SAND2007-7110C

Space Telescope Design, Analysis, Modeling

Directions & Needs

US-Europe Workshop on
Adaptive Aerospace Structures and Materials:
Current Capabilities, Future Requirements and Developments

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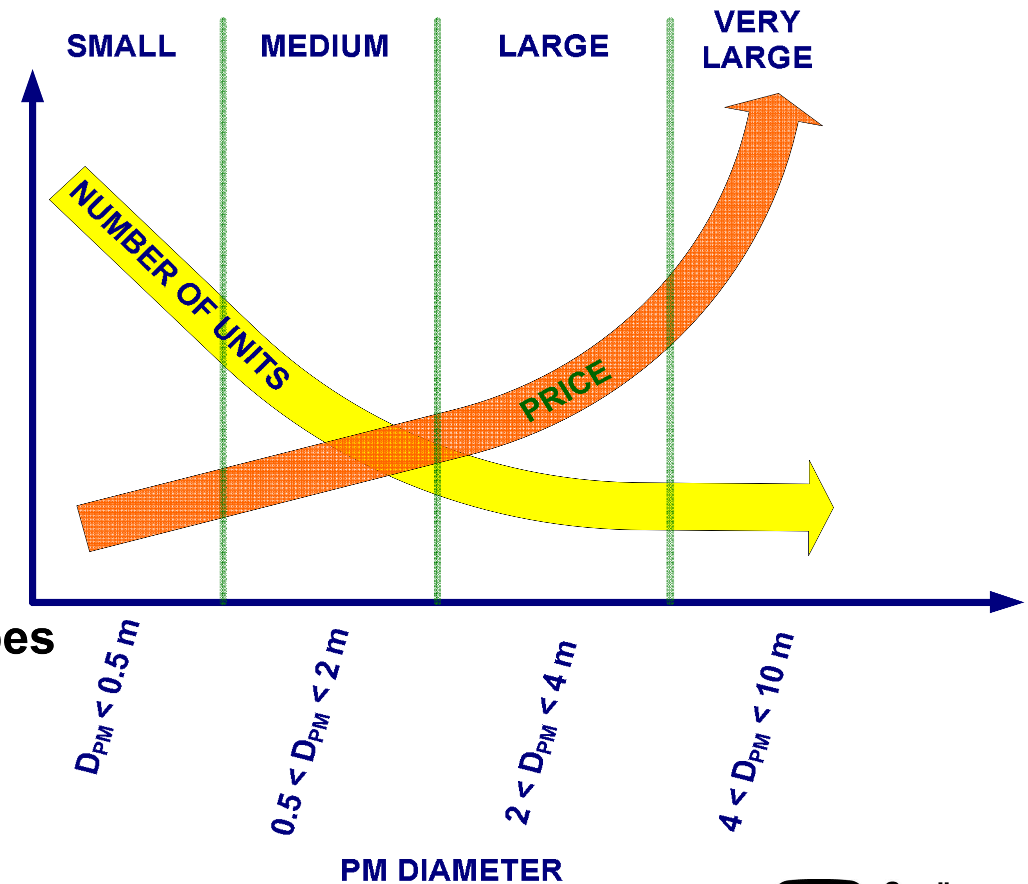
Overview

- **Objective**
  - Contribute some planks to the platform on which to base discussions in the Space Telescopes Theme Area
- **Background**
  - Characteristics of "Future Space Telescopes"
- **Modeling of Space Telescopes**
  - On-orbit, deployed configuration
- **Challenges and opportunities for active structures**

What are "Future Space Telescopes"?

- **Small (PM < 0.5 m)**
  - **Reflective & refractive systems**
  - **Primary payloads, secondary payloads, small instruments**
- **Medium (0.5 – 2 m PM)**
  - **Primary payloads**
- **Large (2 – 4 m PM)**
  - **Hubble class**
- **Very Large (4 – 10 m PM)**
  - **JWST class**
- **Others**
  - **X-ray grazing mirror telescopes**



