

DRAFT

Statement of Work

M3S Preliminary Design Phase

During the Tertiary Mirror System (M3S) Preliminary Design Phase (PDP): (1) the designs shall be brought to a preliminary design level; (2) sources shall be found for the components, custom fabrications and special services needed to produce the M3S; (3) the error budgets, the design requirements document (M3S DRD) and the interface control documents (ICDs) shall be updated as required; (4) the performance of the M3S shall be modeled and compliance with the requirements shall be demonstrated; (5) technical risks shall be identified and appropriate technology development and risk mitigation activities shall be accomplished; (6) a preliminary design review (PDR) shall be conducted; and (7) the activities required during the Final Design/Fabrication Phase (FDFP) shall be planned, scheduled and the costs estimated.

The tasks that the Contractor shall complete during the M3 System Preliminary Design Phase are described in greater detail, below.

1. Project Plan

Contractor shall develop a detailed Work Breakdown Structure (WBS), schedule and staffing plan for the TMT Tertiary Mirror System (M3S) Preliminary Design Phase (collectively termed the Project Plan), which shall be consistent with the schedule milestones listed in Section 7 of this document. The M3S consists of the TMT Tertiary Mirror Cell Assembly (M3CA) and the TMT Tertiary Mirror Positioner Assembly (M3PA). The Project Plan shall be submitted to TMT for approval no later than six weeks after receiving the contract (ARC). Upon TMT approval, the contractor shall subsequently track progress against this plan in each of its monthly reports, using earned value management methods specified by TMT.

2. Document Review

Contractor shall review the Tertiary Mirror System Design Requirements Document (M3S DRD), the related Interface Control Documents (ICDs) and the sections related to the M3S in the Observatory Requirements Document (ORD) and the Observatory Architecture Document (OAD). (Collectively all the requirements pertaining to the M3S in these documents are called the “M3S Requirements”). The M3S DRD references the relevant requirements listed in the ORD and OAD, and lists the relevant ICDs. If Contractor finds any inconsistencies among these documents, it shall notify TMT and provide recommendations for changes to remedy the inconsistencies.

As the preliminary design work progresses, Contractor shall notify TMT of any changes to the ICDs or the M3S DRD that it believes are necessary.

3. Sensitivity Analysis and Error Budget

Contractor shall develop budgets to allocate errors and other performance factors (e.g., mass, reliability, etc.) among the subsystems and components of the M3S. For purposes

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of this discussion, all of these budgets are termed error budgets. Contractor shall perform a sensitivity analysis on each parameter in the error budgets and allocate the errors to the components of the M3S in a manner that optimizes the performance and minimizes the cost of the system. The error budgets shall factor in possible corrections from telescope active optics systems in accordance with the TMT plans for operating the telescope that are defined in the M3S Operational Concept Document. The error budgets shall comply with all of the M3S Requirements. The error budgets shall be submitted to TMT for approval.

4. Preliminary Design

Contractor shall develop Preliminary Designs for: (a) the Tertiary Mirror Cell Assembly (M3CA), including all component subsystems; (b) The Tertiary Mirror Positioner Assembly (M3PA), including all component subsystems; (c) the special fixtures and equipment, including control hardware and software, that will be needed for fabrication and testing of the M3S; (d) the M3 Cell Assembly Lifting Fixture (M3CALF) that will be used in the observatory to install and remove the M3CA from the telescope; (e) the M3 Mirror Lifting Fixture (M3MLF) that will be used to install or remove the M3 Mirror in the M3CA; and (f) the M3 Positioner Assembly Lifting Fixture (M3PALF) which will be used to install the M3 Positioner and Cable Wrap into the TMT telescope structure. The preliminary design activities shall include, but not be limited to, the following tasks:

4.1 M3 Mirror Blank (M3M Blank)

Contractor shall design and analyze the M3M Blank to ensure that it will meet the M3S Requirements, working with TMT to select the most appropriate material and design for the TMT Project. The contractor shall review the preliminary TMT specification for the M3M Blank and shall update the specification as required to be consistent with the M3S preliminary design and the error budgets. The specification, as modified by Contractor, shall be sufficient to ensure that the purchased M3M Blank will meet the requirements in the M3S DRD and be acceptable to the Contractor.

