



Auxiliary Optical Systems - AOS

Transmission Monitoring Telescope and Suspension – TMS

Eric Gustafson

aLIGO NSF Review
LIGO Livingston Observatory

April 25-27, 2011

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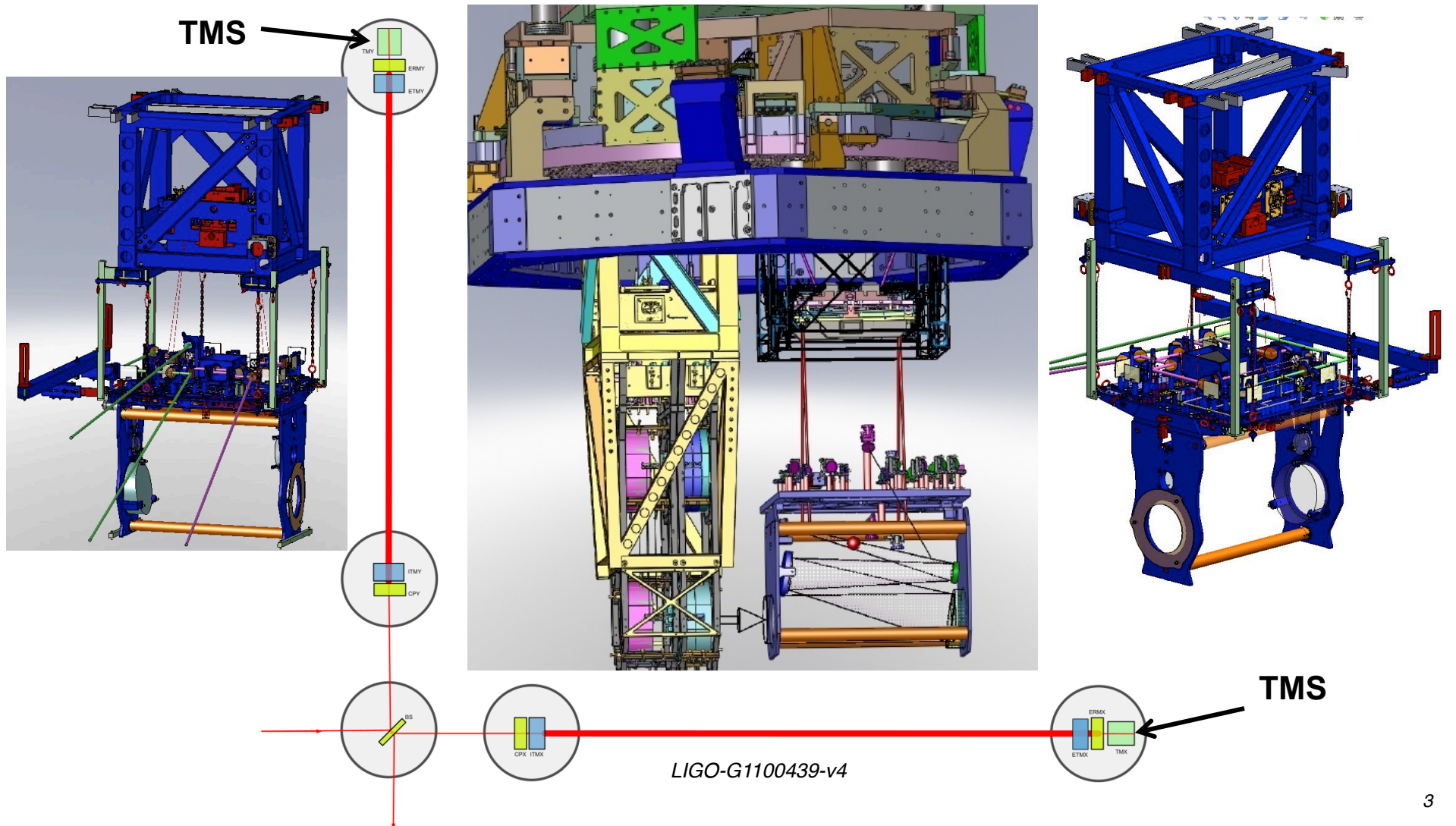


