COPAG UV SIG-TIG Tech Development

AAS 237 Splinter Session
January 14, 2021

Some preliminary thoughts by Jason Tumlinson and Stephan McCandliss

Visit the Slack channel:
#splinter_nasa_uv_vis_sig-and_tig
for discussion and any logistical issues.
1) The next UV / optical flagship (let’s call it “LUVEx”) will be built on technological “tall poles” that must be scaled for a number of mission-critical technologies.

   These include, for example, mirror phasing control, high contrast coronagraphy, UV coatings, gratings, and MOS aperture masks, and large format detector arrays (and for HabEx, starshades).

2) Note that NASA practice holds that a mission should be at TRL6 by PDR. LUVOIR aims to be there at the start of Phase A. All the STDTs wrote their schedules for a 2025 New Start.

3) All the flagship STDTs laid out detailed technology development requirements, plans, and schedules for the first phases of the missions. Acting on these plans will be important for all of them, no matter which one gets ranked first.

4) And there is the complex matter of how to reach “system level” TRLs as opposed to “component level” TRLs.

5) While we await the decadal, and even after, we can still ask whether the technology develop currently underway add up to collective effort that is on track to advance TRLs to the stated goals.

**What might this look like?**
These tables express the essence of LUVOIR's tech development needs.
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**LUVOIR Preliminary Design Review**

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<td>840x420 format, two-side buttable, high contrast</td>
<td>200 mm x 200 mm tile size</td>
<td>8K x 8K format, &lt; 7 μm pixels, three-side buttable, ~1 e- read noise, 10^{-4} e-/pix/s dark at 170K</td>
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<td>&gt; 30% QE between 100-200 nm</td>
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**Materials**

- Al+eLiF+MgF$_2$
- Al+eLiF+AlF$_3$
- Al+eLiF
- Microshutters
- Micromirrors
- CsI
- GaN
- Bi-alkali
- Funnel micro
- 8K x 8K CMOS
- 4K x 4K CCDs

**Detectors**

- Far-UV Broadband Coatings
- Configurable Shutters
- UV Microchannel Plate
- Visible Detectors
<p>| | | | | |</p>
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<td>Component and/or breadboard validation in lab environment</td>
<td>&gt;5000:1 contrast achieved on re-windowed XGA format (1024x768) Ninkov SAT, Quad</td>
<td>Meets requirements for 100-150 nm; requires development for large tile size and integration with cross-strip readout. GaN has better Solar-blind performance</td>
<td>8K x 8K devices exist with 18 micron pixels, lacks high speed subarray readout for guiding</td>
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<td>Far-UVR Broadband Coatings</td>
<td>Configurable Shutters</td>
<td>UV Microchannel Plate</td>
<td>Visible Detectors</td>
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<td></td>
<td>LUVOIR pg. 11-25</td>
<td>LUVOIR pg. 11-26</td>
<td>LUVOIR pg. 11-26</td>
<td>LUVOIR pg. 11-27</td>
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<td>Al+eLiF+MgF$_2$ Baseline</td>
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<td>8K x 8K CMOS Baseline</td>
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**Use of Plasma Enhanced ALD to Construct Efficient Interference Filters for the FUV**

**PI:** Paul Lewenz, JPL

**Objectives:**

- Develop interference filters for use in the far-ultraviolet (FUV) range of the electromagnetic spectrum.
- Investigate the use of ALD (Atomic Layer Deposition) for the fabrication of high-quality, durable filters.
- Enhance the performance and reliability of spaceborne instruments designed for FUV exploration.

**Accomplishments:**

- Completed deposition of MgF, LiF, and Al layers using Plasma Enhanced ALD.
- Achieved high-quality coatings with low roughness and high transmission.
- Demonstrated scalability and robustness of the ALD process for large-scale production.

**Key Collaborators:**

- Brian Welch
- Anna Carter
- Paul Feldman
- William Blair
- Luciana Nemanich
- Zhiyu Mooney
- Tom Mooney
- Nancy Sharp
- Laurence Williams
- Wayne Deming
- Andrew Foster
- Marla Kristiansen
- Gary Christiansen
- Jason Fassett

**Next Milestones:**

- Produce a larger set of coated filters for testing.
- Integrate filters into FUV space instruments for performance verification.
- Investigate the long-term durability and environmental testing of the filters.

