# Telescope Development for Space-based Gravitational Wave Observatories

Jeff Livas
NASA Goddard Space Flight Center
September 2015

# Telescopes for Space-Based Gravitational-Wave Observatories: High-level Summary

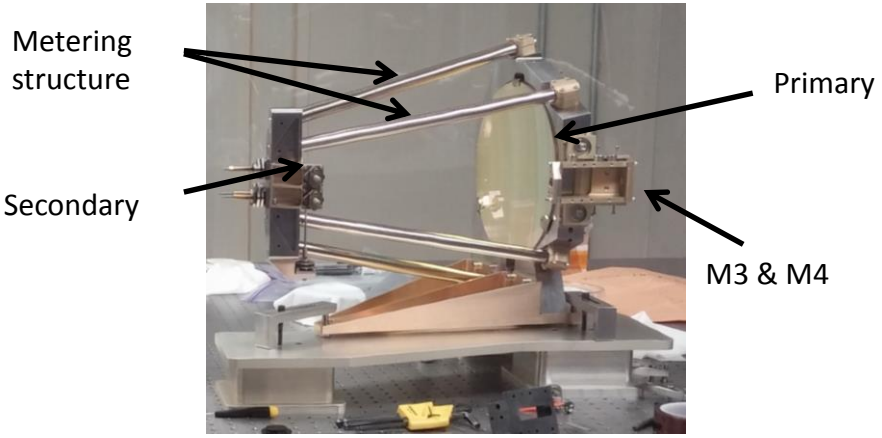
## Objectives and Key Challenges:

- Establish a complete telescope design meeting optical, mechanical, thermal, and manufacturability requirements for possible US contribution to the eLISA L3 mission
- Fabricate and test a prototype
- Validate stray-light model
- Verify dimensional stability

## Significance of Work:

- First demonstration of a validated scattered-light model, and combined with previous demonstration of dimensional stability, provides a firm basis for realistic engineering-model design for a flight-qualifiable off-axis telescope.

**Off-axis Prototype Model**
**Afocal modified Cassegrain**




## Approach:

- Use SGO-Mid and the ESA eLISA concepts as a reference
- Generate requirements per the ESA/SRE "Yellow Book"
- Use outside vendor design study results
    - (off-axis SiC recommended)
- Fabricate a prototype from the design
- Validate stray light model
- Need another iteration to demonstrate stability

## Key Collaborators:

- NASA Goddard optics branch
- Mechanical contractor Justin Ward
- Postdoc Shannon Sankar and Prof. Guido Mueller

## Current Funded Period of Performance:

- Oct 2012 – Sep 2015 NASA HQ SAT grant: scattered light
- Oct 2015 – Sep 2017 follow-on SAT grant: dimensional stability

## Recent Accomplishments:

- ✓ Signed prototype model contract
- ✓ Prototype CDR
- ✓ Prototype telescope delivered to GSFC
- ✓ Aligned prototype telescope at GSFC

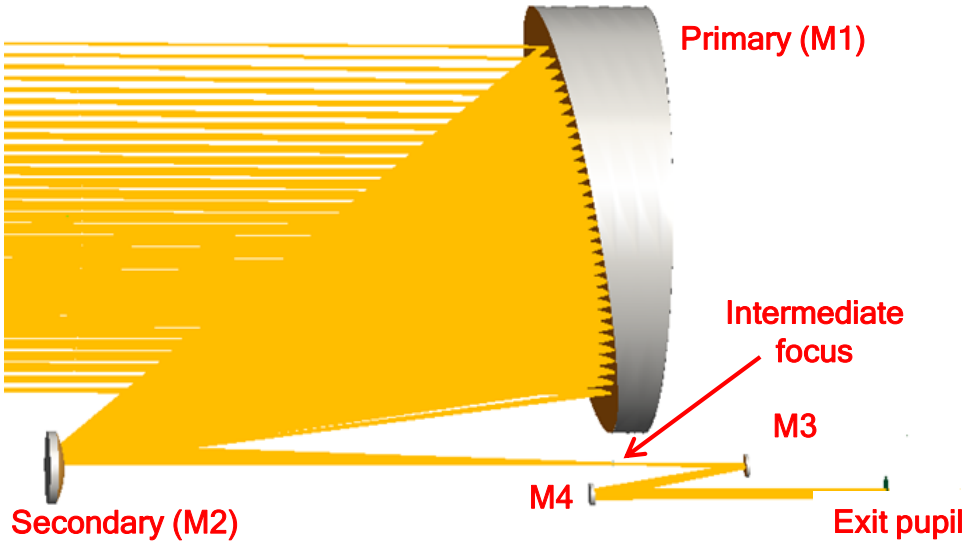
## Next Milestone:

