

## **Statement of Work**

### **M3 System Final Design and Fabrication**

This Statement of Work is organized into two sections: Section 1 describes the Final Design Phase, and Section 2 describes the Fabrication Phase. Below is a list of the tasks which the Contractor shall complete during these phases.

#### **1. Final Design Phase**

##### **1.1 Project Planning**

Contractor shall develop a detailed Work Breakdown Structure (WBS), schedule and staffing plan for the TMT Tertiary Mirror System (M3S) Final Design/Fabrication Phase (collectively termed the FDFP Project Plan), which shall be consistent with the schedule milestones listed in Section 2.6 of this document. The M3S includes the TMT Tertiary Mirror Cell Assembly (M3CA) and the TMT Tertiary Mirror Positioner Assembly (M3PA). The FDFP Project Plan shall be submitted to TMT for approval no later than six weeks after receiving the contract (ARC). Upon TMT approval, Contractor shall subsequently track progress against this plan in each of its monthly reports, using earned value management methods specified by TMT.

##### **1.2 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”). If Contractor finds any inconsistencies among these documents, it shall notify TMT and provide recommendations for changes to remedy the inconsistencies.

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

##### **1.3 Order Long-Lead Components**

The list of long-lead components identified during the PDP shall be reviewed and a schedule shall be developed to identify when each type of long-lead component must be ordered. Items that must be ordered before the Final Design Review shall be submitted to TMT for approval.

##### **1.4 Sensitivity Analysis and Error Budget**

Contractor shall review and update the sensitivity analysis performed in the Preliminary Design Phase (PDP) for all of the designs, including optical testing. Contractor shall update the error budgets that were developed in the PDP. The error budgets shall factor in achievable 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.

## **1.5 Final Design**

Contractor shall develop final designs for: (a) the M3CA and M3PA, including all component subsystems; (b) the special fixtures and equipment, including control hardware and software, that will be needed for fabrication and testing of the M3CA and M3PA; (c) the M3 Cell Assembly Lifting Fixture (M3CALF); (d) the M3 Mirror Lifting Fixture (M3MLF); (e) the M3PA Lifting Fixture (M3PALF) and (f) the shipping container required for shipping the M3M. The final design activities shall include, but not be limited to, the following tasks:

### **1.5.1 M3 Mirror Polishing**

Contractor shall: (a) finish the design of required test instruments and stands; (b) update the error analysis to demonstrate that the test equipment will meet the M3S Requirements; and (c) finalize the test procedures and submit them for TMT's approval.

### **1.5.2 M3 Support System (M3SS)**

Contractor shall design, fabricate and test prototype M3SS actuators, as necessary, update the analyses that demonstrate compliance with the M3S Requirements, and then complete the design of the M3 Support System.

### **1.5.3 M3 Cell (M3C)**

Contractor shall complete the design and analysis of the M3C.

### **1.5.4 M3 Positioner Assembly (M3PA)**

Contractor shall design, fabricate and test prototype M3PA actuators, as necessary, update the analyses that demonstrate compliance with the M3S Requirements, and then complete the design of the M3PA.

### **1.5.5 M3 Control System for the Cell (M3CSC) and Positioner (M3CSP)**

All hardware and software designs shall be completed and shown to meet the requirements; any exceptions shall be discussed and approved by TMT. All hardware and software interfaces, including data structures, shall be completed and agreed upon between the Contractor and TMT. A final thermal analysis shall be completed. Prototyping of critical assemblies and software interfaces shall be completed and validated. All components shall be identified and shown to meet TMT standards. Suppliers of major/critical components shall be identified. Fabrication plans shall be completed. All design documentation shall be completed including test and integration plans. Draft maintenance and installation procedures shall be completed. Provisions for spares shall be coordinated with TMT. The designs for hardware and software required for shop integration/test and integration at the observatory site shall be completed.

### **1.5.6 M3 Cell Assembly Lifting Fixture (M3CALF)**

Contractor shall complete the design and analysis of the M3CALF.

### **1.5.7 M3 Mirror Lifting Fixture (M3MLF)**

Contractor shall complete the design and analysis of the M3MLF.