Problems and opportunities depend on class

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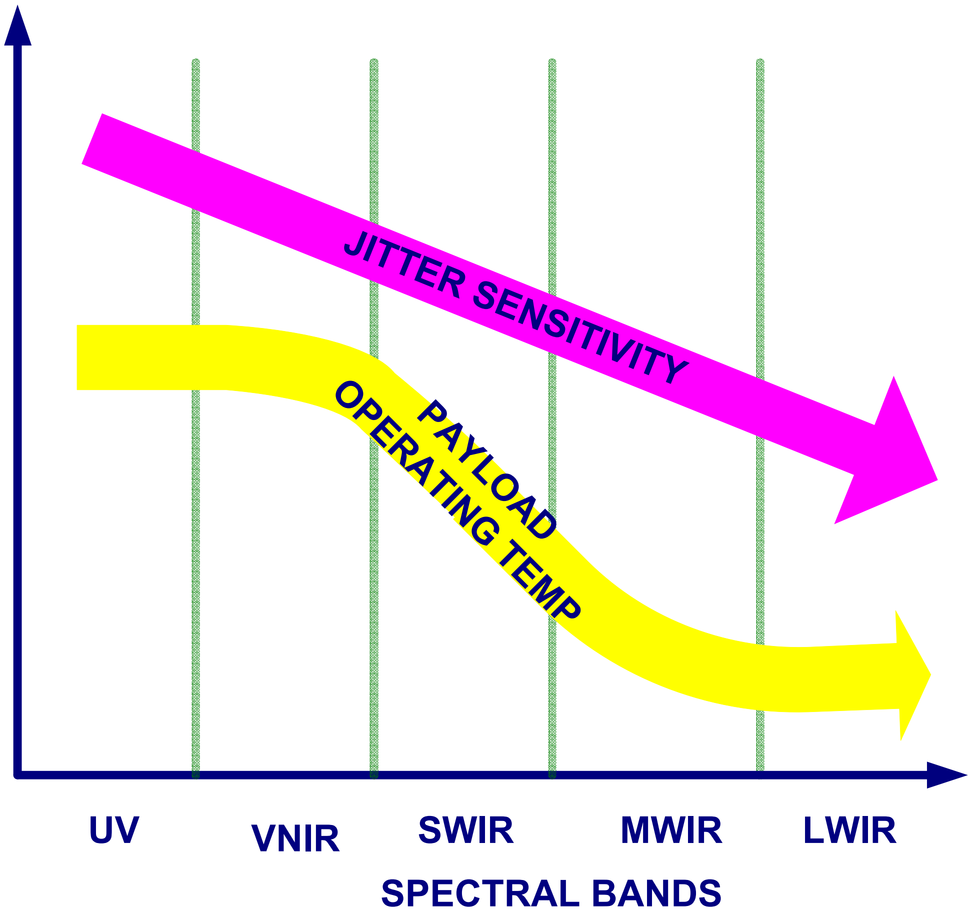
Types of Future Space Telescope Missions

- Earth Remote Sensing
  - Science, Military, Commercial
  - Spectral Bands
    - VNIR – LWIR
    - Radar
  - Monolithic, deployable, sparse PM designs
- Astronomy
  - Science
  - Interferometry, Imaging
  - Spectral Bands
    - X-Ray- UV - LWIR



ERS Drivers for Future Space Telescope

- **Non-commercial non-science ERS**
  - **The desire for persistence (near continuous coverage of a target) drives systems in 2 directions**
    - **Constellation of LEO imagers**
      - **Inexpensive, reliable, quick launch**
    - **Very large aperture GEO or HEO systems**
      - **Lightweight, packaged**
- **Commercial ERS**
  - **Mapping, Resource monitoring**
    - **Inexpensive, reliable**
      - **3rd world countries desire imaging satellites**

