UVOIR Technology Overview

Cosmic Origins Program Analysis Group

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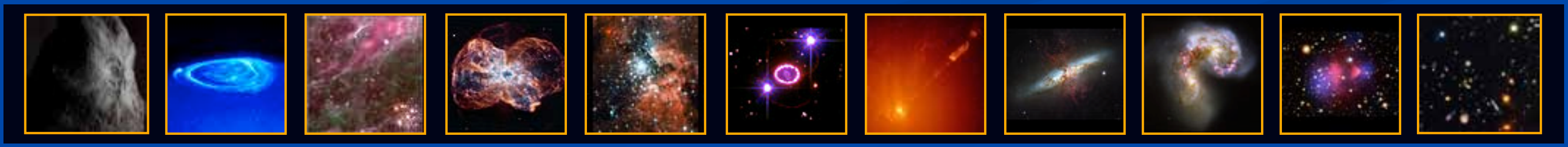


Technology Investment Areas

- **Determine technology focus areas for a large UVOIR mission in the next decade**
  - Possible areas of investment benefitting missions of all sizes
    - Detectors
    - Optical coatings
    - Grating improvements
    - Multiplexing elements / IFUs
  - Possible areas of investment specifically benefitting large-aperture missions
    - Wavefront sensing and control
    - Lightweight mirrors

> committee highly recommends a modest program of technology development to begin mission trade-off studies, in particular those contrasting coronagraph and star-shade approaches, and to invest in essential technologies such as detectors, coatings, and optics, to prepare for a mission to be considered by the 2020 decadal survey. A notional budget of $40 million for the decade is recommended.

Technology Development Areas for the Cosmic Origins Program (TCOP)

- Detectors
  - Highly sensitive detectors and large arrays of detectors are fundamental to Cosmic Origins mission's capabilities. Detectors that work from the extreme ultraviolet to the submillimeter portion of the spectrum and their associated technologies (e.g., manufacturability, read-out electronics, packaging) will be critical to achieving the goals of future Cosmic Origins investigations.

Technology Development Areas for the Cosmic Origins Program (TCOP)

- Ultraviolet Coatings
  - Improved reflective coatings for optics, particularly in the ultraviolet part of the spectrum, could yield dramatically more sensitive instruments and permit more instrument design freedom. Increasing system throughput is a very cost effective way to achieve more science and often is less costly than simply using a larger primary mirror. Studies of improved deposition processes for know UV reflective coatings (e.g., MgF_2); investigations of new coating materials with promising UV performance, and examination of handling processes, contamination control; and safety procedures related to depositing coatings, storing coated optics, integrating coated optics into flight hardware are all areas where progress would be valuable.

Technology Development Areas for the Cosmic Origins Program (TCOP)

- Advanced Normal Incidence Optics
  - Missions within the Cosmic Origins Program rely heavily on their ability to collect enough light energy with appropriate angular resolution to address important Cosmic Origins questions. Therefore, a premium is placed on the ability to manufacture, test and control optics of sizes greater than ~2 meters in diameter. Keys to advancements in this arena are new techniques and technologies for reducing areal density of optics, production times; manufacturing ultra-precise, low-mass deployable structures to reduce launch volume for large-aperture space telescopes and interferometers; cryogenic optics; and mechanisms and methods for improving control of the surface figure.

SAT/COR Selections in FY12

(Slide from Mario Perez, NASA HQ)

Proposal Title	PI	Institution	Area
Advanced UVOIR Mirror Technology Development for Very Large Space Telescopes	Phillip Stahl	Marshall Space Flight Center	*Advanced, Normal Incidence Optics*
High performance cross-strip micro-channel plate detector systems for spaceflight experiments	John Vallerga	UC Berkeley	*Detectors*
Enhanced MgF2 and LiF Over-coated Al Mirrors for FUV Space Astronomy	Manuel Quijada	Goddard Space Flight Center	*Ultraviolet Coatings*

Increasing Throughput

- The throughput of optical systems at ultraviolet wavelengths has considerable headroom for growth.
- Even Optical/IR designs can be improved via multiplexing.
- Technology investments can be traded against aperture size.

