Planetary Science Experiments as Hosted Payloads on Commercial Satellites

Eliot F. Young, *SwRI*
Catherine B. Olkin, *SwRI*
Phillip C. Kalmanson, *Orbital Sciences Corp*.
Russell R. Mellon, *Equinox Interscience*
Malcolm Young, *University of Colorado*

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Planetary Science Experiments as Hosted Payloads on Commercial Satellites

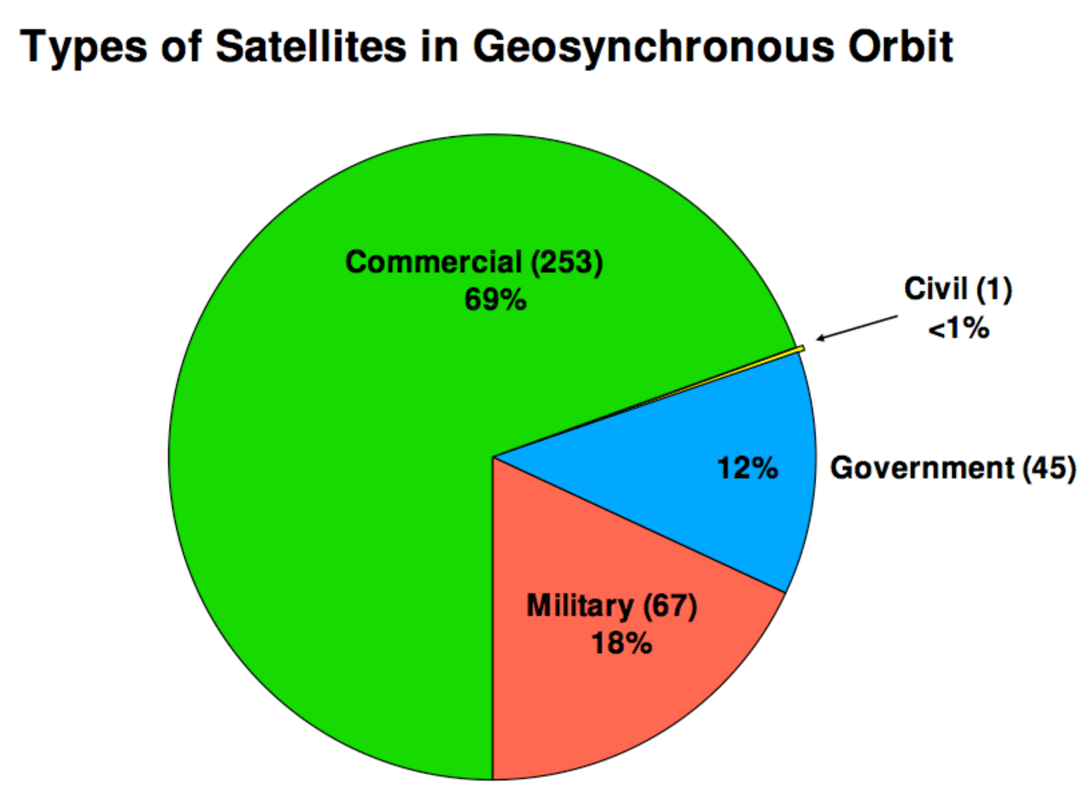
- The case for geosynchronous satellites
- Hosted payloads on a STAR-2 bus
- Some planetary science mission concepts
- Design concept for a UV telescope:
  - Optical design parameters for 0.1” resolution
  - Detectors
  - Pointing and Tracking

The Case for Hosted Payloads on Commercial GEO Satellites

Fact: the vast majority of satellites in GEO are commercial.
Question: why would a commercial satellite owner want to add risk and mass (and shorten the satellite's lifetime)?

Satellite Quick Facts			
Total number of operating satellites: 888			
LEO: 422	MEO: 56	Elliptical: 39	GEO: 371
United States: 425	Russia: 85	China: 54	
Total number of U.S. Satellites: 425			
Civil: 8	Commercial: 193	Government: 120	Military: 104

includes launches through 4-1-09



Source: Union of Concerned Scientists database (http://www.ucsusa.org/assets/documents/nwgs/quick-facts-and-analysis-4-13-09.pdf)