Auxiliary Optical System Talks Outline

- Transmission Monitoring Telescope and Suspension (TMS) – Eric Gustafson
- Optical Levers (OptLev) – Eric James
- Thermal Compensation System (TCS) – Phil Willems
- Initial Alignment System (IAS) – Doug Cook
- Photon Calibration System (PhotonCal) – Rick Savage
- Stray Light Control (SLC) and Viewports (VP) – Mike Smith

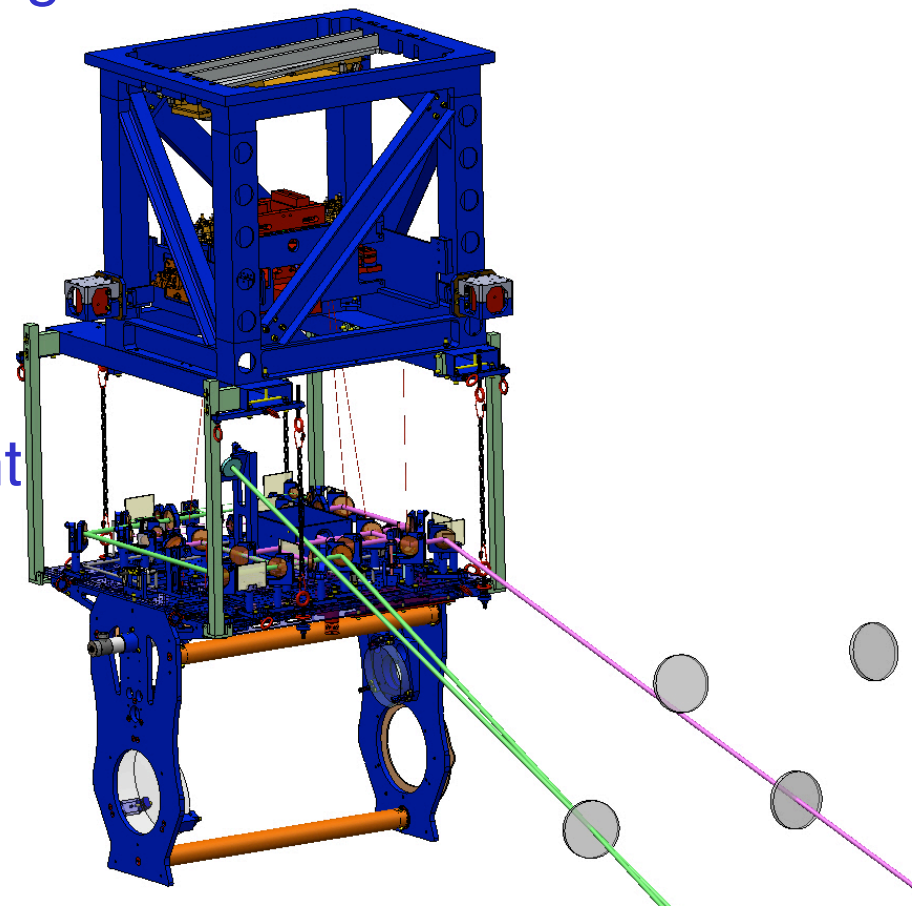


Transmission Monitoring Telescope and Suspension - TMS



TMS Functions

- Collects 1064 nm light transmitting through ETM and provides it for Interferometer Sensing and Control
- Transmits 532 nm light for Arm Length Stabilization
- Transmits 532 nm for intermittent Hartmann ETM monitoring
- Transmit any residual 1064 nm radiation to beam dump