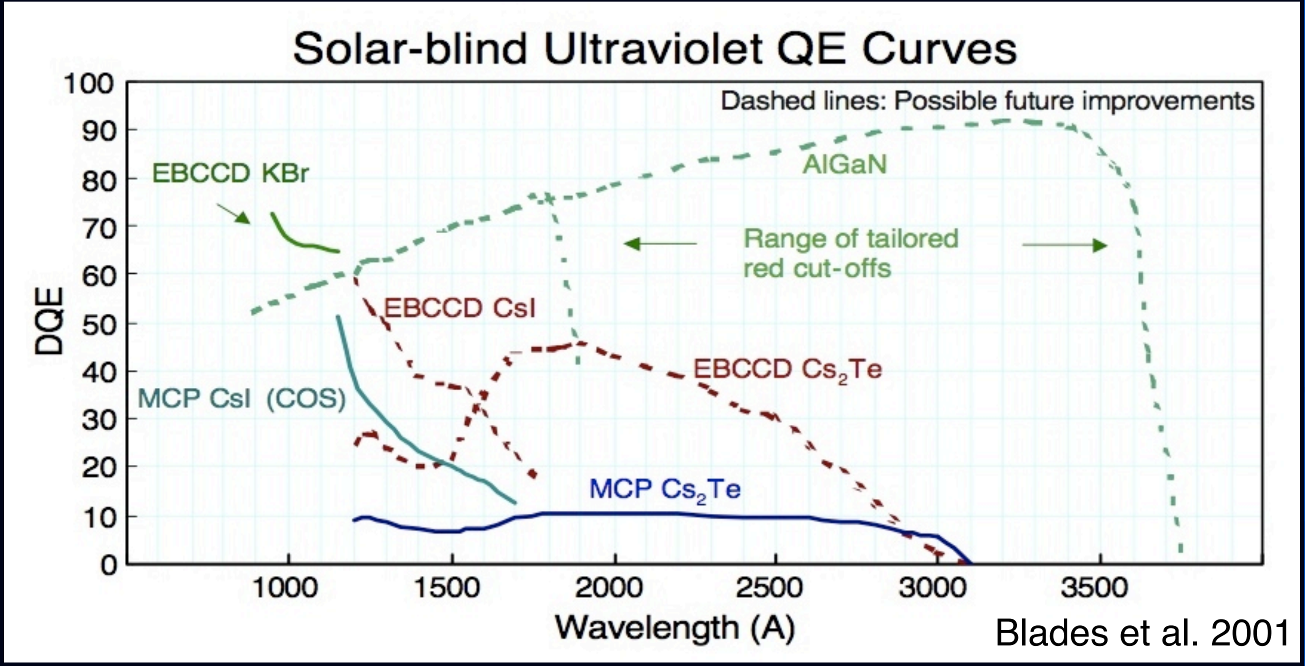
Table 1: Exposure Times for Telescopes With and Without New Technology Investments

Flux (erg cm^{-2} s^{-1} Å^{-1})	GALEX FUV (mag)	Exposure Time to Reach S/N =10 at R = 20,000			
		HST / COS	4m HST or Optimized 2m	8m HST or Optimized 4m	16m HST or Optimized 8m
1x10^{-15}	19.2	9.8 ksec	3.6 ksec	900 sec	220 sec
1x10^{-16}	21.7	115 ksec	39 ksec	9.1 ksec	2.2 ksec
1x10^{-17}	24.2	2.9 Msec	700 ksec	110 ksec	24 ksec

Calculations assume a 2-mirror OTA with 12% secondary linear obscuration, feeding a single reflection spectrograph with a detector dark count rate of 2.7x10^{-4} cnt s^{-1} per resolution element.
Optimized telescope configurations assume a factor of 4 improvement in system throughput compared to existing (Hubble) technology.