The Case for Hosted Payloads on Commercial GEO Satellites

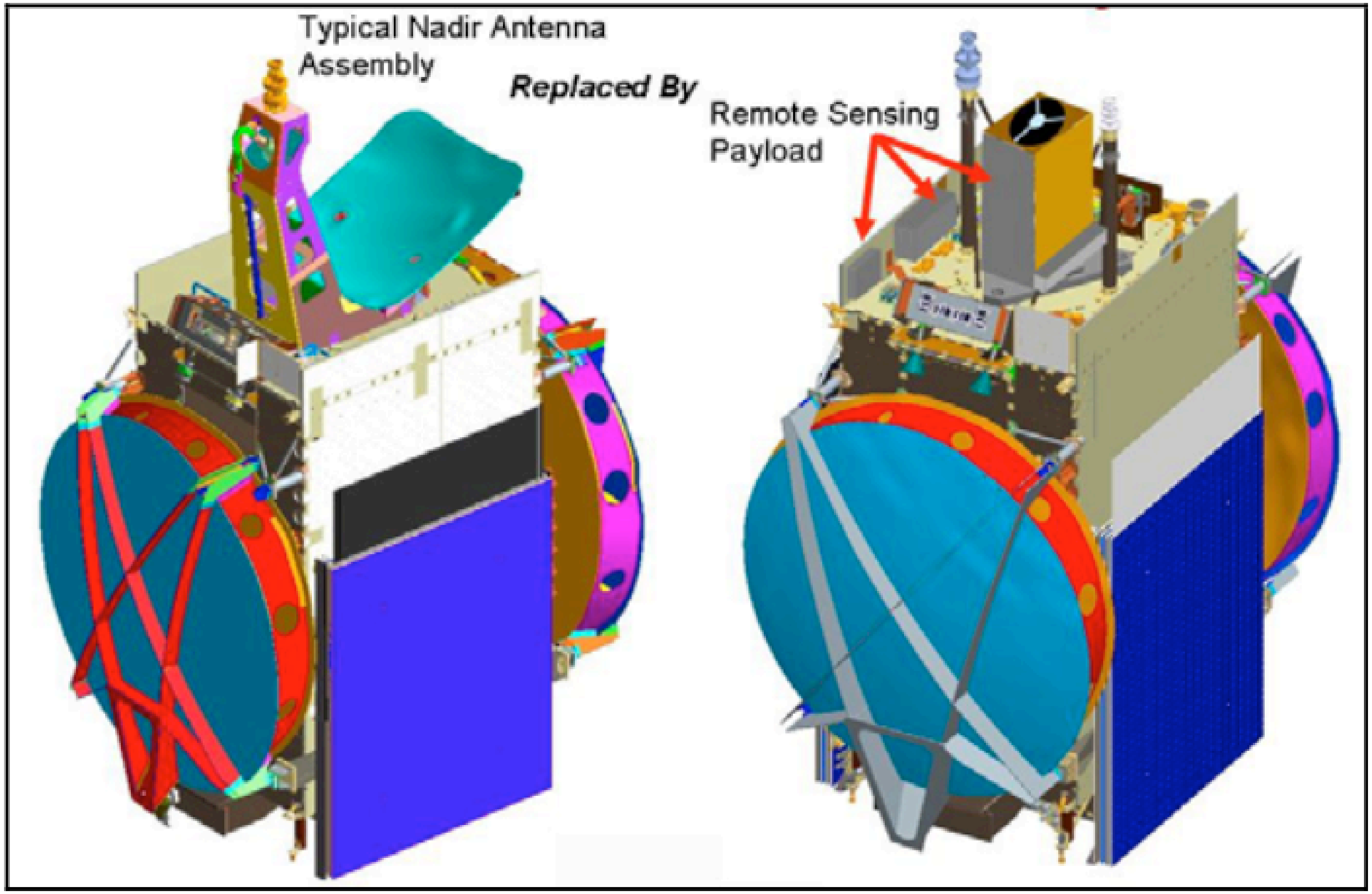
Fact: the vast majority of satellites in GEO are commercial. Question: why would a commercial satellite owner want to add risk and mass (and shorten the satellite's lifetime)?

Answer: if a commercial operator can defray some of the up-front cost of a satellite by selling excess mass and power margins to a hosted payload customer, and if that customer is also willing to pay for bandwidth to download data, then the added mass and shortened lifetime is more than made up by the hosted payload revenues.

Examples:

- FAA L-band payload (Intelsat)
- USAF CHIRP (Commercially Hosted IR Payload; AMERICOM GS)
- GOLD (Global-scale Observations of the Limb and Disk; SES AMERICOM)

