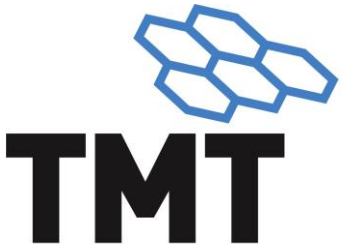

THIRTY METER TELESCOPE

LARGE OPTICS HANDLING BEST PRACTICES

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1. INTRODUCTION

1.1 INTRODUCTION

The Thirty Meter Telescope is comprised of a number of large optical elements. In order to assure success in the creation of TMT, it is necessary to implement the safe handling practices specified in this document. In this document, "safety" refers to part safety and personnel safety, equally.

1.2 PURPOSE

This document will be used by Partners and suppliers to assure the safe handling of TMT large optics.

1.3 SCOPE

This document describes the best handling practices required in the fabrication, inspection and acceptance of the large optical elements making up the Thirty Meter Telescope. Large optics lifting, flipping, transfers and storage are covered within this document.

For the purposes of this document, we will consider "large optics" as those, like the TMT M1 segments (RD4), the TMT M2 mirror (RD5) and the TMT M3 mirror (RD6), larger than a half meter across. All large optics require tooling, equipment and procedures for their safe handling.

1.4 APPLICABLE DOCUMENTS

Not applicable.

1.5 REFERENCE DOCUMENTS

RD1 TMT Polished Mirror Assembly – Intermediate Polishing Specification (TMT.OPT.SPE.11.001)

RD2 TMT M1 Plano-Plano Segment Blank Drawing (CAD Drawing M1S-001-01003, dcc Document TMT.OPT.DWG.14.002)

RD3 TMT M1 Meniscus Segment Blank Drawing (CAD Drawing M1S-001-01002; dcc Document TMT.OPT.DWG.14.001)

RD4 TMT M1 Polished Segment Drawing (CAD Drawing M1S-001-01000; dcc Document TMT.OPT.DWG.14.005)

RD5 M2M Blank – Secondary Mirror Drawing (CAD Drawing M2S-001-01000; dcc Document TMT.OPT.DWG.15.009)

RD6 M3M Blank – Tertiary Mirror Drawing (CAD Drawing M3S-001-01000; dcc Document TMT.OPT.DWG.15.010)

1.6 ACRONYMS AND ABBREVIATIONS

CAD	Computer Aided Design
dcc	Document Control Center (Docushare)
ES&H	Environmental, Safety and Health
HARA	Hazard and Risk Assessment
M1	Primary Mirror

M2	Secondary Mirror
M3	Tertiary Mirror
RTV	Room Temperature Vulcanization
TMT	Thirty Meter Telescope

2. LARGE OPTICS HANDLING BEST PRACTICES

2.1 LARGE OPTICS

2.1.1 Work Area

Requirements:

1. A large optics handling area shall be designated for such activities. The area needs to free of clutter and other distractions which would put the personnel or hardware at risk. Otherwise, if there is not a designated handling zone, then a work zone shall be created with safety cones and signs.

2.1.2 Personnel Training

Requirements:

1. All personnel involved in the handling operation shall complete a safety and operator training prior to handling any large optics.
2. The training shall be executed using pertinent and released handling procedures. Supplier and TMT Quality Assurance and Safety Groups shall verify this.
3. A "Training Matrix", listing the certified handlers for each specific handling procedure shall be posted in the area where large optics are handled. Supplier and TMT Quality Assurance and Safety shall verify and monitor that updates to the matrix are made and that only certified personnel are performing the work.

2.1.3 Hazard and Risk Analysis

Requirements:

1. A Hazard and Risk Assessment (HARA) shall be conducted in the planning stages of particular handling procedures in order to identify methods and equipment and to mitigate and correct risk deficiencies. The HARA shall be delivered to the TMT Work Package Manager for review and approval prior to proceeding with any TMT Optics handling.
2. After the HARA has been approved and the associated Handling Procedures have been approved by the Supplier and TMT, a dry run for new handling procedures shall be conducted to verify the effectiveness of the assessment and mitigations. Handling dry-runs shall first be performed using a Dummy Optic having the same dimensions and mass as the TMT Optic. Supplier and TMT Quality Assurance and Safety Groups shall verify that the handling risks have been sufficiently resolved and that the procedures are judged to be sufficiently safe.