4.2 M3 Mirror Polishing

Contractor shall develop and document the processes that it proposes to use to grind, polish, figure and test the M3M to meet the M3S Requirements. Contractor shall: (a) perform a trade study to determine the most appropriate methods to test the M3M during fabrication and as part of the completely integrated cell assembly, (b) design the required test instruments and stands, (c) perform an error analysis to demonstrate that the test equipment will meet the M3S Requirements, and (d) develop a test procedure and submit it for TMT's approval.

4.3 M3 Support System (M3SS)

Contractor shall design the M3 Support System to meet all the M3S Requirements. Contractor shall perform detailed analyses to demonstrate compliance with the M3S Requirements, including: (a) analysis of the M3SS performance over zenith angles ranging from 0 to 90 degrees (including rotation and tilt requirements on the M3 Positioner for each instrument location) and temperatures ranging from 22 to 2 degrees Celsius; (b) analysis of the active optics capabilities of the design; (c) evaluation of the

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effects of fabrication tolerances on performance; (d) analysis of the heat dissipation from the M3SS; (e) analysis of the stiffness of the design to resist wind pressure on the mirror; and (f) analysis of the resonant frequencies of the M3M supported on the M3SS. This modeling shall include the entire M3CA, where appropriate. An error analysis shall be performed to demonstrate that the accuracy and repeatability of the support actuators will meet the M3S Requirements.

4.4 M3 Cell (M3C)

Contractor shall design and analyze the M3C to meet all of the M3S Requirements, including survival of a maximum likely earthquake.

4.5 M3 Positioner Assembly (M3PA)

Contractor shall design the M3 Positioner Assembly, including the M3 Rotator (M3R), the M3 Tilt Mechanism (M3T) and M3 Cable Wrap (M3CW) to meet all the M3S Requirements.

4.6 M3 Control System for the Cell (M3CSC) and Positioner (M3CSP)

Contractor shall work with the TMT Project to review, refine, and update the relevant M3CSC and M3CSP hardware and software requirements and interfaces. Operational concepts, including use cases, shall be developed. Contractor shall develop and validate via analysis and modeling any active optics control algorithms including analysis of the disturbance sensitivity, parameter value sensitivity and stability margins. Contractor shall complete major design tradeoffs. The overall software and hardware architectures shall be developed. Contractor shall select, with TMT approval, baseline software and hardware platforms. The electronics enclosure form factor shall be identified and a preliminary thermal analysis shall be completed. Contractor shall define preliminary software data structures. The use of legacy hardware and software shall be identified and discriminated from required new designs. Predicted performance shall be compared with the requirements and risk areas identified. Preliminary acceptance test and integration plans shall be developed.

4.7 M3 Cell Assembly Lifting Fixture (M3CALF)

The contractor shall design the M3CALF to meet all of the associated requirements stated in the Optics Handling Equipment Design Requirements Document (HNDL DRD) and in the ICD for the M3S and Optics Handling Equipment.

4.8 M3 Mirror Lifting Fixture (M3MLF)

The contractor shall design the M3MLF to meet all of the associated requirements stated in the Optics Handling Equipment Design Requirements Document (HNDL DRD) and in the related ICDs.

4.9 M3 Positioner Assembly Lifting Fixture (M3PALF)

The contractor shall design the M3PALF to meet all of the associated requirements stated in the Optics Handling Equipment Design Requirements Document (HNDL DRD) and in the related ICDs.

5. Preliminary Design Documentation

The Preliminary Design Phase documentation shall include the: (a) Executive Summary; (b) Design Summary; (c) Technical Reports; (d) Manufacturing Package; (e) Risk Management Summary; (f) Verification Plan; and (g) Final Presentation. These packages will serve as a comprehensive set of organized documents that capture all aspects of the preliminary M3S design. The PDP documentation, with the exception of the PDR presentations, shall be delivered one month before the PDR. Additional detail about the PDP documentation is described below.

5.1 Executive Summary

An Executive Summary of the Preliminary Design, which shall be no longer than 12 pages in length.