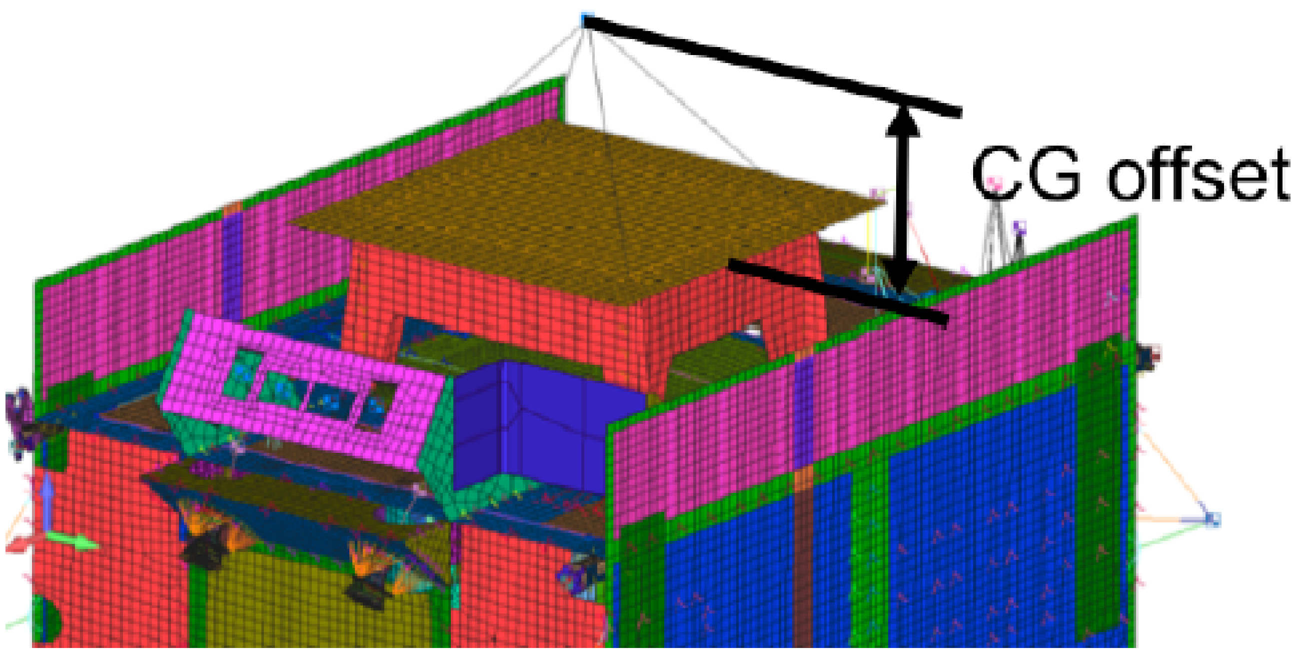
Hosted payloads on a STAR-2 bus



Source: Kalmanson, P.C., Lam, Q.M., and Do, M. 2008a, "Hosted Secondary Payloads on Communications Satellites: Looking at the Whole Problem." AIAA 2008-5493.

Hosted payloads on a STAR-2 bus

- The nadir deck is the only location for significant hosted payloads.
- Rough payload parameters: 50 kg in a 25” x 30” x 28” volume. Maximum aperture: around 16 - 20 inches.
- HPSD (Hosted Payload Support Deck), a modular stand on the nadir deck.



Source: Orbital’s *STAR-2 Bus Hosted Payload Fact Sheet*.

Planetary Science Hosted Payload Mission Concepts

Consider four planetary science mission candidates that span some of the possible choices for missions:

- A downward-looking spectrograph to identify the composition of meteor trails.
- A wide-field visible imager with three TDI arrays in the focal plane to detect moving objects.
- An infrared spectrograph for icy objects in the outer system.
- A UV telescope with 0.1” resolution.

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A difficult problem from GEO. Better suited to LEO, or even a balloon-borne mission that looks upwards.