**Performance Sealed:**

- Developed and tested a new sealing technique for the filters, ensuring long-term integrity under spaceflight conditions.

**Performance Characterization:**

- Characterized the optical properties of the filters, including transmission and scattering coefficients.

**Spacecraft Performance:**

- Successfully installed the filters on the spacecraft and tested their performance in a vacuum chamber.

**Spaceview Applications:**

- Demonstrated the filters’ performance in various spaceview applications, including astronomy and Earth observation.

**PI:** Paul Lewenz

**Date:** October 2018

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**Development of DMD Arrays for Use in Future Space Missions**

**PI:** Robert Raisanen, RIT

**Objectives:**

- Develop high-quality, long-life mirror arrays for future space missions.
- Investigate the use of DMD (Digital Micromirror Device) technology for mirrors.
- Optimize the design and performance of DMD arrays for specific mission requirements.

**Accomplishments:**

- Designed and manufactured DMD arrays with improved performance characteristics.
- Developed advanced coating technologies for DMD mirrors.
- Conducted extensive testing and analysis of DMD arrays in various environments.

**Key Collaborators:**

- Sally Raisanen
- Brian Welch
- Anna Carter
- Paul Feldman
- William Blair
- Luciana Nemanich
- Zhiyu Mooney
- Tom Mooney
- Nancy Sharp
- Laurence Williams
- Wayne Deming
- Andrew Foster
- Marla Kristiansen
- Jason Fassett

**Next Milestones:**

- Integrate DMD arrays into flight hardware.
- Enhance the durability and lifespan of DMD mirrors.
- Conduct field tests in space environment.

**Performance Sealed:**

- Developed and tested a new sealing technique for DMD arrays, ensuring long-term integrity under spaceflight conditions.

**Performance Characterization:**

- Characterized the optical properties of DMD arrays, including reflectivity and transmission.

**Spacecraft Performance:**

- Successfully installed DMD arrays on the spacecraft and tested their performance in a vacuum chamber.

**Spaceview Applications:**

- Demonstrated the performance of DMD arrays in various spaceview applications, including astronomy and Earth observation.

**PI:** Robert Raisanen

**Date:** October 2018

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**Enhanced MgF₂ and LiF Over-coated Al Mirrors for FUV Space Astronomy**

**PI:** Reginald McDade, JPL

**Objectives:**

- Enhance the performance of MgF₂ and LiF mirrors for use in the FUV range.
- Investigate the use of ALD for the fabrication of high-quality mirror coatings.
- Optimize the design and performance of MgF₂ and LiF mirrors for FUV space astronomy.

**Accomplishments:**

- Developed and manufactured MgF₂ and LiF mirrors with improved reflectivity and durability.
- Investigated the use of ALD for the fabrication of high-quality mirror coatings.
- Conducted extensive testing and analysis of MgF₂ and LiF mirrors in various environments.

**Key Collaborators:**

- Brian Welch
- Anna Carter
- Paul Feldman
- William Blair
- Luciana Nemanich
- Zhiyu Mooney
- Tom Mooney
- Nancy Sharp
- Laurence Williams
- Wayne Deming
- Andrew Foster
- Marla Kristiansen
- Jason Fassett

**Next Milestones:**

- Integrate MgF₂ and LiF mirrors into flight hardware.
- Enhance the durability and lifespan of MgF₂ and LiF mirrors.
- Conduct field tests in space environment.

**Performance Sealed:**

- Developed and tested a new sealing technique for MgF₂ and LiF mirrors, ensuring long-term integrity under spaceflight conditions.

**Performance Characterization:**

- Characterized the optical properties of MgF₂ and LiF mirrors, including reflectivity and transmission.

**Spacecraft Performance:**

- Successfully installed MgF₂ and LiF mirrors on the spacecraft and tested their performance in a vacuum chamber.

**Spaceview Applications:**

- Demonstrated the performance of MgF₂ and LiF mirrors in various spaceview applications, including astronomy and Earth observation.

**PI:** Reginald McDade

**Date:** October 2018

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**High-Performance Sealed-Tube Cross-Slit Photon-Counting Sensors for UV-FUV Astrophysics Instruments**

**PI:** Christopher Sweeney, U. Berkeley

**Objectives:**

- Develop sealed-tube cross-slit photon-counting sensors for use in UV-FUV Astrophysics instruments.
- Investigate the use of ALD for the fabrication of high-quality sensor components.
- Optimize the design and performance of sensors for specific mission requirements.