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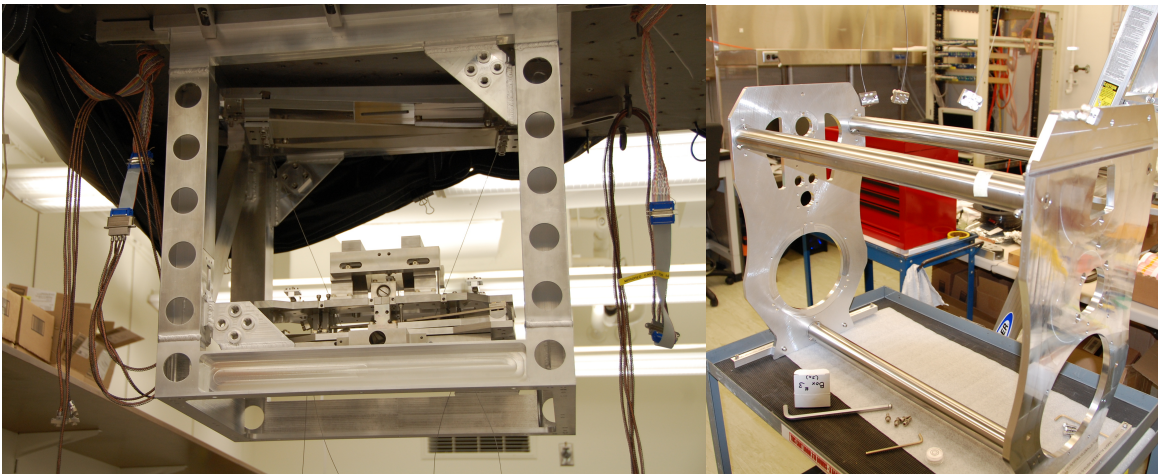
TMS Requirements

- Suspension and Noise
 - » 6 DOF of platform are isolated
 - » Suspension Eigen frequencies between 0.5-5 Hz
 - » All rigid body modes damped to $Q < 10$
 - » Above 10 Hz isolation factor > 1000 all 6 DOF
 - Displacement noise $< 1 \text{ pm}/\sqrt{(\text{Hz})}$
 - Angular noise $< 1 \text{ rad}/\sqrt{(\text{Hz})}$
 - » Internal modes of suspension structure 150 Hz or higher
 - » At 3 Hz isolation factor > 10 all DOF
- Telescope
 - » Reduce 1064 nm beam by 20x to fit 2 inch optics on optics table
 - » Alignment sensors with 90 degree Gouy phases within ± 10 deg.
 - » Handle 1064 nm, 532 nm sensor wavelengths