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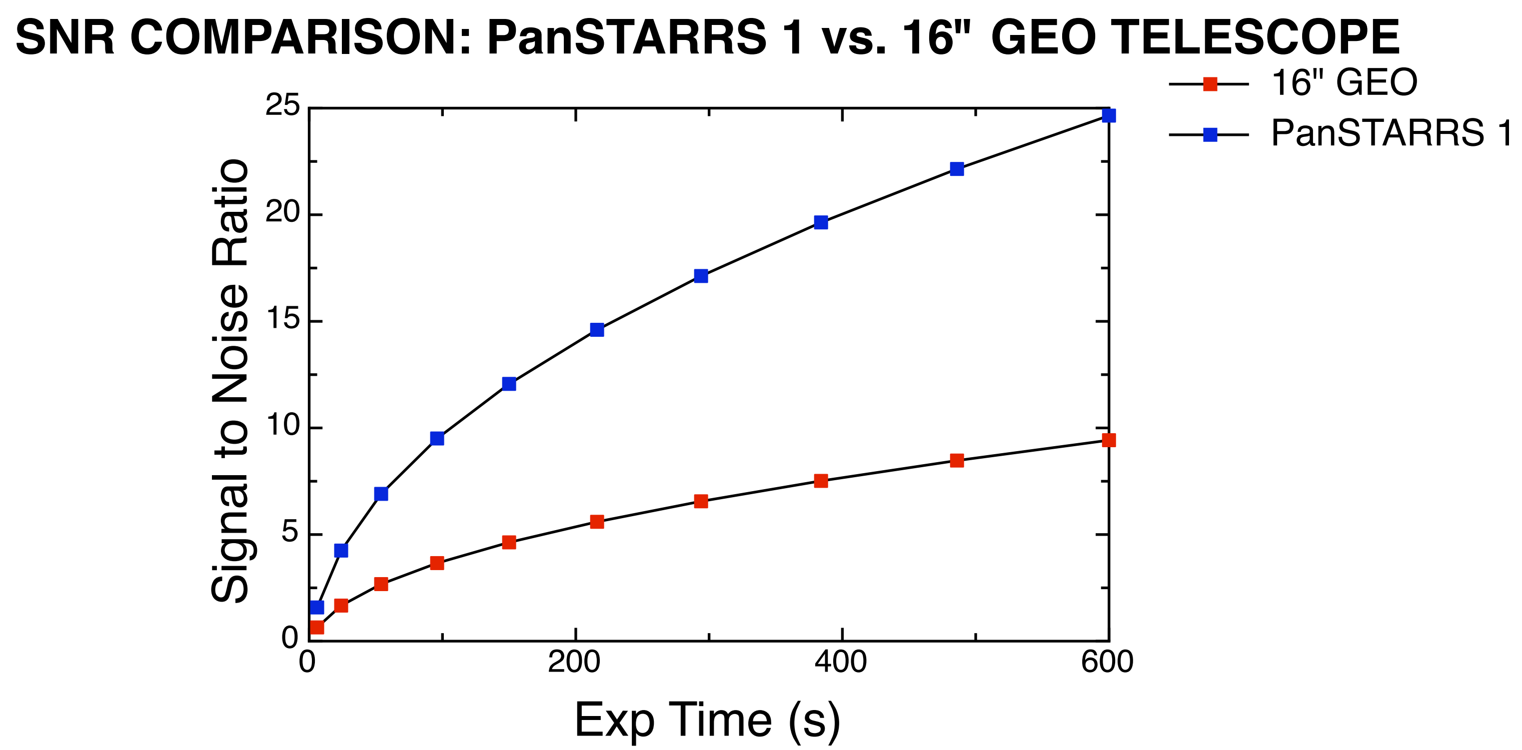
Problems: diffraction limit of a 50 cm aperture is only ~0.3”. PanSTARRS 1 can detect fainter objects from the ground!

Planetary Science Hosted Payload Mission Concepts



- Even assuming favorable detectors for the GEO mission (e.g., GAIA flight spares with low read noise), the ground-based telescope is superior.

- Worth looking at on larger satellite buses... "*The SS/L 1300 satellite platform is particularly well-suited to carry secondary payloads because of its size and power generation capability," said Martin Halliwell, president and CEO of SES Engineering*.

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Similar to the USAF mission, CHIRP, but must overcome a hot environment. Possible, but complicated and expensive.

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A good fit for a GEO/STAR-2 hosted payload. Much lower geocoronal flux than HST, plus a useful diffraction limit.

Hosted Payload Mission: Bulk Parameters for a UV Imaging Telescope

Science Drivers: Repeated observations of Jupiter and the Io Torus at 0.1” resolution or better. λ: 100 - 200 nm to resolve energies of auroral-causing particles. Acquire the torus in the FOV (6”).