Science & Astronomy Drivers

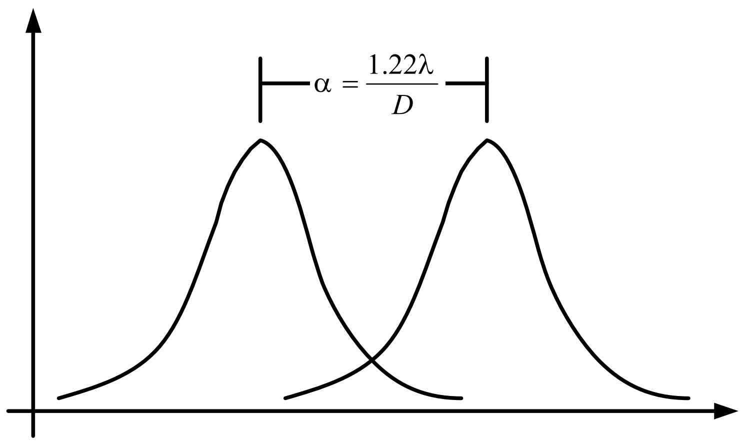
- Missions from X-ray to IR
  - Grazing incidence mirrors to very large parabolic mirrors
- In 2005 NASA identified 6 areas critical to enabling future space telescopes*
  - Optics
  - Wavefront sensing and control, and interferometry
  - Distributed and advanced spacecraft systems
  - Cryogenic and thermal control systems
  - Large precision structures for observatories
  - Infrastructure essential to future space telescopes and observatories
- The key is lightweight, low cost large optics
  - < 3 kg/m^2 areal density
  - < 0.1 $\$M/m^2$ areal cost
  - Reduced fabrication time
    - mirrors are always the longest lead items

*Stahl, Phil, *NASA defines mirror technology needs for future space telescopes, http://spie.org/x8715.xml*

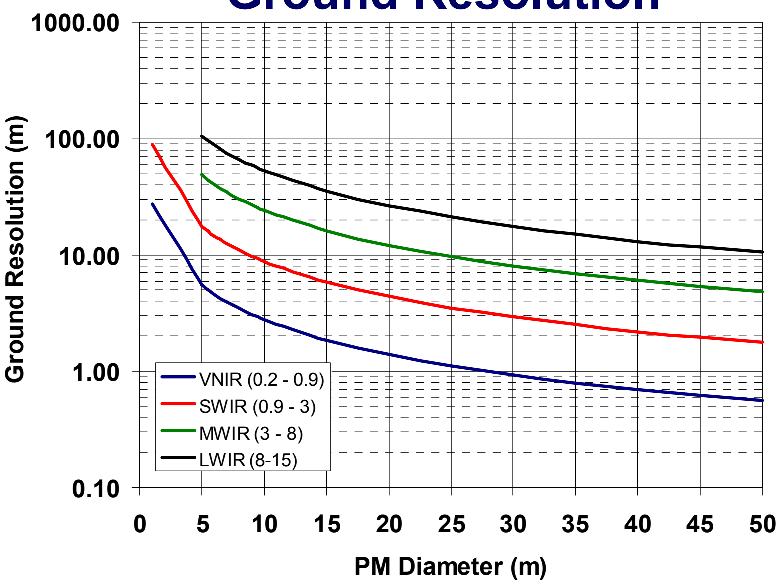
Fundamental Size Constraints

- The minimum ground resolution is limited by fundamental physics
- Diffraction limited conventional optics provide the most efficient performance for their size

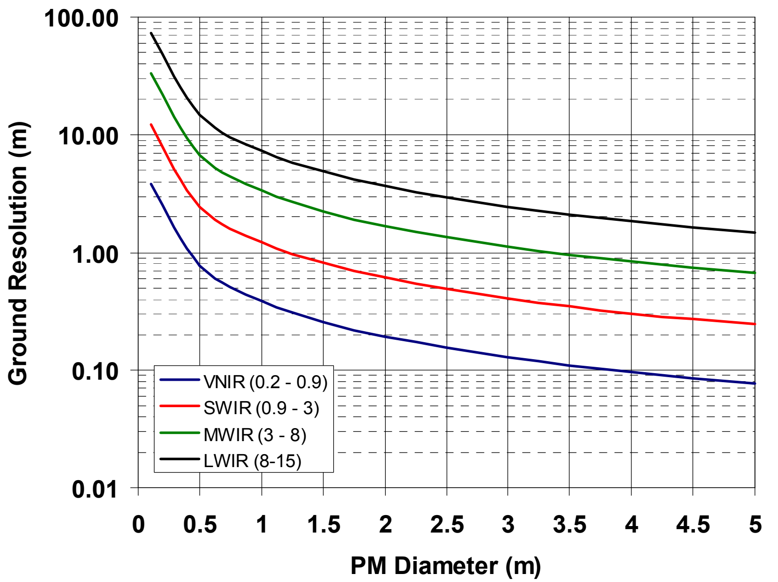
$$GSD = \frac{1.22\lambda}{D\sin(EL)}h$$