Detectors (1/3)

- Improving UV quantum efficiency is a key issue
  - Particularly, band-averaged values
  - Matching to optical λs is important for data quality uniformity when exposing for similar times

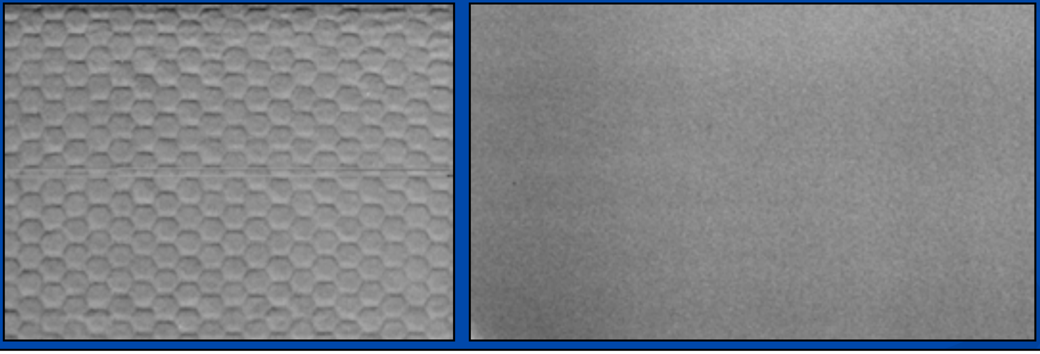


Blades et al. 2001

COS FUV MCP	
1216 Å	~34%
1300 Å	~30%
1400 Å	~23%
1500 Å	~20%
1600 Å	~13%
1750 Å	~ 10%
COS NUV MAMA	
2000 Å	~10%
2500 Å	~9%
3000 Å	~4%

Detectors (2/3)

- Other key detector issues
  - Better photocathode materials are needed
    - Example: AlGaN, GaN show great promise (QEs > 70% at 122 nm) but have high dark noise and are not yet suitable for large formats
    - Considerable work is needed to extend results to semi-transparent mode or to use in opaque mode on microchannel plates
  - Flatfields



(Left) HST-COS flat field image of a 10 x 13 mm area of the far-ultraviolet MCP detector. The fiber bundles imprint an obvious fixed-pattern noise features in the image. (Right) A new glass process MCP flat field for a similar image area, demonstrating the absence of fixed-pattern noise (Siegmund et al. 2007).

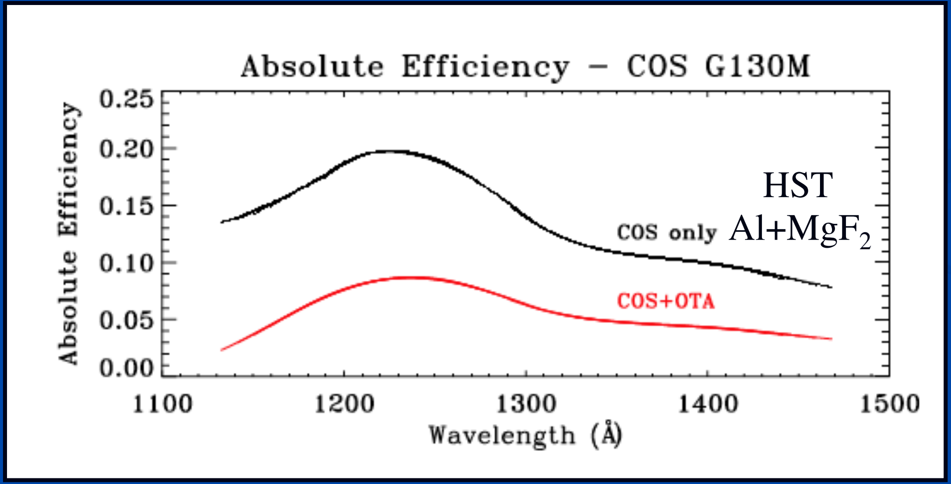
Detectors (3/3)

- Other key detector issues
  - Format
    - Long MCP detectors (1st order apps)
    - Large-format UV-sensitive CCDs
    - Extremely large format optical/NIR detectors
  - Backgrounds (photon counting)
  - Radiation hardness
    - Charge transfer efficiency primarily an issue for large CCDs in space
    - p-channel vs. n-channel can help
    - CMOS (or APS) devices hold great promise but currently have higher read noise and lower QE than conventional CCDs; need development
  - Operation at "room" temperature
    - Contamination of UV optics and detectors is a major concern at cryogenic temperatures

HST-COS far-ultraviolet detector showing the two abutting microchannel plate detector segments (each 85 x 10 mm) curved to the focal plane of the spectrograph.