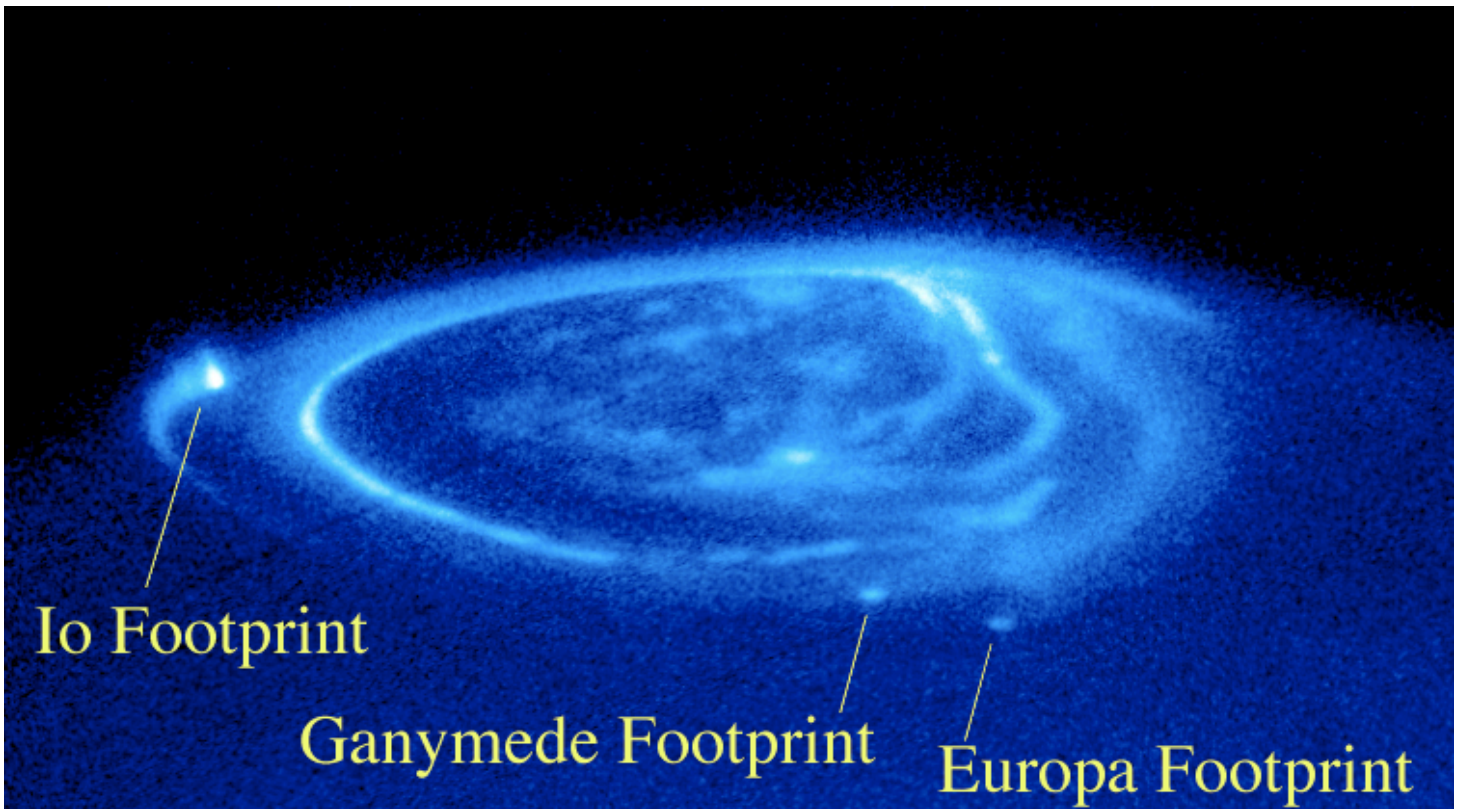
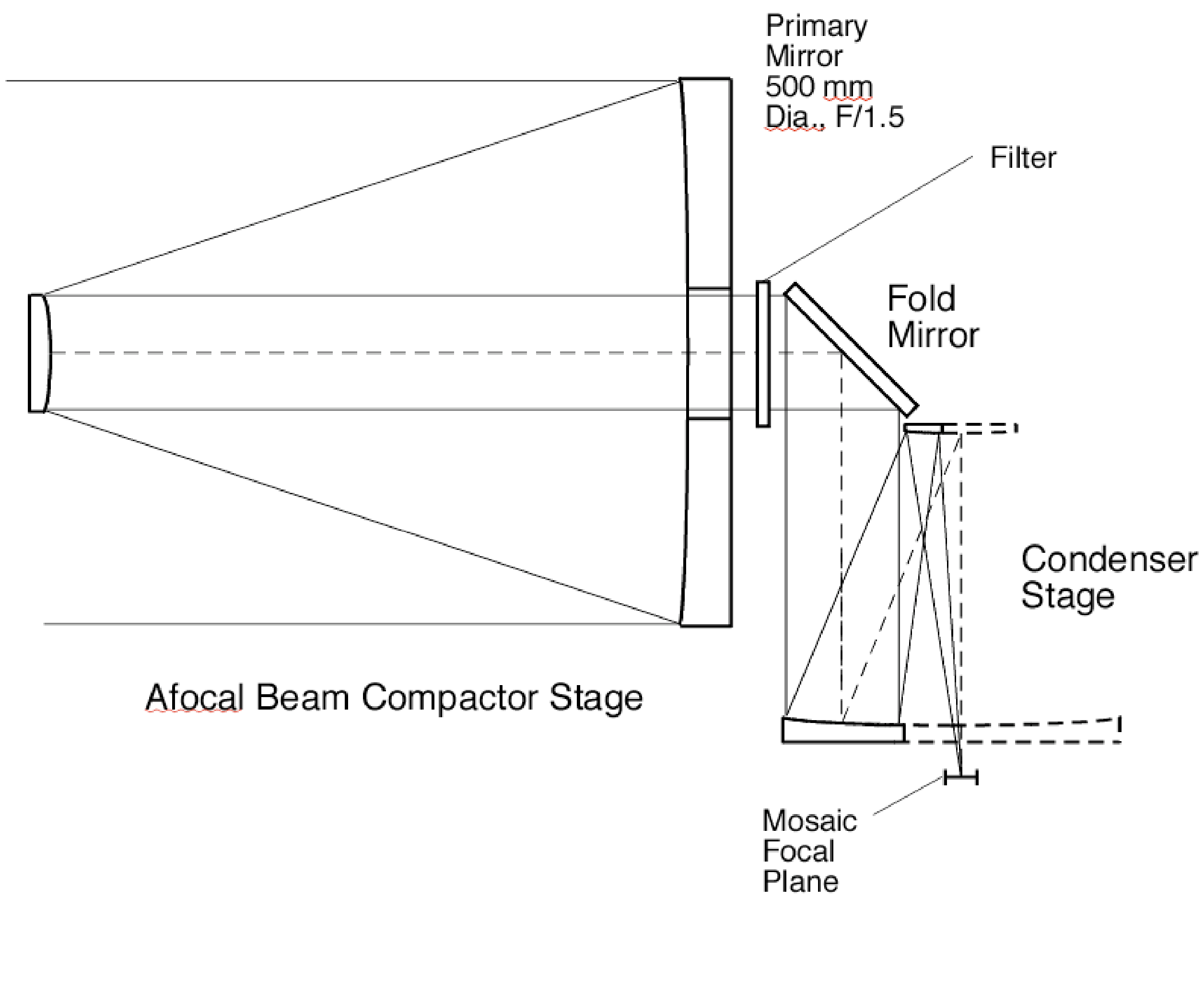