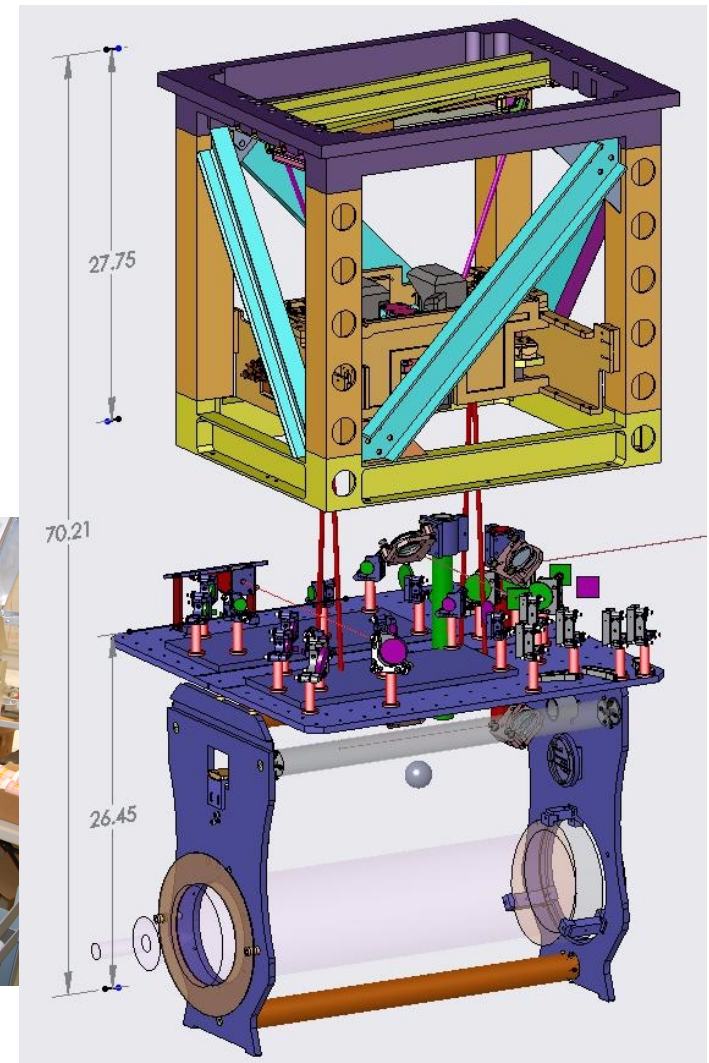


TMS Design Concept

- Double pendulum suspension based on upper stage of Quad Suspension
- Telescope
 - » Reflective off-axis parabolic mirrors
 - » Folded design
- Optical routing done on optical table
- High Power in vacuum beam dump



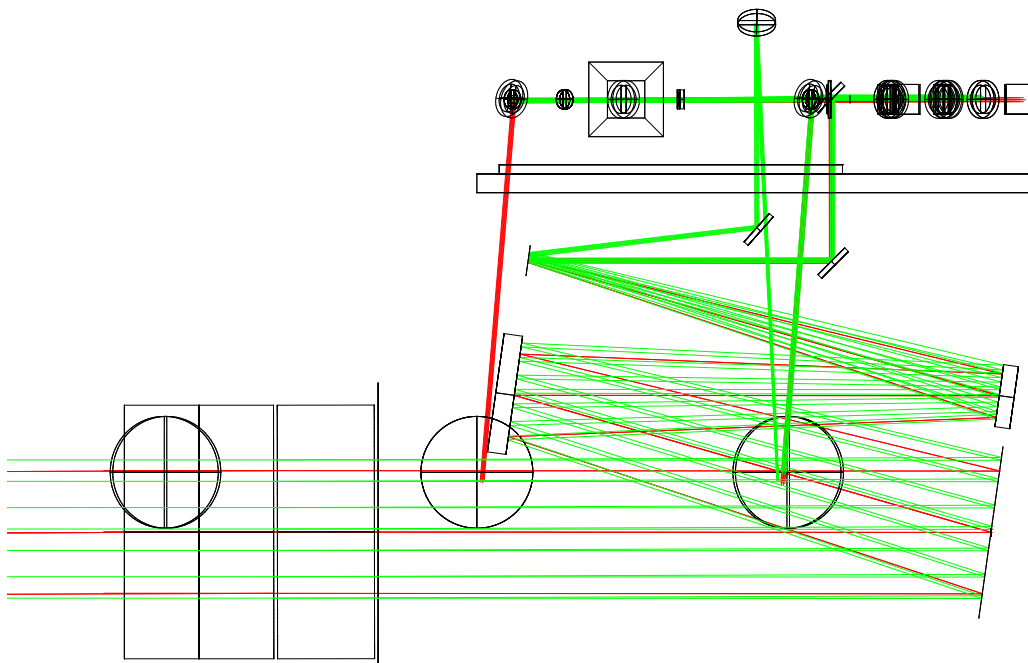
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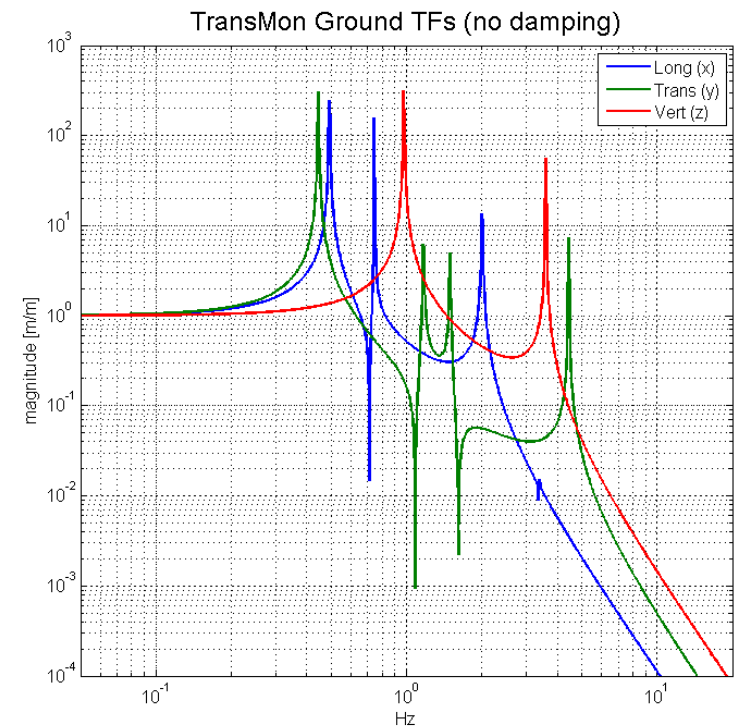


