designed for robust, efficient operations and low maintenance will pay back in hours available for science observations.

The distance between these two estimates is spanned by an ability to enable design and implementation decisions that may be more expensive initially but will pay back in long-term scientific productivity.

A.5 OPERATIONS WORKFLOWS

For the purposes of operations staff, process, and software planning, the TMT Project shall develop a set of operations workflows. These workflows shall be periodically reviewed and revised.

The list of required workflows is still under development. Example workflows include:

- High-level observatory management
  - Develop annual operating plan
  - Develop annual observatory report
  - Administer Call for Proposals
  - Develop, coordinate, and manage semi-annual night-time activity schedule
  - Develop, coordinate, and manage long-term technical work schedule
  - Perform community outreach
- Science operations
  - Execute one observation: classical, remote, or queue
  - Coordinate and execute night time operations
  - Support classical observers (local or remote)
  - Support technical performance monitoring
  - Maintain Web portal content
  - Operate electronic user help desk system
  - Track TMT-related publications
- Technical operations
  - Coordinate and execute daily operations
  - Execute telescope system maintenance program
  - Execute enclosure maintenance program
  - Execute optics maintenance program
- Facility operations
  - Operate dormitory and food services
  - Maintain non-technical facilities
- Instrument development office
  - Coordinate new concept development with SAC
  - Administrate new starts
  - Monitor on-going contracts
  - Coordinate AIV for upgrades and new instruments

A.6 OBSERVATORY SCIENCE USE CASES

This section will provide narrative scientific use cases that describe how astronomers will interact with the observatory in the following modes:

- Classical observer
- Remote observer
- Queue observer