Optical Coatings

- Technological "tall poles"
  - Smoothness, surface quality/uniformity, polarization
  - High reflectivity (>90%) coatings over large bandpasses (100 nm – 1μm)
    - Compatibility with use at UV wavelengths is highly desirable
    - Coatings like Al+LiF may be difficult to handle on large optics



HST OTA	
1150 Å	26%
1200 Å	41%
1500 Å	41%
2000 Å	49%
2500 Å	60%
3000 Å	61%

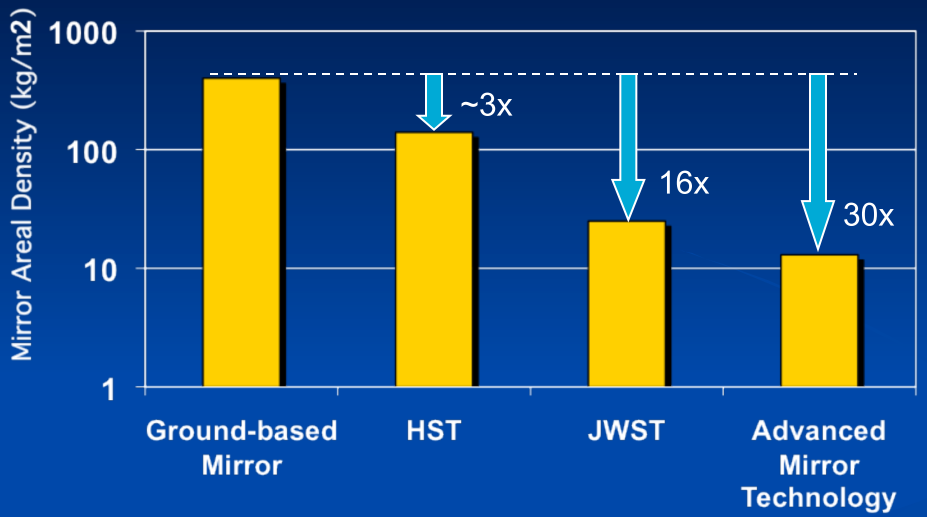
Light loss from Three 70% reflections = Ten 90% reflections = Twenty-One 95% reflections

Large Mirrors

Lightweight Mirrors

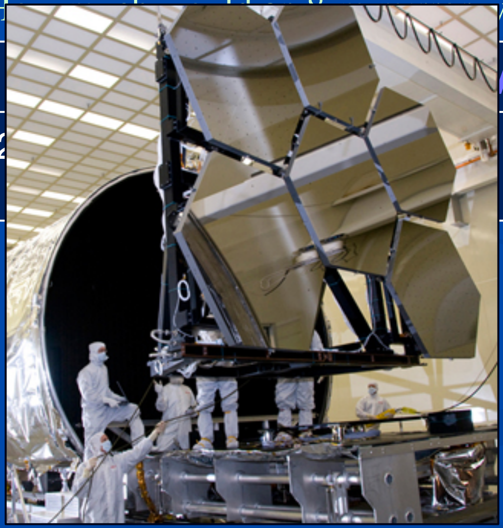

VLT Mirror


HST Mirror

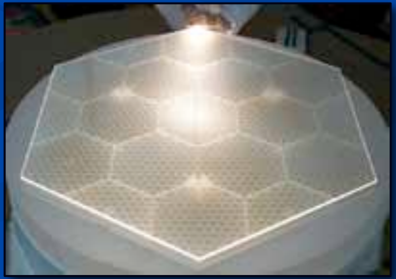


H… veigh?