Photo ID: STScI-PRC2000-38

Hosted Payload Mission: Bulk Parameters for a UV Imaging Telescope

Detector resolution and desired plate scale determine the focal length. *Example*: 10 μm pixels, 0.05” per pixel -> 40 m focal length.

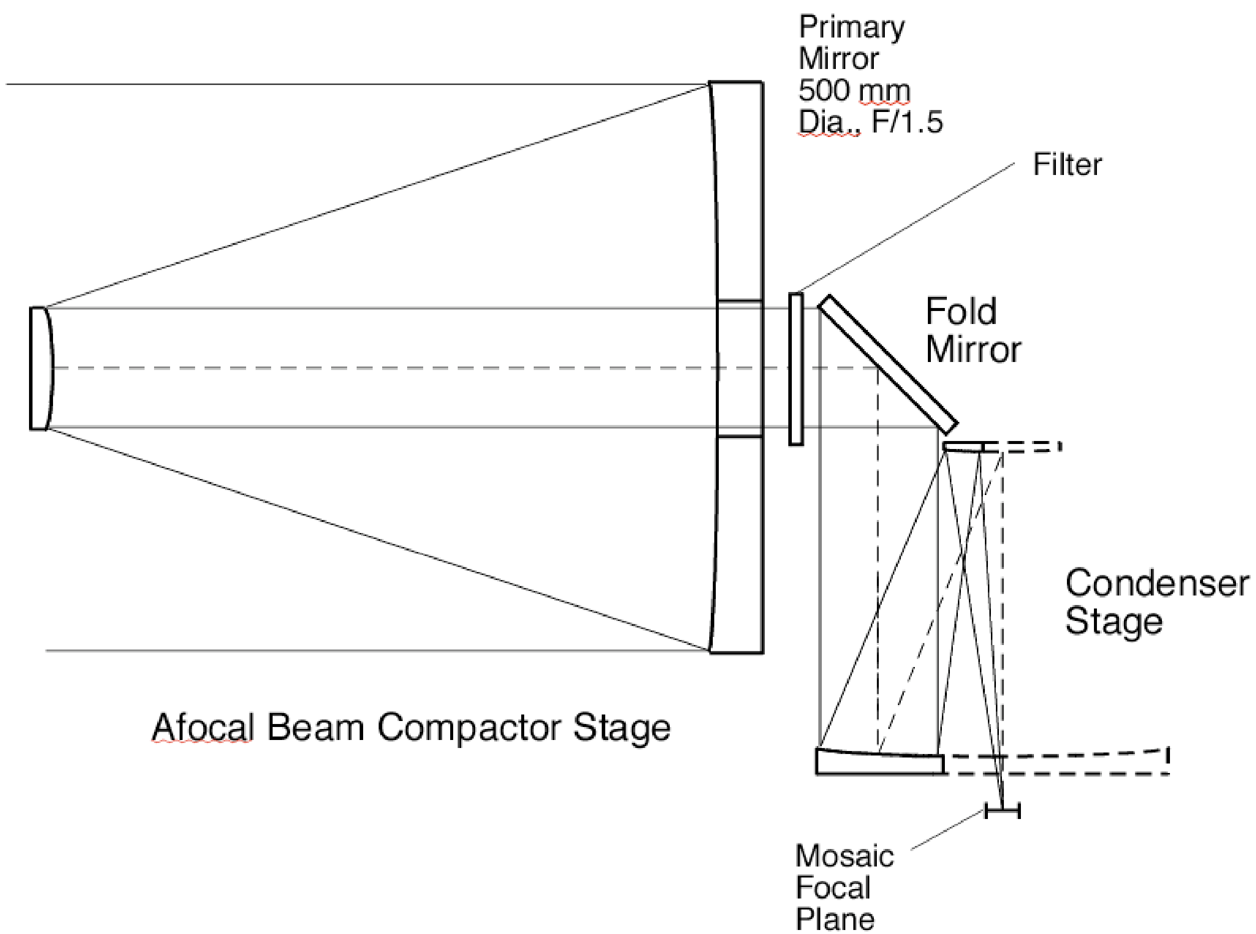
Question: Can we fit a 50 cm (f/80) telescope in the box?