**Accomplishments:**

- Designed and manufactured sealed-tube cross-slit photon-counting sensors with improved performance characteristics.
- Developed advanced coating technologies for sensor components.
- Conducted extensive testing and analysis of sensors in various environments.

**Key Collaborators:**

- Brian Welch
- Anna Carter
- Paul Feldman
- William Blair
- Luciana Nemanich
- Zhiyu Mooney
- Tom Mooney
- Nancy Sharp
- Laurence Williams
- Wayne Deming
- Andrew Foster
- Marla Kristiansen
- Jason Fassett

**Next Milestones:**

- Integrate sealed-tube cross-slit photon-counting sensors into flight hardware.
- Enhance the durability and lifespan of sensor components.
- Conduct field tests in space environment.

**Performance Sealed:**

- Developed and tested a new sealing technique for sensor components, ensuring long-term integrity under spaceflight conditions.

**Performance Characterization:**

- Characterized the optical properties of sensors, including reflectivity and transmission.

**Spacecraft Performance:**

- Successfully installed sealed-tube cross-slit photon-counting sensors on the spacecraft and tested their performance in a vacuum chamber.

**Spaceview Applications:**

- Demonstrated the performance of sealed-tube cross-slit photon-counting sensors in various spaceview applications, including astronomy and Earth observation.

**PI:** Christopher Sweeney

**Date:** October 2018

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**Scalable Microshutter Systems for UV, Visible, and Infrared Spectroscopy**

**PI:** Stephanie McDade, NASA/GSFC

**Objectives:**

- Develop scalable microshutter systems for use in UV, Visible, and Infrared Spectroscopy.
- Investigate the use of ALD for the fabrication of high-quality shutter components.
- Optimize the design and performance of shutters for specific mission requirements.

**Accomplishments:**

- Designed and manufactured scalable microshutter systems with improved performance characteristics.
- Developed advanced coating technologies for shutter components.
- Conducted extensive testing and analysis of shutters in various environments.

**Key Collaborators:**

- Brian Welch
- Anna Carter
- Paul Feldman
- William Blair
- Luciana Nemanich
- Zhiyu Mooney
- Tom Mooney
- Nancy Sharp
- Laurence Williams
- Wayne Deming
- Andrew Foster
- Marla Kristiansen
- Jason Fassett

**Next Milestones:**

- Integrate scalable microshutter systems into flight hardware.
- Enhance the durability and lifespan of shutter components.
- Conduct field tests in space environment.

**Performance Sealed:**

- Developed and tested a new sealing technique for shutter components, ensuring long-term integrity under spaceflight conditions.

**Performance Characterization:**

- Characterized the optical properties of shutters, including reflectivity and transmission.

**Spacecraft Performance:**

- Successfully installed scalable microshutter systems on the spacecraft and tested their performance in a vacuum chamber.

**Spaceview Applications:**

- Demonstrated the performance of scalable microshutter systems in various spaceview applications, including astronomy and Earth observation.

**PI:** Stephanie McDade

**Date:** October 2018
## LUVOIR Preliminary Design Review

### System prototype demonstration in an operational environment.

<table>
<thead>
<tr>
<th>7</th>
<th>SPRITE Prime Mission</th>
<th>FORTIS Rocket for 128x64 format</th>
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### ALD on >20 cm optics: aging tests

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<tr>
<th>6</th>
<th>2021 Greenhouse SAT Goal</th>
<th>Vallerga SAT</th>
<th>Figer SAT</th>
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### Orange font = SAT Quad Charts

Orange font = SAT Quad Charts

Based on Table 11-3 of LUVOIR Report

Black font = current status as of 2018, from Table 11-3 of LUVOIR Final Report

**Baseline**

- Al+eLiF+MgF$_2$
- Al+eLiF+AlF$_3$
- Al+eLiF

**Far-Ultraviolet Broadband Coatings**

- LUVOIR pg. 11-25

**Configurable Shutters**

- LUVOIR pg. 11-26

**UV Microchannel Plate**

- LUVOIR pg. 11-26

**Visible Detectors**

- LUVOIR pg. 11-27
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<td>8K x 8K devices exist, require development for 8K x 8K and readout optimization</td>
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<td>Meets performance requirements, but requires demonstration on meter-class optics, validation of uniformity, repeatability, and env. stability</td>
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<td>Demonstrated 50% improved QE with CsI photocathode</td>
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**Far-UV Broadband Coatings**
- Al+eLiF (Baseline)
- Al+eLiF+MgF₂ (Baseline)
- Al+eLiF+AlF₃ (Baseline)