2.1.4 Preparation for Handling – Hardware Safety

Requirements:

1. Prior to the commencement of large optics handling, the trained and certified handlers are required to take the following precautions:
    - Remove or "tape up" rings on their fingers
    - Remove necklaces, bracelets, watches, earrings, or other jewelry
    - Remove glasses or use glasses straps
    - Empty ALL materials out of their pockets – phones, pens, keys, coins, etc.
    - Wear gloves if the surfaces are polished or coated
    - Wear a face mask if the surfaces are coated

2.1.5 Preparation for Handling – Personnel Safety

Requirements:

1. Prior to the commencement of large optics handling, the operators shall use the appropriate Personal Protection Devices as required by the released procedure:
    - Safety glasses
    - Safety shoes
    - Protective clothing
    - Respirators
    - Head protection
    - Fall protection gear
    - Oxygen sensor

2.1.6 Training

Requirements:

1. Certified "Chief Trainers" shall be established for each specific task. Only these Certified Chief Trainers are permitted to train others in the specific handling procedure.
2. The training shall be task-specific.
3. In the case of large optics handling, the initial training is performed using a "Dummy Optic".
4. After a sufficient level of expertise is achieved the trainee may, at the discretion of the certified Chief Trainer, be allowed and certified to handle real glass or "prime" optics.
5. The training level of the personnel shall be captured on a posted "Training Matrix" listing all of the certified handling personnel and the level of their training on specific moves and operations.

2.1.7 Handling Equipment

Requirements:

1. The equipment needs to be in good working condition, inspected and have passed Manufacturing Readiness Review attended by Supplier and TMT Quality Assurance and Safety Groups. The following equipment is typically required for the handling of large optics. The collection of handling equipment and the collective handling approach must be approved by TMT.
    - Vacuum Lift and/or Spanner
    - Flipping Fixture and/or Flipping Box
    - Transfer Carts
    - Safety Covers
    - Crates
    - Dummy Optic
    - Slow (Vertical) Crane or Hoist
    - Lifting Fixtures & Spreader Bars

2.2 LIFTING

Definition: For the purposes of this document, we will consider a lift as a simple vertical movement of the optic.

2.2.1 Hand Lift

Discussion: If the optic is small and light enough, say less than 10 kg, it may be permissible to lift the optic by hand. Even a hand lift shall be practiced using procedures. The lifting of Dummy

Optics, test plates, test pieces etc. are likely acceptable. Consult TMT for hand lift appropriateness.

The weight of the TMT M1 segment or the M1 Roundels, for instance, is too great for a hand lift. In this case, a mechanized lift is required.

2.2.2 Mechanized Lift

Discussion: For a mechanized lift, the use of lifting equipment is employed – typically either vacuum lifts or spanners, although numerous devices can be devised.

Important Note: Most overhead cranes move too fast vertically for the safe movement of large optics and they need to be modified and geared down to move much slower. It is also recommended to add a fine-adjustment hydraulic device for the fine control needed for initial lift offs and set downs. This is a critical transition for a large optic lift and fine vertical control is required.

2.2.2.1 Vacuum Lift

Discussion: With vacuum lifts, suction cups are applied to the optical or back surface of the optic. It is permissible to use vacuum lifts on a fine ground (finer than 300 grit) surface providing that the leak rate (with the vacuum valves closed) is acceptable. The following are required for the use of vacuum lifters:

Requirements:

1. Released and controlled training and operation procedures.
2. It is strongly recommended that for Vacuum Lifts that an operational checklist be developed and used by the partner or vendor.
3. Working load certification affixed to lift equipment
4. Leak rate checks performed before each and EVERY lift. Leak rate shall be less than 50mm Hg per 2 minutes.
5. Reserve volume tank mounted on the vacuum lifter. The volume of the tank shall be at least 10 liters per 100 kg of rated load.
6. Vacuum pump mounted to the Vacuum Lifter. Vacuum pump is to remain powered at all times during the during the lift.
7. Check valves on each of the vacuum cups to guard against leaks in the up-stream vacuum components and plumbing.
8. Mechanical safety catch that makes the Vacuum Lifter “Fail Safe”. For example: In the event of loss of vacuum, the optic only falls a short distance and is safely caught using mechanical means.
9. Vacuum lifts shall be dynamically load tested by intentionally removing vacuum at the cups and letting the Dummy Optic fall and then be caught by the mechanical safety catch as described in 2.2.4.
10. For a polished optical surface it is permissible to place lens tissue between the cups and the polished surface provided that the leak-rate measured prior to lifting meets requirements stated herein.
11. The key required elements are the leak rate tests and the mechanical safety system.