- Validate system-level scattered-light model (Sep 2015)

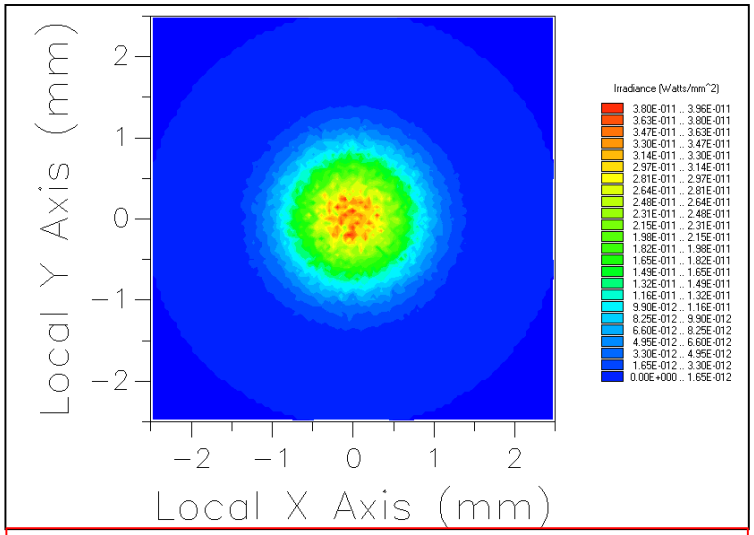
## Applications:

- Flagship gravitational-wave missions (eLISA)
- Laser ranging; precision metrology applications
- Laser communications

# Scattered Light Analysis




## Pupil Plane Scatter Irradiance




| Mirror | RMS surface roughness (Å) | MIL-STD 1246D CL |
|---|---|---|
| M1 | 15 | 300 |
| M2 | 15 | 200 |
| M3 | 5 | 200 |
| M4 | 5 | 200 |

**Conflicting accounts of on-orbit levels**

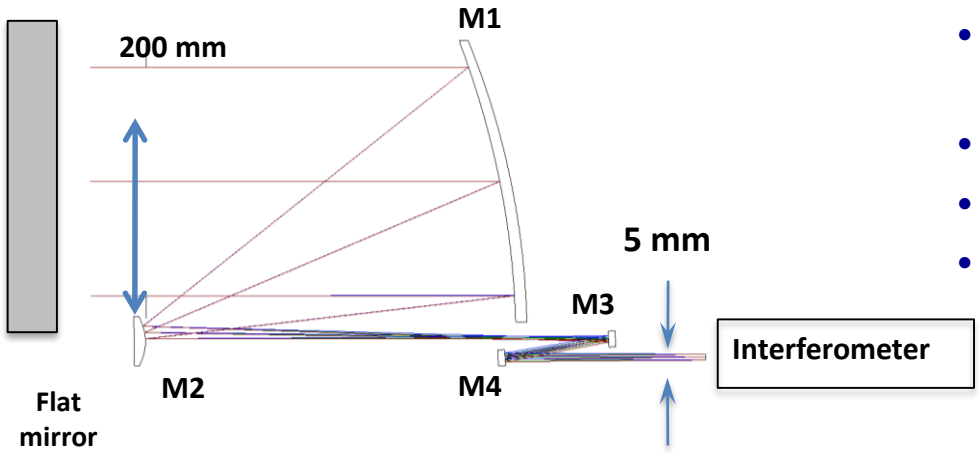
- Source power = 1W
- Total power on the detector = $6.6 \times 10^{-11}$ W → (barely) meets specification of less than $10^{-10}$