Yes – in two stages: an f/4 beam compactor (an afocal Mersenne) and an f/20 condenser (a Ritchey-Chretien)

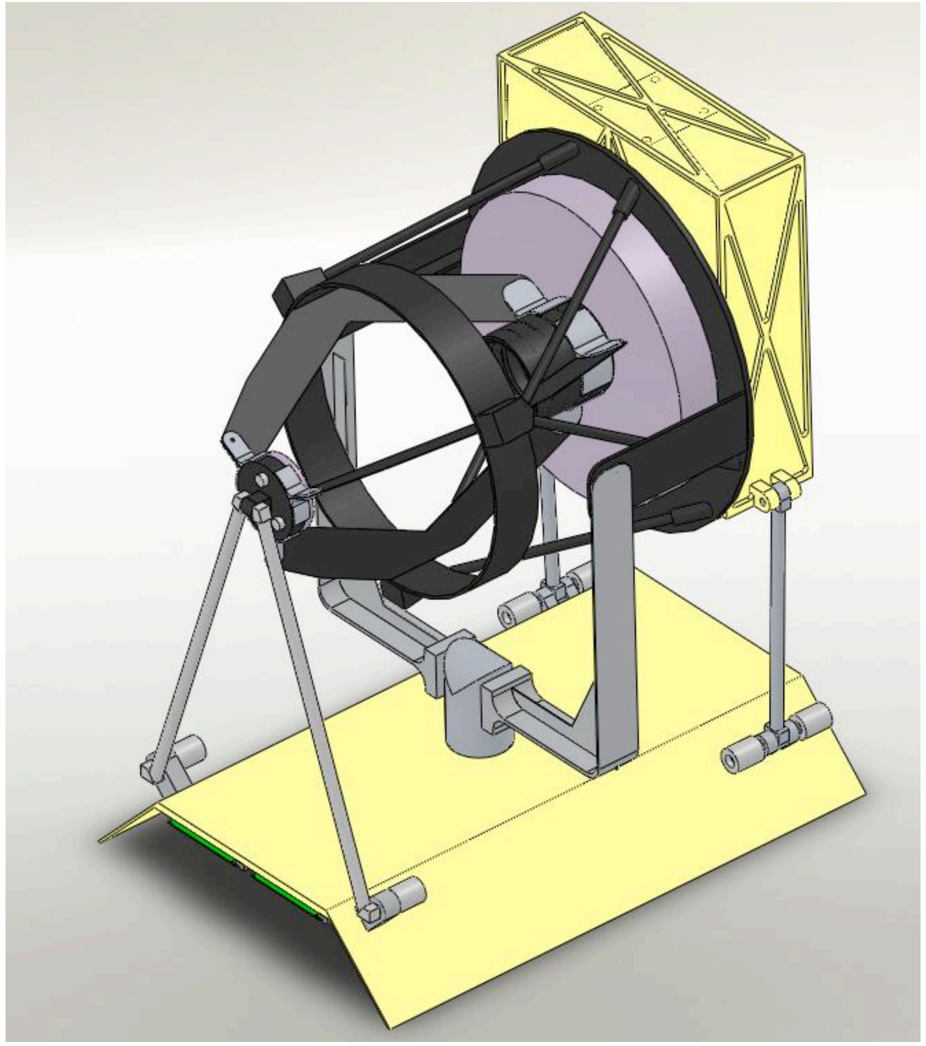
Hosted Payload Mission: Optical Layout for a UV Imaging Telescope