TMS Development Accomplishments

- Compared Three Telescope Designs and selected off axis parabolic design
- Telescope modeled with Ray Tracing Program
- Modeled Suspension Transfer Functions with LIGO Software



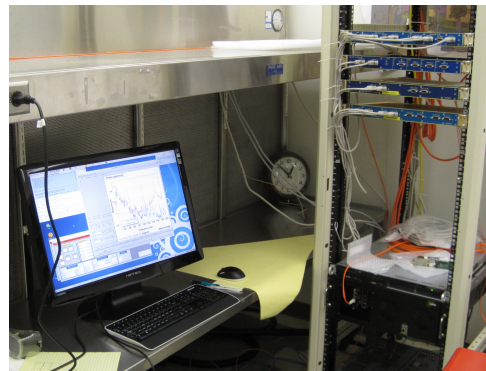
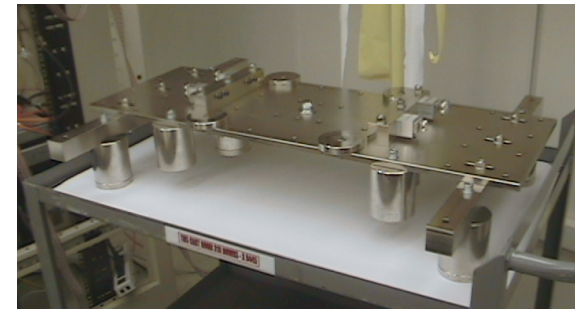
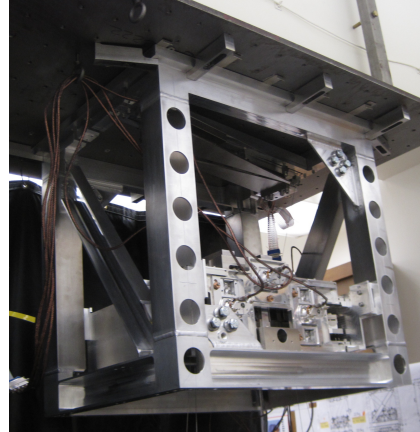
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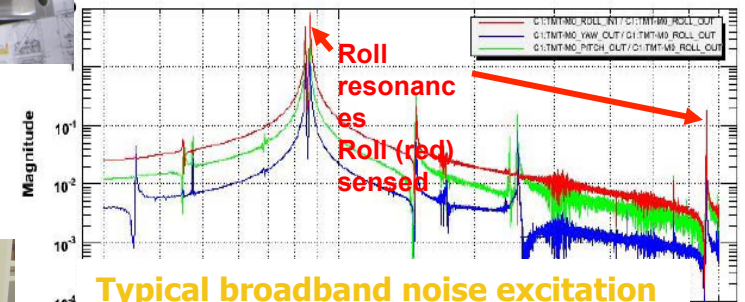


TMS Suspension Prototype Tests

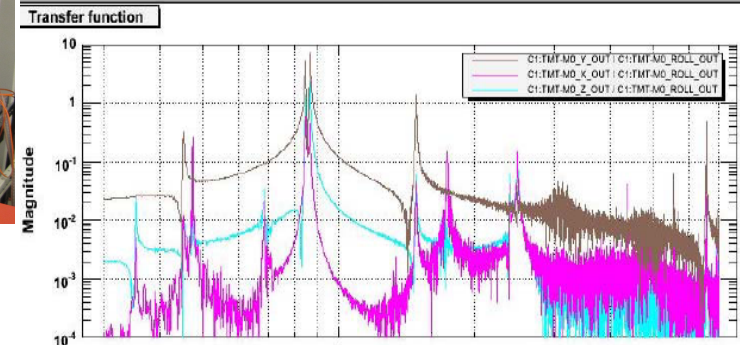
- Establish all 6 BOSEMs operational and interference free
- Measured all 12 body resonance frequencies
- Response Rough cut at orthogonalizing DOF response
- Confirm resonant frequencies assignments via TF for all DOFs
- Good agreement with prototype model
- Established good damping



