S2 Topic Summary

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S2 “Advanced Telescope Systems”

- S2.01 **Proximity Glare Suppression for Astronomical Coronagraphy**
  S2.02 **Precision Deployable Optical Structures and Metrology**
  S2.03 **Advanced Optical Component Systems**
  S2.04 **Optics Manufacturing and Metrology for Telescope Optical Surfaces**

SMD SBIR Technology Areas – S2.01, JPL

Subtopic:	Proximity Glare Suppression for Astronomical Coronagraphy
Manager:	Subtopic Mgr: Stuart Shaklan, JPL
Center(s):	Lead Center: JPL; Participating Centers: ARC, GSFC

Starlight suppression technologies: hybrid metal/dielectric masks; pupil apodization technologies; systems to measure optical density and phase uniformity in apodizing masks	**Science Traceability**	AFTA Coronagraph (M. Levine) Exoplanet Exploration Program (G. Blackwood)
	Need Horizon	2-3 yrs, for mid-decade technology downselect
	State of Art	Hybrid masks have been used to achieve better than 1e9 contrast in 20% bandpass. Performance is limited by mask uniformity. Characterization is difficult due to high-resolution needs on sub-mm mask scale.
	Importance	AFTA needs complex circular masks. These have never been used for high contrast imaging. Equally important is the ability to characterize the masks.
Artificial star and planet sources, with programmable aberrated wavefront	**Science Traceability**	AFTA Coronagraph (M. Levine) Exoplanet Exploration Program (G. Blackwood)
	Need Horizon	2-3 yrs, for mid-decade technology downselect and
	State of Art	Simultaneous observations of an artificial planet and star at high contrast ratio have not been tried yet. A front-end telescope based on low-order DM has not been used with a coronagraph.
	Importance	An artificial planet is needed to prove efficacy of planet extraction algorithms. The deformable front-end telescope is needed to prove ability to measure and control time-variable wavefront.
Wavefront Measurement and Control Technologies: scale, low-order aberration sensing; process improvements for yield, precision, and repeatability	**Science Traceability**	AFTA Coronagraph (M. Levine) Exoplanet Exploration Program (G. Blackwood)
	Need Horizon	2-3 yrs, for mid-decade technology downselect
	State of Art	64 x 64 DM used for 1e-9 broadband contrast. <5 dead or poor actuators. 4K wires to mirror. Low-order wavefront sensor shown to work on paper but not for multiple aberrations in the laboratory.
	Importance	Only one vendor's mirrors have so far achieved < 1e-9 contrast. Competing. approaches including ongoing SBIR are improving reliability and scale of MEMs DMs. LOWFS is critical to success of AFTA.

SMD SBIR Proposed Technology Areas –S2.02, JPL (1/2)

Subtopic:	S2.02, Precision Deployable Optical Structures and Metrology
Manager:	Greg Agnes (Lead), JPL; Rajeev Sharma, GSFC; Keith Belvin, LaRC
Center(s):	JPL (Lead), GSFC, LaRC

Precision deployable structures and metrology for optical telescopes (e.g., innovative active or passive deployable primary or secondary support structures);
• Architectures, packaging and deployment designs for large sunshields and external occulters.
Important subsystem considerations may include:
• Innovative concepts for packaging fully integrated subsystems (e.g., power distribution, sensing, and control components) into multifunctional structures;
• Mechanical, inflatable, or other precision deployable technologies;
• Thermally-stable materials (CTE < 1ppm) for deployable structures;
• Innovative systems, which minimize complexity, mass, power and cost;
• Innovative testing and verification methodologies.