		AMT
2		650 kg

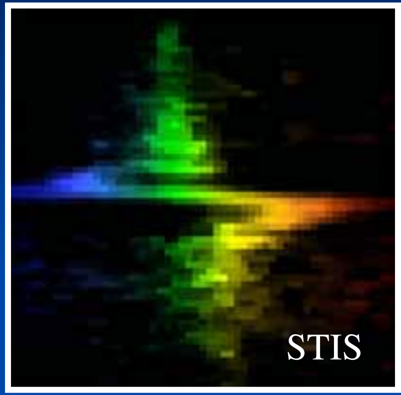

JWST Mirrors


AMT Prototypes



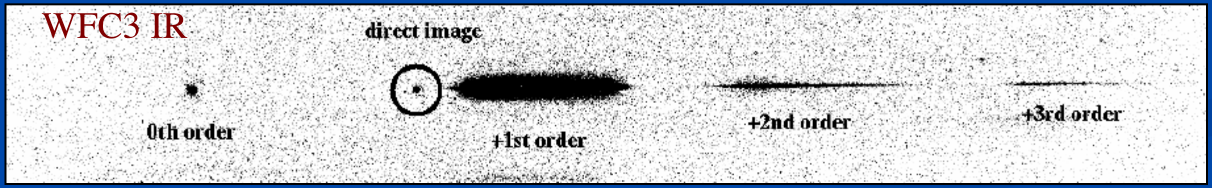
Optical Designs

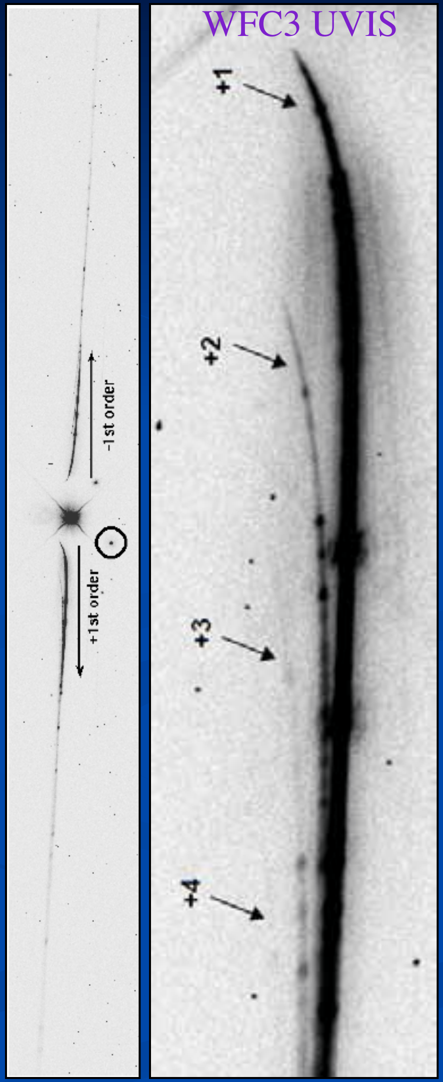
- Multiplexing can improve efficiency by orders of magnitude
  - Slitless spectroscopy
  - Multi-object aperture arrays
  - Integral field units
    (even all-reflecting IFUs in UV)



- JWST is taking advantage of spectroscopic multiplexing

- Grism spectroscopy with HST-WFC3 is being applied to fields ranging from ExoPlanets to Cosmology





Key Points

- Improvements in throughput present new science opportunities
  - Bringing UV throughput on par with optical/NIR wavelengths will require better detectors and optical coatings
- Improvements in UV throughput can be cost effective
  - Factor of 4 should be achievable (equivalent to doubling primary)
- Detectors need dedicated investment strategy
  - QE improvements, photon-counting, large formats, environmental tolerance in UV
  - Large focal planes, low readnoise, good cosmetics in optical/NIR
- Optics and coatings need to be improved as well
  - Reflections (currently) cost dearly in the ultraviolet
  - Instrument design possibilities abound with higher reflectivity