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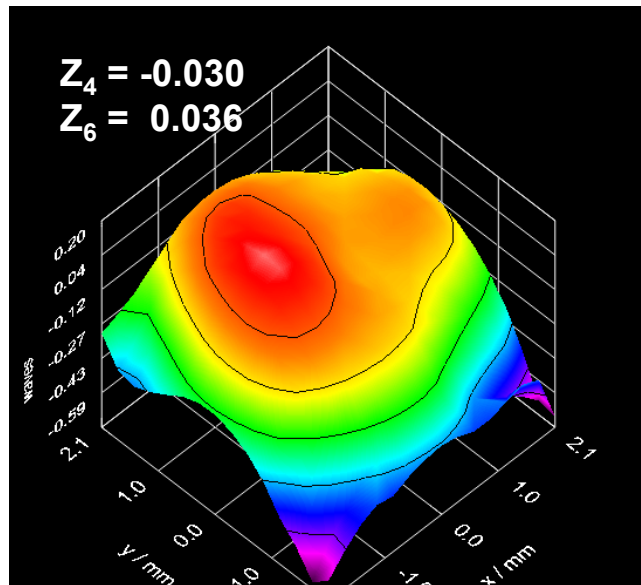
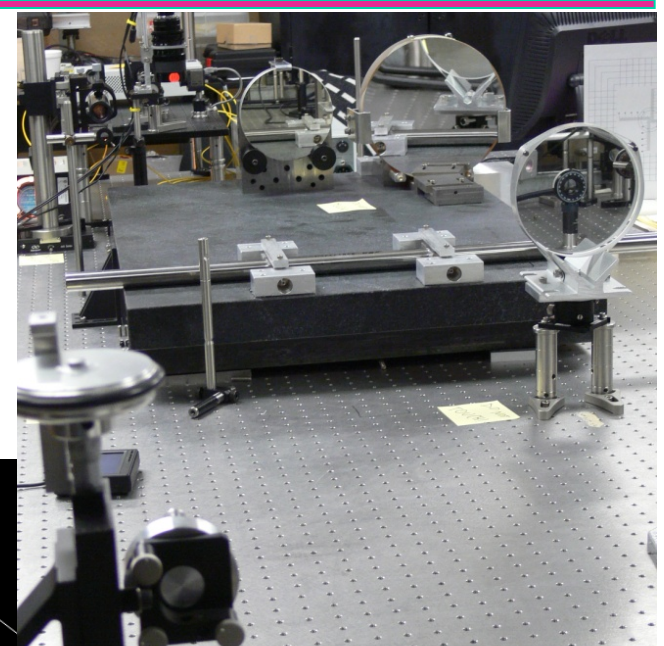




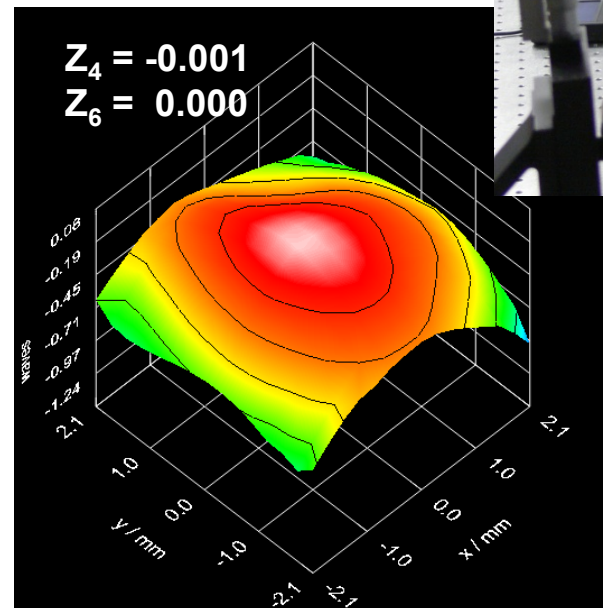
TMS Telescope Mirror Alignment & Characterization