GEO Diffraction Limited Ground Resolution



LEO (500 km) Diffraction Limited Ground Resolution



Space Telescope Configurations

- Non-deployable systems
  - On-orbit configuration is very similar to stowed (launch) configuration
    - Launch locks must be released
    - Perhaps solar arrays or communications antennas require deployment
  - Typical of small – large systems
- Deployable systems
  - Applies only very large systems with launch vehicle shroud constraints
  - Many designs
    - None are space proven

Challenges in Modeling Future Space Telescopes

- We know how to model and build non-deployable telescopes
- Challenges
  - How can we improve modeling to enable more robust and tunable designs?
  - How can active materials and structure concepts advance this goal?
- Implications
  - Improved optical performance
  - Reduced system optical performance testing
  - Easier (late) system alignment
  - New system designs

Improved confidence in modeling and analysis results

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Challenges in Modeling Future Space Telescopes

- Performance of deployable systems will not be testable prior to launch
  - Represents a huge paradigm shift with implications for modeling and analysis
- Challenges
  - How do we design and analyze space telescopes in this new paradigm?
  - What role do active materials and structures have in this "new" paradigm?
- Implications
  - Increased emphasis on subsystem V&V
  - Improvements in predictive modeling at the system level
  - On-orbit structural tuning will be required

Modeling and Analysis

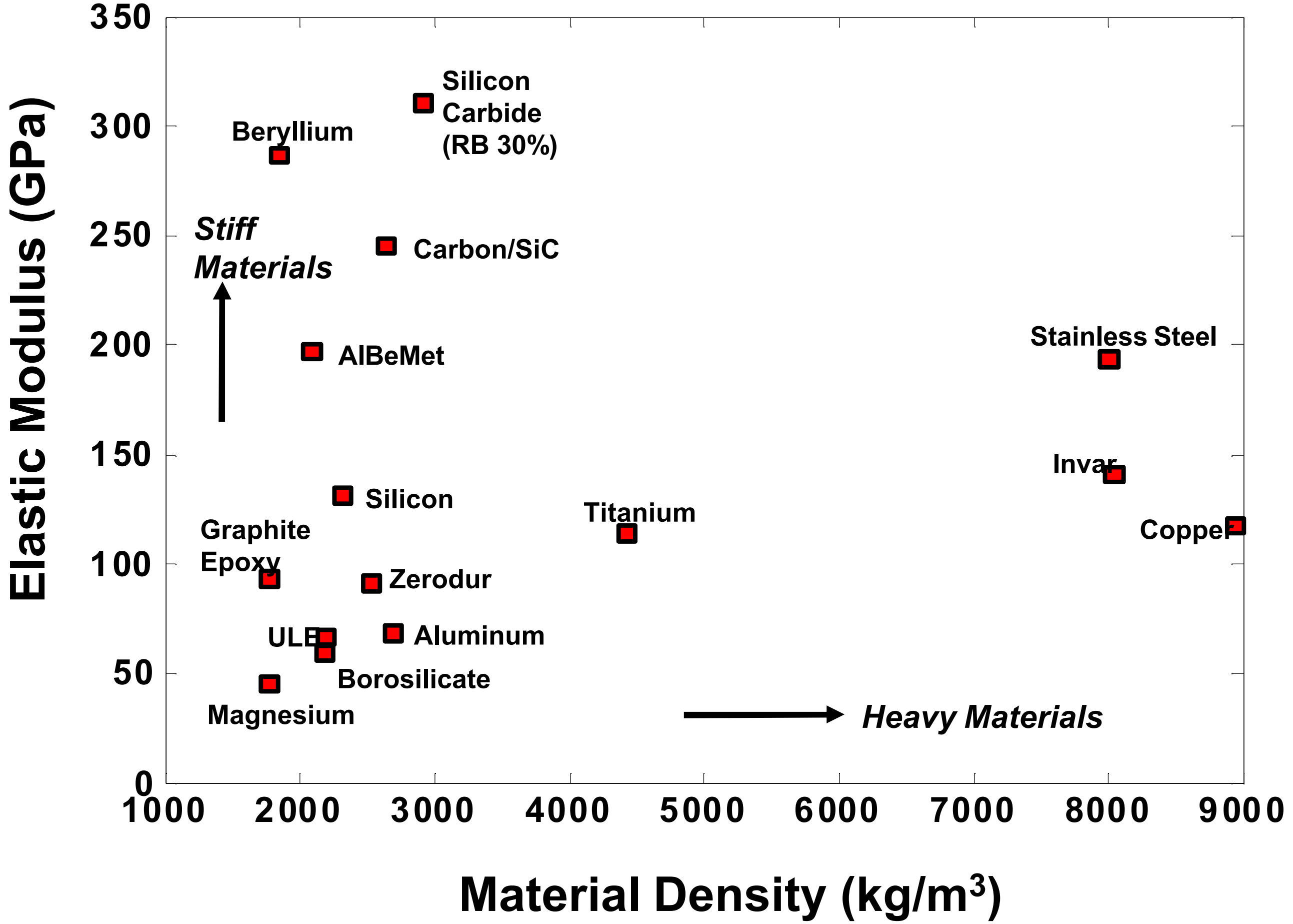
- Improve subsystem model correlation and validation
  - Bottom up approach
- Understand and use previously neglected structural components
  - Cable harnesses
    - Mass fractions up to 30%
    - Stiffness and damping contributions have been ignored
- Identify dominant uncertain parameters
- Incorporate uncertainty into performance predictions
- Untangle model errors from system uncertainties
  - Understand modeling and analysis expectations