### **1.5.8 M3 Positioner Assembly Lifting Fixture (M3PALF)**

Contractor shall complete the design and analysis of the M3PALF.

### **1.5.9 M3 Mirror Shipping Container**

Contractor shall design the shipping container for the M3 Mirror and develop a test plan to verify the adequacy of the shipping container before it is used.

## **1.6 Documentation Packages**

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

### **1.6.1 Executive Summary**

An Executive Summary of the Final Design, which shall be no longer than 18 pages in length.

### **1.6.2 Design Description**

The design summary shall include documentation on all aspects of the final design of the M3CA, M3PA, M3CALF, M3LF, M3PALF, the fabrication and test equipment, and the M3M shipping container, including: (a) 3-dimensional computer-aided design (CAD) models including all subsystems and components; (b) detail drawings of all subsystems and components; (c) cross section drawings, exploded views, etc. as required to explain the relationships among components; (d) specification sheets for commercially available components; (e) spreadsheets tabulating the error budgets, the properties of the components, etc.; and (f) bill of materials listing the required quantities of components.

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).

### **1.6.3 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

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parameters of the designs; (c) trade studies and design optimizations; (d) analyses predicting the performance of the final design; (e) reliability analyses and (f) other important design/analysis calculations.

### **1.6.4 Risk Management Report**

The identified technical, schedule and cost risks shall be documented in a Risk Management Report, which shall include reports on all risk mitigation, technology development and prototype studies undertaken.

### **1.6.5 Manufacturing Package**

The Manufacturing Package shall contain: (a) fabrication drawings for all components that will be custom fabricated; (b) assembly drawings and assembly procedures, where required; and (c) a quality control and assurance plan.

### **1.6.6 Verification Plan**

The Verification Plan shall be updated as required for the final design.

### **1.6.7 Integration and Test Plan**

The Integration and Test Plan shall describe the integration and testing of the M3CA and the M3PA in the fabrication facility, the reassembly and checkout of the M3CA and the M3PA at the observatory, installation and checkout of the M3CA and M3PA in the telescope, and verification of the functionality and performance of the M3CA and M3PA after installation.

### **1.6.8 Final Design Review (FDR) Presentation Package**

The Final Design Review Presentation Package shall contain the Final Design Review presentations, in Microsoft PowerPoint and PDF format.

## **1.7 Scheduled Reports, Meetings and Reviews**

### **1.7.1 Monthly Report**

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. The monthly report shall track the earned value of the work utilizing methods defined by TMT.

### **1.7.2 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.

### 1.7.3 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.

### 1.7.4 Final Design Review (FDR)

Contractor shall present a Final Design Review (FDR) to TMT in Pasadena, CA. At the FDR, presentations shall be given summarizing the activities described in Sections 1.3 through 1.7, above. After the FDR, Contractor shall revise the Final Design Documentation to address the issues raised by the review committee.

## 1.8 Project Milestones for the Final Design Phase

The Contractor shall accomplish the milestones shown in Table 1.

**Table 1 Final Design Phase Milestones**

<b>Milestones for Final Design Phase</b>	<b>Completion Date</b>
Start Final Design Phase	July 2010
Deliver FDFP Project Plan	September 2010
Deliver Final Design Documentation	May 2011
Final Design Review	June 2011

## 2. Fabrication Phase

### 2.1 Fabrication

For each subsystem and component, the Contractor shall decide whether it will be made in-house, purchased or subcontracted. Major subcontracts must be approved by TMT. The mechanical components shall be fabricated or purchased by Contractor. Internal Quality Control, Assurance and inspection procedures shall be used.

The M3 Mirror shall be generated, ground, polished, figured and tested.

Contractor shall arrange for all M3CSC and M3CSP hardware (electronics, packaging, interconnect panels, cables) to be built to TMT workmanship standards. The Contractor shall build the hardware and software necessary to assemble and test the M3CSC and M3CSP and to integrate the M3CSC and M3CSP into the M3S. The M3CSC and M3CSP software code shall be built, tested, and integrated in a continuous process using TMT standards.