- Shack-Hartmann Test Facility @ Caltech
- Telescope astigmatism spec: $<1/20\lambda$ @ 1064nm
 - » Requires Zernike coefficients Z_4 and $Z_6 < 0.02$ waves
 - » Zernike 5 defocus TBD

Telescope Meets Astigmatism Specification



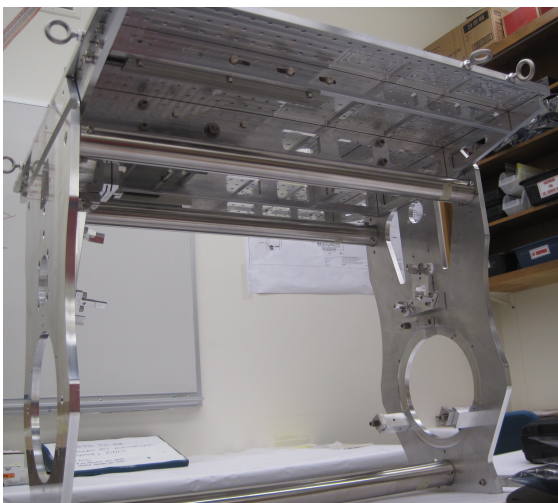
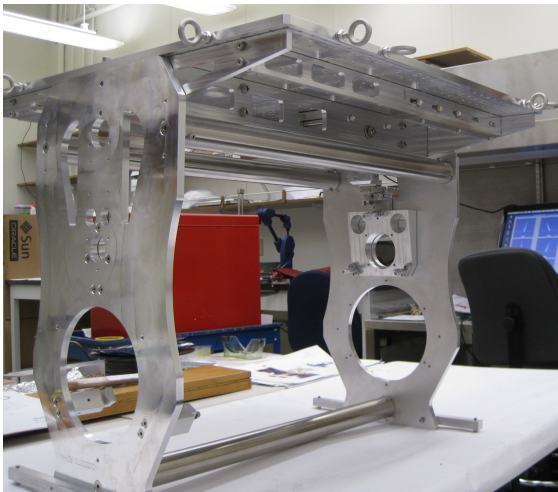
Preliminary autocollimator alignment



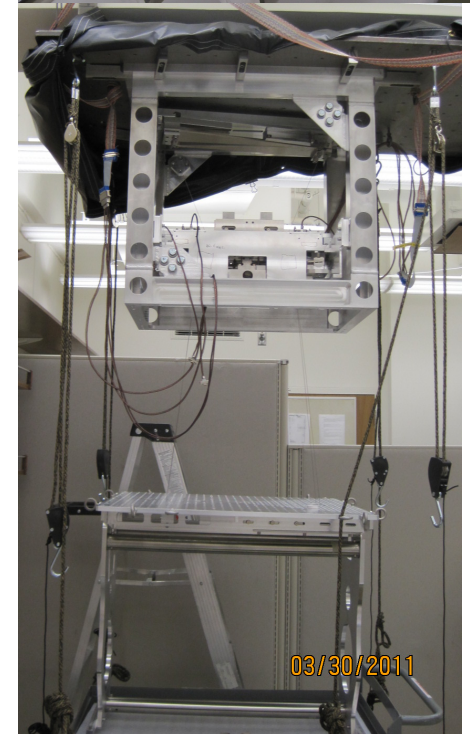
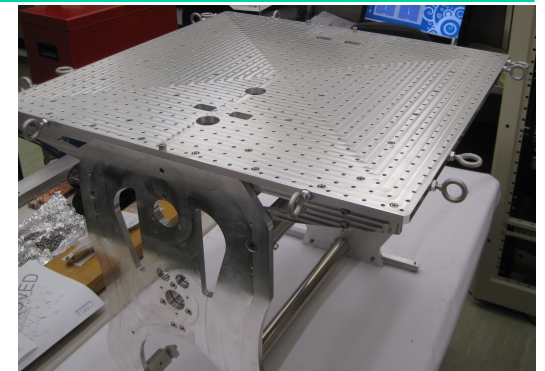
Final Shack-Hartmann alignment