2.2.2.2 Spanner Lift

Discussion: Spanners typically mechanically engage the Outside Diameter (or edges) with “feet”, steps or clamps. The “Spanner” gets its name because it spans across the optic, grasping it mechanically. The optic is mechanically grasped at the edge and clamped using soft interface

materials such as RTV or felt. The use of spanners is typically combined with an overhead crane for the vertical motion.

It is strongly recommended that for Spanner Lift that an operational checklist be developed and used by the partner or vendor.

Important Note: Most overhead cranes move too fast vertically for the safe movement of large optics and they need to be modified and geared down to move much slower. It is also recommended to add a fine-adjustment hydraulic device for the fine control needed for initial lift offs and set downs. This is a critical transition for a large optic lift and fine vertical control is required.

2.2.3 Lift Training

Requirements:

1. All handlers need to trained and certified for the specific lift
2. The training level of personnel conducting lifts shall be captured on a "Training Matrix" showing all handling personnel and the level of their training.
3. Dummy Optics need to be used for the initial training, followed up with prime optics once the personnel, procedures and equipment have successfully passed the gate of the Manufacturing Readiness Review.

2.2.4 Lift Equipment Proof Load Certification

Requirements:

1. The lifting equipment shall be proof-load tested with a minimum of 2X nominal load using a Dummy Optic and weights at least every 12 months.
2. Mechanical Safety Stops (fail-safe devices) shall be proof tested at least once every 12 months using the nominal Dummy Mass (2.0 proof factor).
3. A working load sticker shall be signed, dated and affixed to the lift equipment.
4. The equipment shall be maintained under a Configuration Control Management system.

2.3 FLIPPING

Definition: For the purposes of this document we will consider "flipping" as a controlled turn over of an optic. In other words, the upper surface moves into the lower position or vice versa. It is strongly recommended that for Flip that an operational checklist be developed and used by the partner or vendor.

Note: The working area needs to be marked off with safety cones as flipping, takes a lot of room and can present handling risk.

2.3.1 Mechanized Flip

Discussion: A mechanized flip generally uses either a flipping box or a flipping fixture.

2.3.1.1 Flipping Box

Discussion: One of the most commonly employed mechanical flips utilizes a flipping box. The box:

1. Has fork lift skids on both the upper and lower lids.
2. Has designed ability to remove either the top or bottom lids as needed.

3. Places the optic in front-to-back compression and laterally constrained using compliant materials while inside the box.
4. Has the ability to be flipped as a unit with the optic safely compressed inside with the use of an overhead crane or other equipment.

The flipping sequence using a flipping box is as follows:

1. Lower the optic into the box and secure any edge foam as needed
2. Secure the lid. Note: The optic should be in compression while inside the box to minimize movement during the flip.
3. Use overhead crane and connected straps (or other TMT approved approach) to lift the box on edge and subsequently lower onto the opposite side, flipping the crate and optic in the process.
4. Remove the straps and the lid which is now facing up.
5. Remove edge foam and lift the "flipped" optic out of the box with approved lifting device.

2.3.1.2 Flipping Fixture

Discussion: For the discussion here, a mechanized flip using a flipping fixture generally involves a custom-designed and dedicated piece of equipment used for flipping a specific optic. Since many such devices can be devised, the details cannot be discussed here beyond the more general requirements and are subject to TMT approval.

2.3.2 Flipping Training

Requirements:

1. Handling personnel shall be trained and certified for the specific flipping equipment and procedures used.
2. Dummy Optics shall be used for the initial training.

2.3.3 Flipping Equipment

Requirements:

1. Several basic and critical requirements for flipping equipment:
   - The equipment must be load tested with a 2X nominal load with an affixed working load sticker.
   - The equipment must be under a Configuration Control Management system.
   - Mechanical safeties must be an integral part of the flipping equipment design so that if any part of the lifting equipment fails, the optic is caught safely.

2.4 TRANSFERS

Definition: For the purposes of this document, we will consider a transfer as a move of the optic from one location to another within the optical shop using Transfer Carts and Safety Covers or Crates.

2.4.1 Transfer Carts and Safety Covers

Requirements:

1. Transferring large optics is generally performed using transfer carts, specifically designed to safely move the optic from location to another in the shop. These carts need the following features and shall:
   - Be load tested at 2X the nominal load with an affixed working load sticker.
   - Be under Configuration Control Management.
   - Have brakes on all wheels.

- Have a provision for the recorded process data package that documents the optic travels with the optic during the transfer.
- Include Safety Covers (see 2.5 below) to protect the optic during the transfer.