Sufficient spare parts shall be produced or purchased to cover anticipated risks involved with integration and installation of the M3CA and M3PA.

### 2.2 Assembly, Integration and Test

The M3CA shall, first, be assembled and tested without the M3 Mirror. The Contractor shall perform a formal acceptance test of the M3CA including rigorous validation of all interfaces. The software interfaces of the M3CSC shall be tested/verified with TMT

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supplied simulators. The Contractor shall provide TMT with formal and comprehensive test records.

After the M3 Mirror has passed acceptance tests as a component, it shall be integrated into the M3CA. The full M3CA shall be tested at multiple orientations to verify that the entire system meets all the M3CA Requirements. Final maintenance and installation procedures shall be completed.

The M3PA shall be assembled and tested with a contractor supplied M3CA mass simulator. The Contractor shall perform a formal acceptance test of the M3PA including rigorous validation of all interfaces. The software interfaces of the M3CSP shall be tested/verified with TMT supplied simulators. The Contractor shall provide TMT with formal and comprehensive test records.

The M3PA, with mass simulator, shall be tested at multiple orientations to verify that the entire system meets all the M3PA Requirements. Final maintenance and installation procedures shall be completed.

### **2.3 Integration into the Observatory**

The Contractor shall be responsible for the delivery of the M3CA and M3PA to the observatory site. Contractor shall unpack the systems and inspect all of the hardware for damage. Any required repairs will be performed promptly. Contractor shall assemble the M3PA, M3CALF, M3LF, M3PALF and shall assemble the M3CA (without the M3M).

Contractor shall provide engineering support for the installation of the M3 Mirror into the M3CA, and for the installation of the M3CA and M3PA into the telescope, including integration of observatory supplied utilities with the M3CA and M3PA and integration of the M3CA and M3PA into the observatory software system. In conjunction with TMT the Contractor shall perform formal acceptance testing of the M3CA and M3PA at the observatory site. The Contractor shall provide training of TMT staff in the operation of the M3CSC and M3CSP. Multiple trips to the observatory site may be required to complete this work.

Contractor shall provide additional remote support, as required, on a time and materials basis.

### **2.4 Fabrication Documentation**

The documentation required at the completion of fabrication is described below:

#### **2.4.1 End Item Data Package**

The End Item Data Package shall contain the following:

##### **As-built Engineering Drawings:**

The 2D engineering drawings that correspond to the hardware as it was finally built in the Fabrication Phase.

**Engineering Parts List:**

A parts list for each of the assemblies and subassemblies, including information about commercial sources for each component and drawing numbers for manufactured components.

**Engineering Change Requests:**

Engineering change requests shall be processed for changes to the established baseline after deliverable hardware and software are placed under configuration management. These documents shall be collected, organized and included.

**Discrepancy Forms:**

All discrepant hardware and software shall be documented, including any consequences or resolutions resulting from the discrepancies.

**Waivers:**

Any waivers to specified requirements approved by TMT shall be documented.

**2.4.2 Reliability Report**

A reliability report shall demonstrate the reliability of the M3CA and M3PA by analysis, testing or heritage.

**2.4.3 Test Reports and Test Data**

All test reports and test data shall be documented for each test conducted on the hardware and software.

**2.4.4 Material and Calibration Certifications**

All certifications on material and test instruments shall be delivered with the hardware.

**2.4.5 Operation and Repair Manuals**

Operation and Repair Manuals shall be delivered on all subsystems and components.

**2.5 Reports and Meeting**

**2.5.1 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. The monthly report shall track the earned value of the work utilizing methods defined by TMT.

**2.5.2 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.

### **2.5.3 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.

### **2.6 Fabrication Phase Milestones**

The Contractor shall accomplish the milestones shown in Table 2.

**Table 2 Fabrication Phase Milestones**

<b>Milestones for Fabrication Phase</b>	<b>Completion Date</b>
Start Fabrication	July 2011
Receive Mirror Blank	August 2012
Complete Mirror Polishing and Figuring	August 2014
M3CA and M3PA Acceptance Testing	November 2014
Ship to Observatory and Check Out	January 2015
On-site Support and Training	September 2015