5.2 Design Summary

The design summary shall include documentation of all aspects of the preliminary design of the M3CA, M3PA, M3CALF, M3LF and M3PALF including: (a) 3-dimensional computer-aided design (CAD) models of the full system including all subsystems and components; (b) cross section drawings, exploded views, etc. as required to explain the relationships among components; (c) spreadsheets tabulating the error budgets, the properties of the components, etc.; (d) a preliminary bill of materials listing the quantities of the major components required; (e) 2-D CAD drawings developed for the ICDs; and (f) 2-D CAD drawings of the M3M Blank developed for its specification.

A complete set of 3D CAD Models shall be uploaded to the TMT-provided Data Management System, in the SolidWorks format. It is preferred that the models be natively created in SolidWorks, though converted files via STEP are acceptable. Contractor shall work with TMT engineers to integrate the M3S models into the global TMT CAD model.

2D drawings shall also be uploaded to the TMT-provided Data Management System. It is preferred that the drawings be natively created in SolidWorks, though other formats are acceptable. Regardless of the CAD file format, the latest revision of each drawing shall also be in the Portable Document Format (PDF).

5.3 Technical Reports

The analyses and technical studies performed by Contractor shall be documented in an organized system of technical reports. These shall include: (a) tolerance studies performed to develop error budgets and specifications; (b) spreadsheets calculating parameters of the designs; (c) trade studies and design optimizations; (d) analyses predicting the performance of the final design; (e) reliability analyses; and (f) a report on the trade study and tolerance studies used to develop the required optical testing methods.

5.4 Risk Management Summary

This section shall tabulate and describe the identified technical, schedule and cost risks. It shall include reports on all risk mitigation, technology development and prototype

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studies undertaken, and shall include recommendations for any additional risk mitigation activities needed in the Final Design/Fabrication Phase.

5.5 Manufacturing Package

The Manufacturing Package shall contain: (a) descriptions of the manufacturing processes required for the components that will be custom manufactured, and potential suppliers capable of making any components that are challenging to manufacture; (b) a description of the optical testing methods to be used in testing the M3M, including the preliminary designs of any test equipment and stands required; (c) a list of all of the long-lead items that will be required in the fabrication phase; (d) specification sheets for the commercially-available components that will be used in the designs; (e) the updated specification for the M3M Blank; and (f) other information required to demonstrate the feasibility of manufacturing the M3CA and M3PA.

5.6 Verification Plan

The Verification Plan shall describe the methods that will be used in the FDFP to verify to TMT that the final designs meet the M3S Requirements.

5.7 Preliminary Design Review (PDR) Presentations

The Preliminary Design Review Presentation Package shall contain the Preliminary Design Review presentations, in Microsoft PowerPoint format.

6. Scheduled Reports, Meetings and Reviews

6.1 Monthly Reports

Monthly reports shall be delivered during the first week of each month and shall cover the previous month. The report shall describe the work completed during the previous month, work planned for the next month, review of the schedule, identification of concerns, proposed resolution of problems and a financial report. TMT plans to use earned value management; the monthly report will track the earned value of the work utilizing methods defined by TMT.

6.2 Quarterly Progress Meetings

Quarterly progress meetings shall be held. The normal location shall be at the Contractor's facility. The quarterly progress meetings shall describe the status of the work, summarize the work planned for the next quarter, review the schedule, identify concerns, and summarize the financial status and the earned value calculations.

6.3 Technical Interchange Meetings

Technical Interchange Meetings shall be held by video or telephone conferencing on a bi-weekly basis. Other Technical Interchange Meetings may be held face-to-face, as required, to solve technical problems.

6.4 Preliminary Design Review (PDR)

Contractor shall present a Preliminary Design Review (PDR) to TMT in Pasadena, CA. At the PDR, presentations shall be given summarizing the activities described in Sections

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4 and 5, above. After the PDR, Contractor shall revise the PDP Documentation to address the issues raised by the review committee.

7. Proposal for the Final Design/Fabrication Phase

Contractor shall develop a proposal for the final design, fabrication, integration and testing of the M3CA and the M3PA. The proposal shall be based on the designs developed and described in the PDP.

8. Project Schedule Milestones

The contractor shall accomplish the indicated milestones by the dates shown below.

Milestones for Preliminary Design Phase	Date
Contract Commencement	May 2009
Deliver Project Plan	July 2009
Deliver PDP Documentation	March 2010
Preliminary Design Review	April 2010
Deliver final PDP Documentation	May 2010
Submit Construction Proposal	June 2010