| mirror | Path# | # Rays | Power % | Power | 1st scatter surface |
|---|---|---|---|---|---|
| 3 | 7 | 2291695 | 74.947 | 4.9421e-11 | .20140417_elisa_baseline.M3.Front |
| 4 | 3 | 2711030 | 23.053 | 1.5201e-11 | .20140417_elisa_baseline.M4.Front |
| 2 | 11 | 2565386 | 1.9733 | 1.3012e-12 | .20140417_elisa_baseline.M2.Front |
| 1 | 14 | 1399213 | 0.026184 | 1.7266e-14 | .20140417_elisa_baseline.M1.Front |
| Totals | | 8967324 | 100 | 6.5941e-11 | |

**M3 and M4 contribute most of the scattered light on the detector**

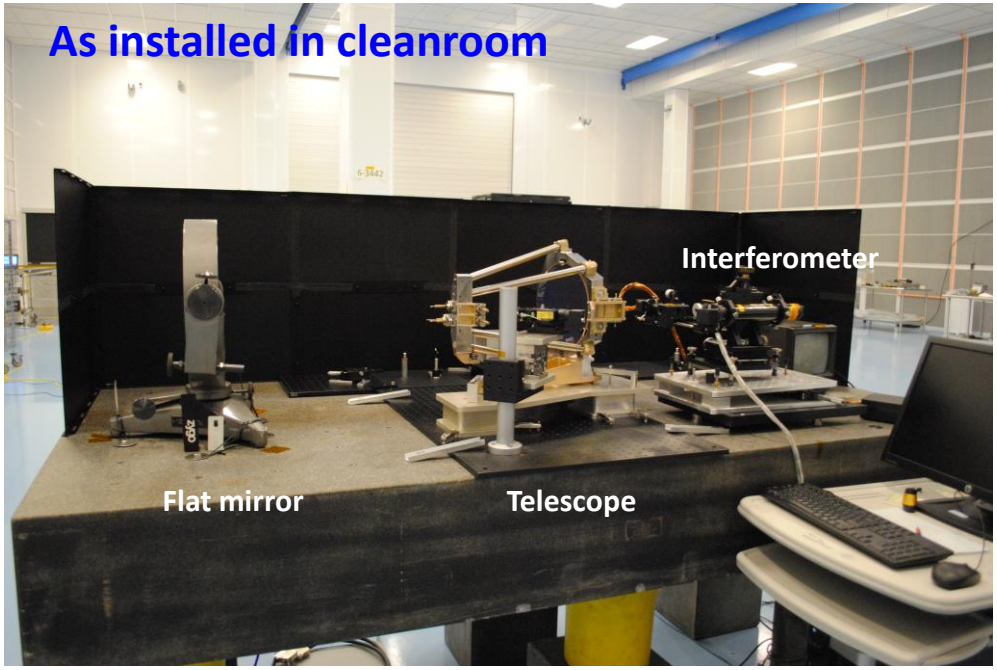
# Optical Test Setup: Current Status

## Optical Layout




- Telescope to be tested double-pass from the small aperture side
- Currently aligned to better than $\lambda/30$
- Room temperature operation only
- Seems to be stable under normal lab conditions

## As installed in cleanroom




- Currently installing 1064 nm laser and test equipment
- Verify the same alignment at 1064 nm as with 633 nm interferometer
- Next step is to start measuring scattering