There will always be a "leap of faith" that the design realization will satisfy successful system operation

If you rely on modeling you better do it right!

Figures of Merit for Space Telescope Materials

- Specific Stiffness E/ρ –stiffness to weight ratio
  - High specific stiffness minimizes gravity sag and maximizes stiffness



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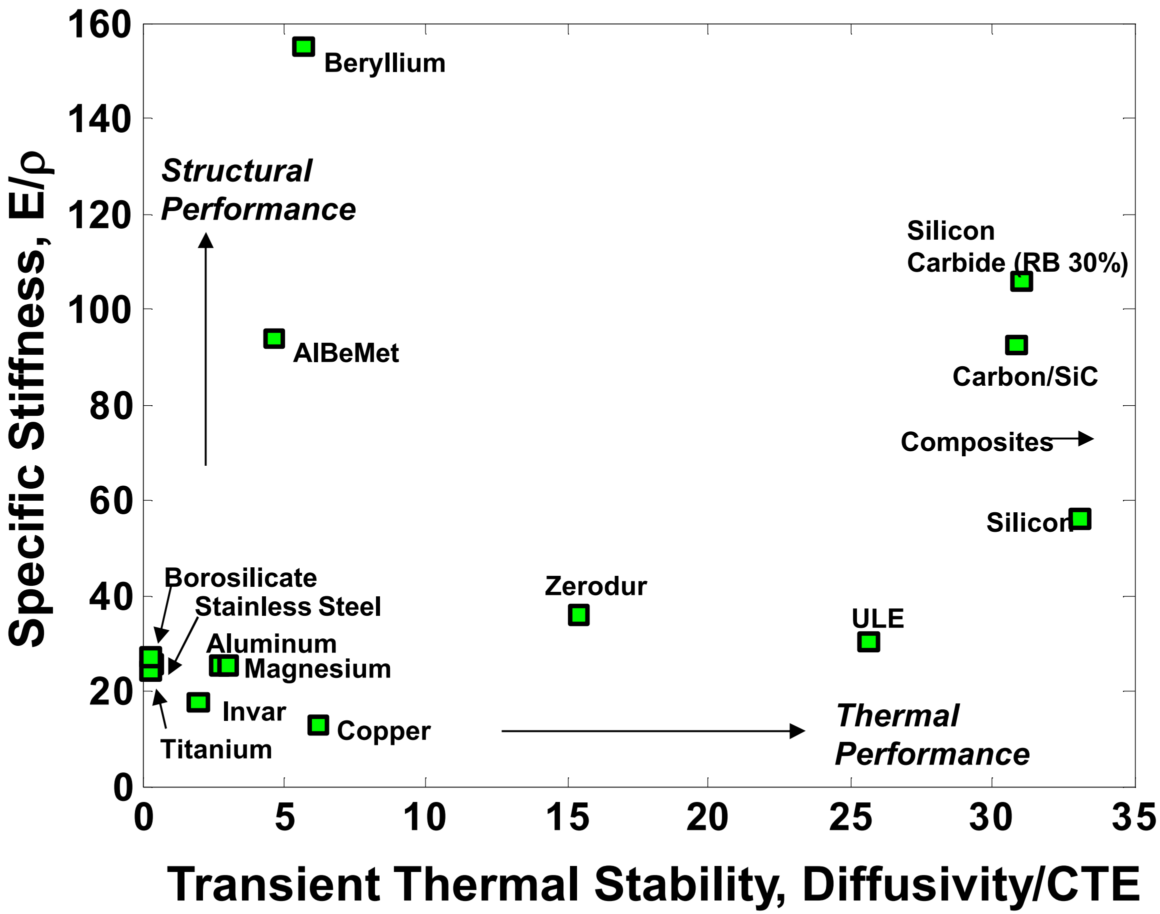
Figures of Merit for Space Telescope Materials