Science Traceability	Astrophysics missions: AFTA/WFIRST and the New Worlds Technology Development Program (coronagraph, external occulter, and interferometer technologies); and the ground-based Cerro Chajnantor Atacama Telescope (CCAT).
Need Horizon	5 to 10 years
State of Art	Current technology is represented by JWST technologies; structural components, rigid-body segment actuators, cabling, thermal control, and actuation are all separate, resulting in high-cost, high-mass, high-complexity design, integration and test. Mission concepts for New Worlds science require 10-30 m class, cost-effective telescopes, diffraction limited from visible to far IR, operating from 4-300 K, with areal densities 1-10 kg/m^2, and packaging efficiencies of 3-10 deployed/stowed diameter. They require static and dynamic wavefront error tolerances to thermal and dynamic perturbations, large deployable sunshades for passive thermal control, and 20m to 50m class external occulters.
Importance	(1) Very High – Critical need, no feasible competitors: Current technology is passive and deployment considered risky. While JWST will demonstrate some technology, future missions will require improved packaging efficiency, lighter mass, adaptive structural alignment/stability.

SMD SBIR Proposed Technology Areas –S2.02, JPL (2/2)

Subtopic:	S2.02, Precision Deployable Optical Structures and Metrology
Manager:	Greg Agnes (Lead), JPL; Rajeev Sharma, GSFC; Keith Belvin, LaRC
Center(s):	JPL (Lead), GSFC, LaRC

Additional risk reduction in operating an actively controlled telescope in orbit, via cost-effective, deployable apertures which conform to CubeSat (up to 6U) or ESPA format.

Demonstrate <10 micron deployment repeatability and sub-micron stability for both thermal and mechanical on-orbit disturbances.

Fabricate demonstration components and subsystems with direct scalability to flight systems through validated models.

Deliver a full-scale mechanism for a cubesat or ESPA ring compatible deployable aperture for Phase I, and a deployable optical metering structure with mock optical elements for Phase II.

Science Traceability	Astrophysics missions: AFTA/WFIRST and the New Worlds Technology Development Program (coronagraph, external occulter, and interferometer technologies); and the ground-based Cerro Chajnantor Atacama Telescope (CCAT)
Need Horizon	5 to 10 years
State of Art	Current technology is represented by JWST technologies; structural components, rigid-body segment actuators, cabling, thermal control, and actuation are all separate, resulting in high-cost, high-mass, high-complexity design, integration and test. The goal for this effort is to mature technologies that can be used to fabricate 16 m class or greater, lightweight, ambient or cryogenic flight-qualified observatory systems.
Importance	(1) Very High – Critical need, no feasible competitors: Risk reduction in operating actively controlled telescopes in orbit

SMD SBIR Proposed Technology Areas – (S2.03, MSFC)

Subtopic:	S2.03 Advanced Optical Systems
Manager:	H. Philip Stahl, MSFC (lead); Peter Blake, GSFC & Stuart Shaklan, JPL (participating)
Center(s):	MSFC (lead) GSFC & JPL (participating)

Affordable High-Performance Optical Component Systems for large aperture EUV, X-Ray, UV/Optical, Infrared Space Telescopes.

Metrics
- Areal Cost < $100k/m2
- Aperture 1 to 4 meters
- Wavefront Figure < 10 nm rms (for UV/Optical)
- Cryo-defomation < 100 nm rms (for Infrared)
- Angular Resolution < 1 arc-sec (for x-ray)
- Slope < 0.1 micro-radian (for EUV)

Ability to fully characterize x-ray mirror optical surface and predict angular resolution performance **(NEW)**