Discussion: It is recommended that only two of the wheels be swivel types, with the other two fixed. Experience has shown that this arrangement makes the cart easier to control, as compared to having all four wheels with swivel-type wheels.

2.4.2 Crates

Discussion: In general crates are used for the longer distance shipping of an optic. But on occasion, it is also desirable to use the shipping container for more local movements, for example, within the fabrication facility. When the optic is placed within a protective crate, then moved, use of a safety cover is not needed and the crated optic can be moved with a fork lift or an overhead crane.

2.4.3 Blanks – Special Case

Discussion: Many of the overarching handling requirements for blanks are covered elsewhere in this document. It is further assumed that **blanks will not be removed from the crate during their handling.** Below we will discuss the special considerations which are related to blank handling (The blank always remains in the box):

- The Work Area shall be created with safety cones and signage (see 2.1.1). If applicable, doors adjacent to the work area need to be manned to prevent other personnel from encroaching on the work area perimeter during handling operations.
- If fork lifts are used, they must have the proper load rating, up-to-date certifications, and fork length appropriate to the lift. Also, the lid needs to be fastened and in place any time that the blank within the crate is moved or transported.
- If battery-powered screwdrivers are used, for instance, to remove the fasteners from the lid of the crate, then the tools must be secured away from the glass once the lid is removed.
- If inspections are carried out, then flashlights and other tools must be tethered to the wrist (see 2.1.4).
- If the blank is not being inspected, then the crate lid needs to be replaced on top to protect the glass.

2.5 SAFETY COVERS – GENERAL USE

Requirements:

1. Safety Covers shall be employed when:
   - Transferring an optic from one location to another within the optical shop.
   - When the polishing, measuring or other machine is not operating (with the optic on board) for more than 15 minutes.
   - Whenever there are other activities in the area with the possibility of objects above the optic falling onto the glass surface.
   - When the optic is not being processed or measured, it shall be covered with a protective Safety Cover.

Discussion:

- Safety Covers can be either “hard shell”, “soft shell” or a combination of the two.

- A Hard Shell Cover incorporates a hard plastic layer, like Lexan, as part of the design. A Soft Shell Cover is made from closed-cell foam.

- During polishing, if the covers contact the optical surface, lens tissue should be placed on the polished surface (for scratch protection), prior to placing the cover over the optic.
- The protection provided by the cover should protect all surfaces of the optic, including the edges.
- Covers should not be placed on optics until the abrasive compound of polishing compound has been fully cleaned off of the surfaces.

2.6 CLEANLINESS

Discussion: There are considerations for cleanliness which are considered good practice. The requirements evolve as the assemblies are integrated in preparation for delivery to the observatory.

2.6.1 Silicone

Discussion: Silicones shall be precluded from the manufacture of roundels, segments, SSAs, and assemblies. Silicones, by nature, are an insidious contaminate that is difficult to mitigate and clean. Further, silicones add risk to coating and integration activities.

2.6.2 Roundel Cleanliness

Discussion: Except for silicones, roundels do not have additional cleanliness considerations.

2.6.3 Segment and Assembly Precautions

Discussion: Once the segments have been machined and further integrated into assemblies, best practices mandate the use of gloved hands and shop smocks.

2.6.4 Coated Assemblies

Discussion: Once the segments have been coated, additional precautions, including the use of face masks, are required.

2.7 STORAGE

Definition: For the purposes of this document, we will consider optic storage as either Temporary or Long-Term Storage.

2.7.1 Temporary Storage

Discussion: The temporary storage time frame can be anywhere from 15 minutes to 10 days. If protected with a safety cover, the clean optic can be temporarily stored:

- At end of the working shift.
- On the polishing machine or metrology equipment if the equipment has an issue and needs to be shut down or repaired.

  Note: If the machine needs to be shut down for more than 8 hours, however, provisions to remove the optic from the machine and move it to a designated safe storage zone shall be exercised.
- If the optic is in queue due to equipment resource limitations.
- Before and after an inspection.

2.7.2 Long Term Storage

Requirements:

1. The long term storage time frame is anything greater than 10 days' time. For long term storage, the optic shall be secured in a crate. Written approval from TMT is required for any deviations.

2.8 COMPLIANCE AND WAIVERS

Requirements:

1. At a minimum, all requirements within this document shall be complied with, without exception. Additional requirements may be required to assure Safety during Optics handling and it is the responsibility of the Supplier to incorporate all other required equipment, equipment features, and procedures to assure Part and Personnel Safety.
2. Deviation from the requirements stated herein may only be undertaken after a written Waiver is submitted to TMT for review, and subsequent approval.