TMS Development Plan



- Preliminary Design Review completed - May 2010 ✓
- Telescope First Article build – May 2011
- Final Design Phase
 - » Optical Table tests completed – April 2011 ✓
 - » Telescope First Article tests completed – June 2011
 - » Suspension testing completed – March 2011 ✓
 - » FDR completed – June 2011
 - » Update all drawings – June 2011

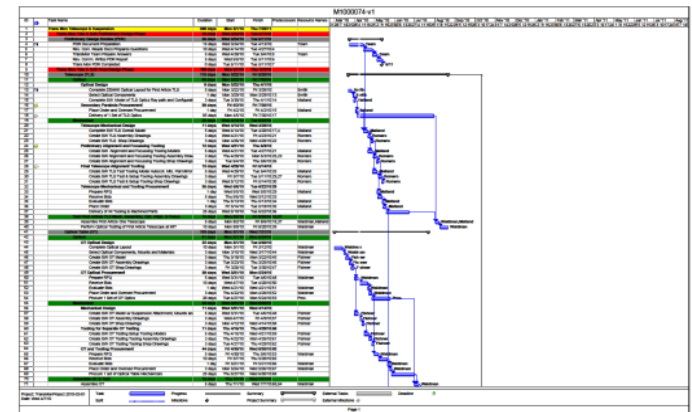


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TMS Project Organization and Plans

- Project Organization
 - » Team Leader/Mechanical Engineer - Ken Mailand - Caltech
 - » Cognizant Scientist - Sam Waldman – MIT
 - » Telescope Optical Design – Mike Smith - Caltech
 - » Mechanical Designer – Mike Miller– Caltech
 - » Draftsperson - **Jesse Terraza** – Caltech
 - » Electronics – Jay Heefner – Caltech
 - » Suspensions Modeling - Matt Evans - MIT
 - » Suspensions Testing – **Bill Kells** - Caltech
 - » Optical Testing - Virginio Sannibale – Caltech
 - » Assembly Technician – **Larry Mossberger** - Caltech
 - » Project Engineer and Planning – **Lisa Austin** - Caltech
- Project Plans
 - » Reworked First Article available for Long Arm Test – June 2011
 - » Remaining production units available – December 2011

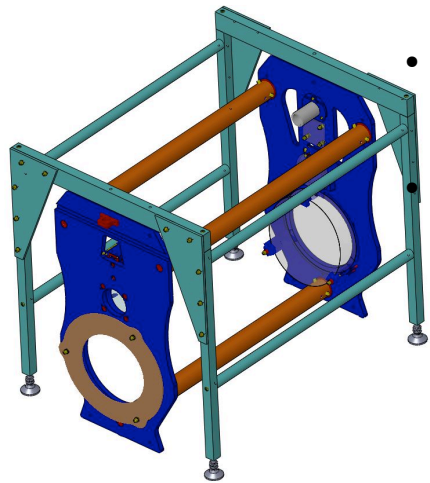




TMS Challenges, Risks, and Mitigations

- Getting First Article delivered to Hanford in time for the Long Arm Test
 - » Draftsperson
 - » Assembly Technician
 - » Project Engineer and Planning
- Optical Aligning and focusing double off axis parabolic telescope
 - » Course alignment with auto collimating telescope
 - » Fine alignment with Shack-Hartmann sensor
 - » Simulation of final alignment with ray tracing simulation
 - » Incoming testing of all parabolic mirrors
- Delivery of off-axis parabolic mirrors
 - » Two suppliers
 - » First Article already Received August 2010 and second Due April 2011

TMS Near Term Activities



- Build and Test First Article Telescope – June 2011

Design and procure the equipment needed for testing

- » Suspension test stand – Caltech – May 2011
- » Electronics test stand – Caltech Completed ✓
- » Fixturing for Telescope testing – Caltech – May 2011

Final Design Review – June 2011

Rework First Article Telescope in time for Long Arm Test