Science Traceability	Astrophysics 2010 Decadal calls for mirror technology investment for: International X-Ray Observatory (IXO) and Future x-ray mission (Gen-X); Future UV/Optical and Exo-Planet missions (THEIA or ATLAST) Heliophysics 2009 Roadmap identifies mirror technology investments useful for: Origins of Near-Earth Plasma (ONEP); Ion-Neutral Coupling in the Atmosphere (INCA); Dynamic Geospace Coupling (DGC); Fine-scale Advanced Coronal Transition-Region Spectrograph (FACTS); Reconnection and Micro-scale (RAM); & Solar-C NRC NASA Technology Roadmap Assessment ranks Low-Cost High-Performance Telescopes as the highest technology priority to: Enhance & expand searches for the first stars, galaxies, & black holes, and understand the universe. Potential future Infrared missions include: SAFIR, CALISTO
Need Horizon	Technology Investment is needed now – 1 to 3 years. Affordable high-performance optical system technology needs to achieve TRL-6 by 2018 to support 2020 Decadal process. Heliophysics need is sooner. Historically, it takes 10 years to mature mirror technology from TRL-3 to 6. To achieve these objectives requires sustained systematic investment.
State of Art	SOA Metrics as defined by JWST, Con-X and Heliophysics Areal Cost < $4-6M/m2 Aperture 1.5 meters Wavefront Figure < 40 nm rms Cryo-defomation < 200 nm rms Resolution < 15 arc-sec Slope ~ 0.3 micro-radian
Importance	Very High: NRC NASA Technology Roadmap Assessment states that new, ultra-stable, normal and grazing incidence mirrors to enable Low-Cost, High-Performance New Astronomical Telescopes as the most important challenge for Objective C (Expanding Knowledge of Earth and Universe).

Subtopic:	**S2.04 Optics Manufacturing and Metrology for Telescope Optical Surfaces**
Manager:	Peter Hill and Petar Arsenovic (GSFC/Code 551)
Center(s):	GSFC, JPL, MSFC

1. Innovative metal mirror substrate materials or manufacturing methods such as welding component segments into one monolith that produce thin mirror substrates that are stiffer and/or lighter than existing materials or methods.
2. Interferometric nulling optics for very shallow conical optics used in x-ray telescopes.
3. Segmented systems commonly span 60 degrees in azimuth and 200 mm axial length and cone angles vary from 0.1 to 1 degree.
4. Low stress metrology mounts that can hold optics without introducing mounting distortion.
5. Low normal force figuring/polishing systems operating in the 1 mm to 50 mm period range with minimal impact at significantly smaller and larger period ranges.
6. In-situ metrology systems that can measure optics and provide feedback to figuring/polishing instruments without removing the part from the spindle.
7. Innovative mirror substrate materials or manufacturing methods that produce thin mirror substrates that are stiffer and/or lighter than existing materials or methods
8. Extreme aspheric and/or anamorphic optics for pupil intensity amplitude apodization.
9. Metrology systems useful for measuring large optics with high precision.
10. Innovative method of bonding extremely lightweight (less than 1 kg/m2 areal density) and thin (less than 1 mm) mirrors to a housing structure, preserving both alignment and figure.
11. Innovative method of improving the figure of extremely lightweight and thin mirrors without polishing, such as using the coating stress.
12. Manufacturing technology and wavefront sensing and control as applied to coronagraph applications for exoplanet detection.

Science Traceability	The 2010 National Academy Astro2010 Decadal Report specifically identifies optical components and the ability to manufacture and perform precise metrology on them needed to enable several different future missions, including: • Light-weight x-ray imaging mirrors for future very large advanced x-ray observatories • Large aperture, light-weight mirrors for future UV/Optical telescopes • Broadband high reflectance coatings for future UV/Optical telescopes Potential Customers: • WFIRST concepts (http://wfirst.gsfc.nasa.gov/), • NGXO (http://ixo.gsfc.nasa.gov/), • SGO (http://lisa.gsfc.nasa.gov/)
Need Horizon	Depending on the innovation. New metrology techniques can be used in the NEAR-TERM, while new manufacturing techniques are most probably MID-TERM and FAR-TERM.
State of Art	At this point, it is very costly and time consuming to produce and measure the thousands of grazing incidence x-ray mirrors needed for a full system. We seek significant reduction in both expense and time. In-situ, non-contact metrology techniques are also critical for many flight missions, up to and including flagship class efforts such as JWST.
Importance	Very High – Critical need