- Steady-state thermal distortion K/α
  - High K/α minimizes the presence and response to thermal gradients
- Transient thermal distortion D/α
  - High D/α minimizes the time of transient thermal gradients



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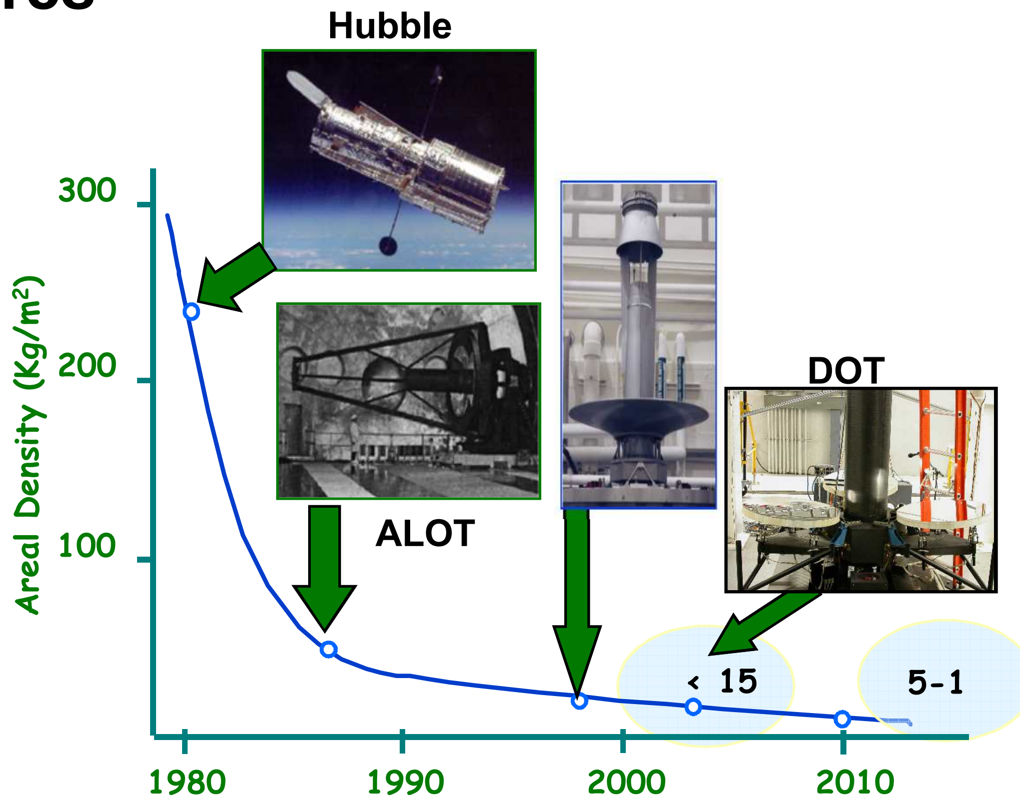
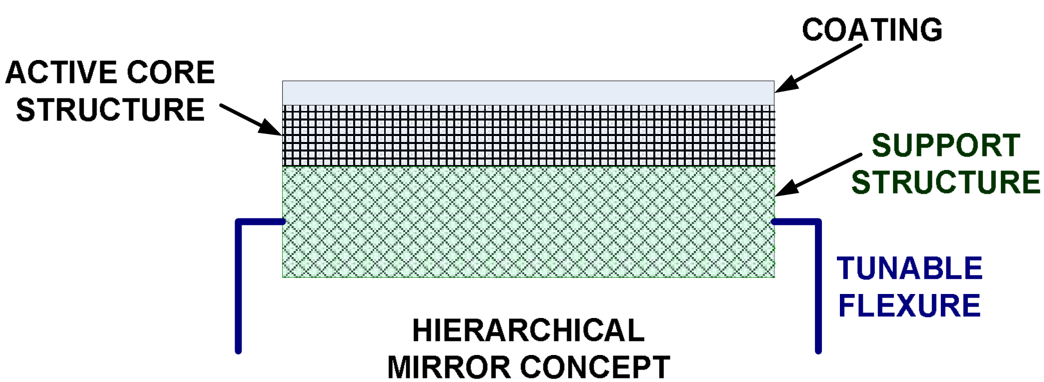
Active structures