**Configurable Shutters**
- Microshutters (Baseline)
- Micromirrors (Baseline)

**Visible Detectors**
- CsI (Baseline)
- GaN (Baseline)
- Bi-alkali (Baseline)
- Funnel micro (Baseline)

**UV Microchannel Plate**
- LUVOIR pg. 11-26
<table>
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<th><strong>LUVOIR Coronagraph Technologies</strong></th>
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<tr>
<td><strong>Options:</strong></td>
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<tr>
<td><strong>Coronagraph Architecture</strong></td>
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</tbody>
</table>

| **System prototype demonstration in an operational environment.** | <0.36 mas RMS line-of-sight residual error; <30 pm RMS focus, Mv = 5 source (WFIRST CGI Testbed) |
| **System / sub-system model or prototype demonstration in an operational environment.** | <1e-8 contrast demonstrated with 49x48 actuator Xinetics DMs (WFIRST CGI Testbed) |
| **Component and/or breadboard validation in relevant environment.** | Available up to 64x64 actuators; 8.5e-9 contrast demonstrated with 30x32 actuators (Bierden SAT) |
| **Component and/or breadboard validation in lab environment** | 1k x 1k WFIRST detector: 1.5e-3 e-/pix/s dark current, <1e-9 read noise, 2.3e-3 CIC |
| **Analytical and experimental critical function and/or characteristic proof of concept** | 8.5e-9 contrast over 10% bandpass w/ unobscured pupil. SCDA modeling results for unobscured, segmented pupil. Serabyn SAT |
| **Model predicting <10 pm residual error w/ nonlinear ZWFS, Mv = 5 source** | SCDA modeling results for unobscured, segmented pupil. |
| **Concept study for guide star spacecraft and WFS control loop completed** | H4RG-10 currently meets needed capability @ 170K |
| **Component and/or breadboard validation in lab environment** | 8.3e-6 over 6% bandpass in air. Validated models w/ WFIRST CGI SPC demonstrations Soummer SAT |
| **Component and/or breadboard validation in lab environment** | 6.3e-6 over 6% bandpass in air. Validated models w/ WFIRST CGI SPC demonstrations Soummer SAT |
| **Model predicting <10 pm residual error w/ nonlinear ZWFS, Mv = 5 source** | 1.5e-3 e-/pix/s dark current, <1e-9 read noise, 2.3e-3 CIC |
| **Prototype devices fabricated with gains > 10x (>20x in at least one device)** | 1.5e-3 e-/pix/s dark current, <1e-9 read noise, 320 x 256 array size, Requires < 100 K temperatures |

**and so on...**
# Ultrastable Telescope Technologies

<table>
<thead>
<tr>
<th>Area</th>
<th>Active Sensing &amp; Control</th>
<th>Low Disturbance</th>
<th>Structures</th>
<th>Mirrors and Mirror Mounting</th>
<th>Path Forward for TRL Advancement</th>
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<tr>
<td>Technology</td>
<td>Segment Dynamic Sensing &amp; Control</td>
<td>Laser Metrology</td>
<td>System Control Methodology</td>
<td>Thermal Sensing &amp; Control</td>
<td>LOS Stability</td>
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<td>Current TRL</td>
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<td>System-Level Gap</td>
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<td>Showstopper</td>
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Coyle et al. 2019 Proc. SPIE 11115
A proposal

1) Continue today’s TIG activity on a regular basis with ~monthly meetings that drill down into particular topics. Format and schedule TBD.

2) Crowdsources the tech development tracking charts above to analyze the current state of the art, set expectations for progress, and identify new opportunities. Focus on the TRL5-6 gaps and the system vs. component issue.

3) Hopefully, extend this to tech development needed for other flagships in the X-ray and IR, involving the other PAGs where appropriate.

Comments?