- Enable further reductions in primary mirror areal density and areal cost
- Solve fundamental problems in thin film mirrors
  - Residual packaging stress distortions
  - Edge effect distortions
- Enable on-orbit system identification and structural tuning



Phil Stahl, 2001 NASA Mirror Development Technology Days Briefing



Summary

- **Modeling & Analysis**
- **TBD**
- **Active Materials**
- **TBD**

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  - Jeffery Martin (Sandia National Labs)
  - Vic Genberg (Sigmadyne)
  - Phil Stahl (MSFC)
    - Material found on the Web

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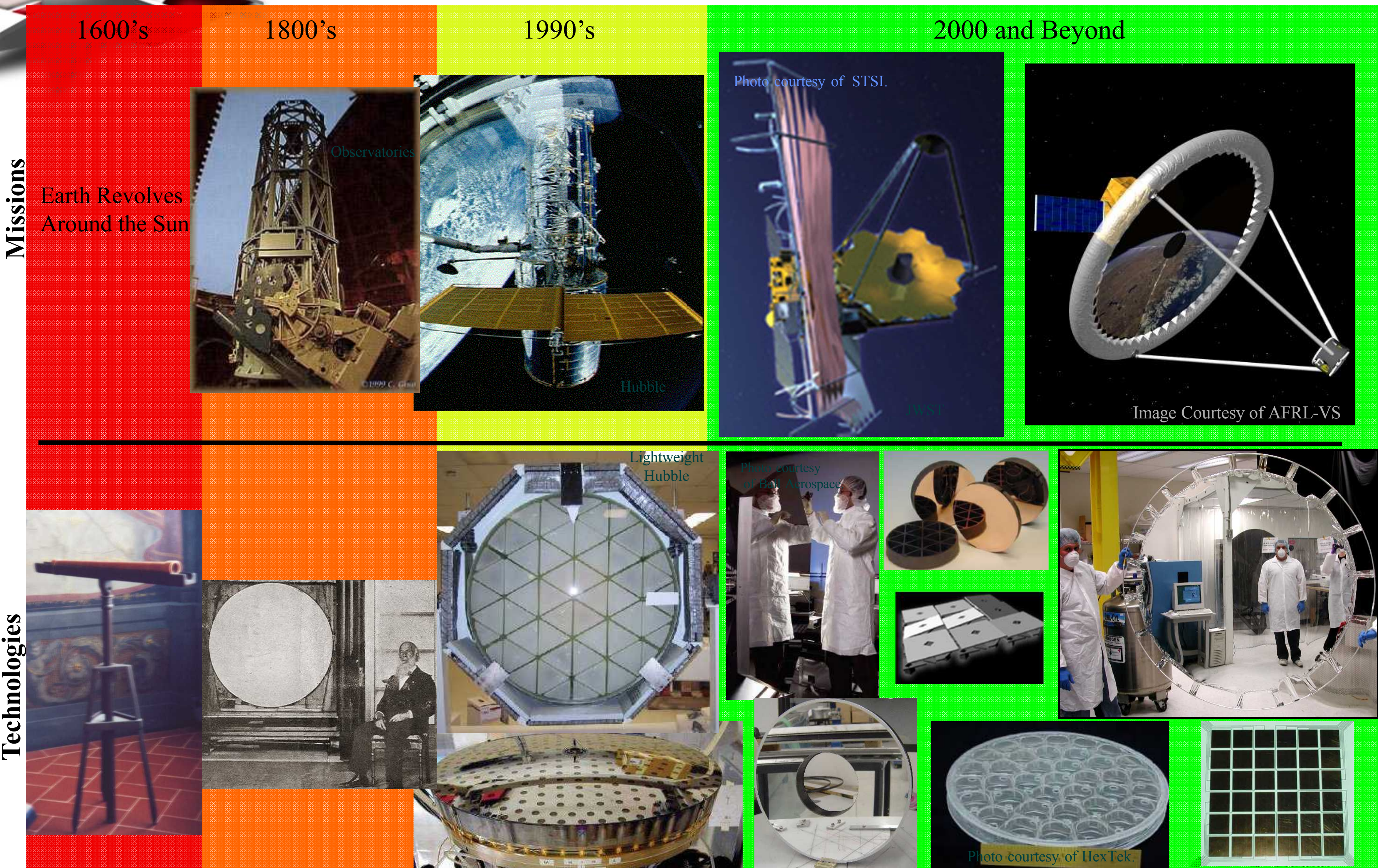
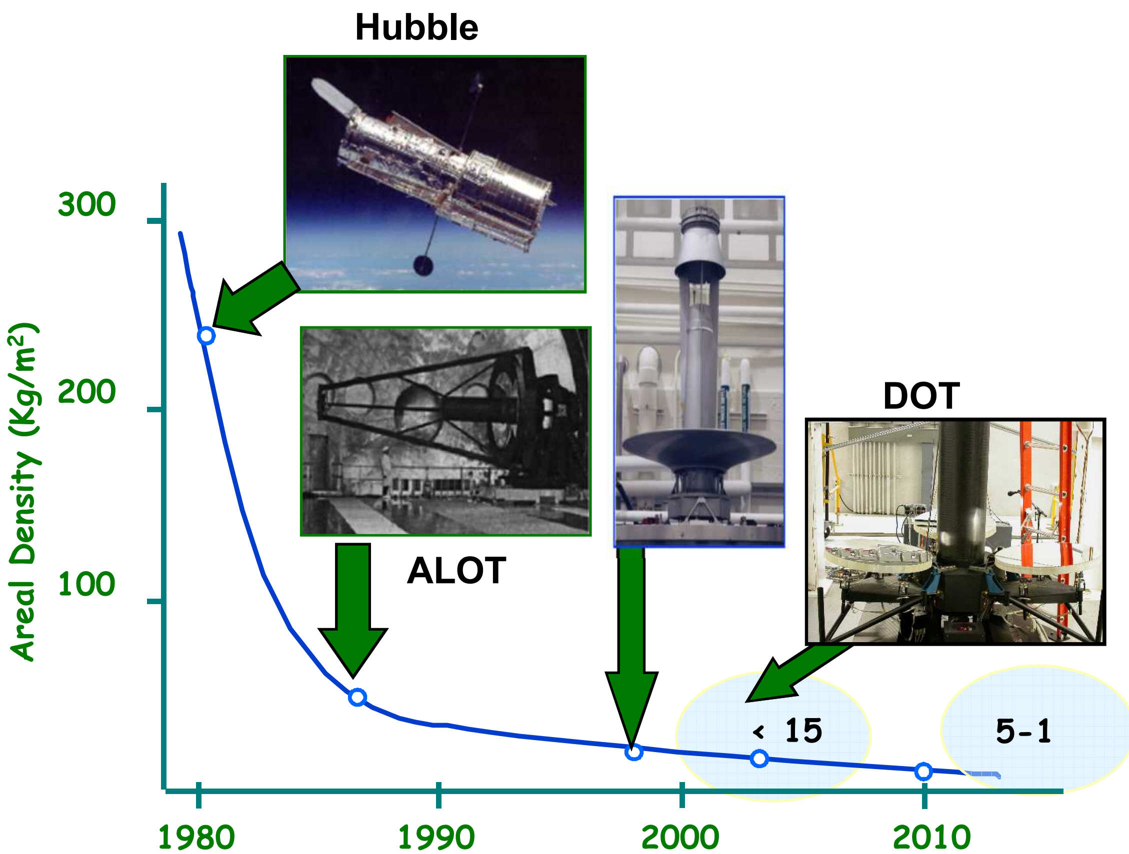
Back-up

Evolution of Optics to Today and Beyond




Hubble
ALOT
DOT
Areal Density (Kg/m^2)
300
200
100
1980
1990
2000
2010
< 15
5-1