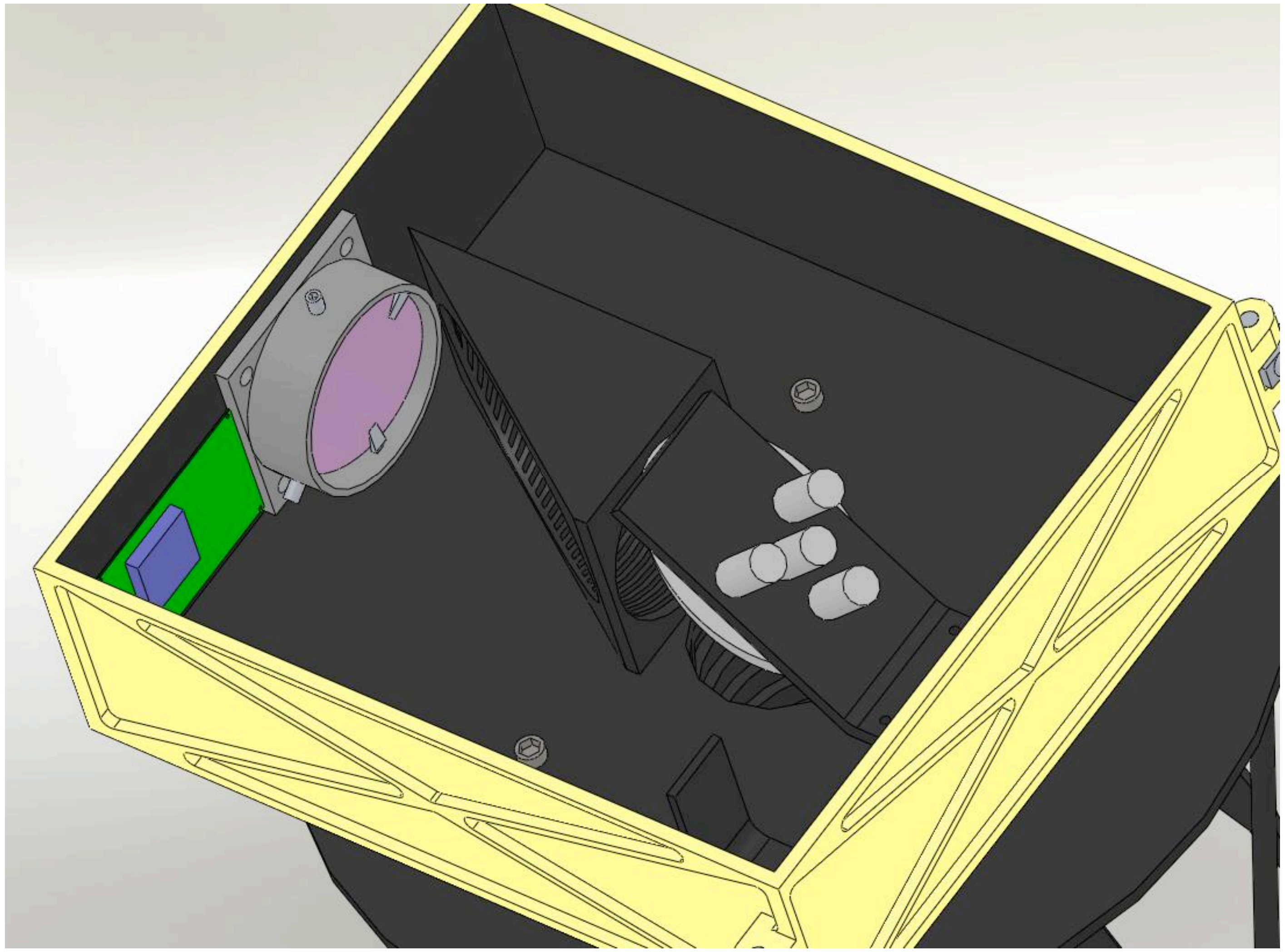
Beam Compactor Stage	Condenser Stage
Primary Mirror Diameter 50.0 cm	Parent Primary Diameter 37.5 cm
Primary Mirror Radius 150.0 cm	Parent Primary Radius 112.5 cm
Primary Mirror Conic Const. -1.00	Parent Primary Conic Const. -1.0266
Spacing to Secondary Mirror Vertex 56.25 cm	Off-Axis Distance to Central Ray Axis 12.5 cm
Secondary Mirror Diameter 13.0 cm	Off-Axis Primary Mirror Segment Diameter 12.5 cm
Secondary Mirror Radius -37.5 cm	Spacing to Secondary Mirror Vertex 44.526 cm
Secondary Mirror Conic Const. -1.00	Parent Secondary Mirror Diameter 12.5 cm
Demagnification Ratio 4:1	Parent Secondary Radius 30.238 cm
	Parent Secondary Conic Const. -2.76997
	Off-Axis Distance to Central Ray Axis 12.5 cm
	Off-Axis Secondary Mirror Diameter 4.166 cm
	Spacing to System Focus 52.146 cm



RIDESHARE TELESCOPE OPTICAL LAYOUT

Hosted Payload Mission: Optical Layout for a UV Imaging Telescope





- Compactor stage is a combination Serrier truss with Meinel struts. We think this provides good strength & stiffness vs. weight, but we need to do more modeling.

- ALT-AZ pointing, but support point is well forward of the COM. Also needs more modeling.

Hosted Payload Mission: Optical Layout for a UV Imaging Telescope

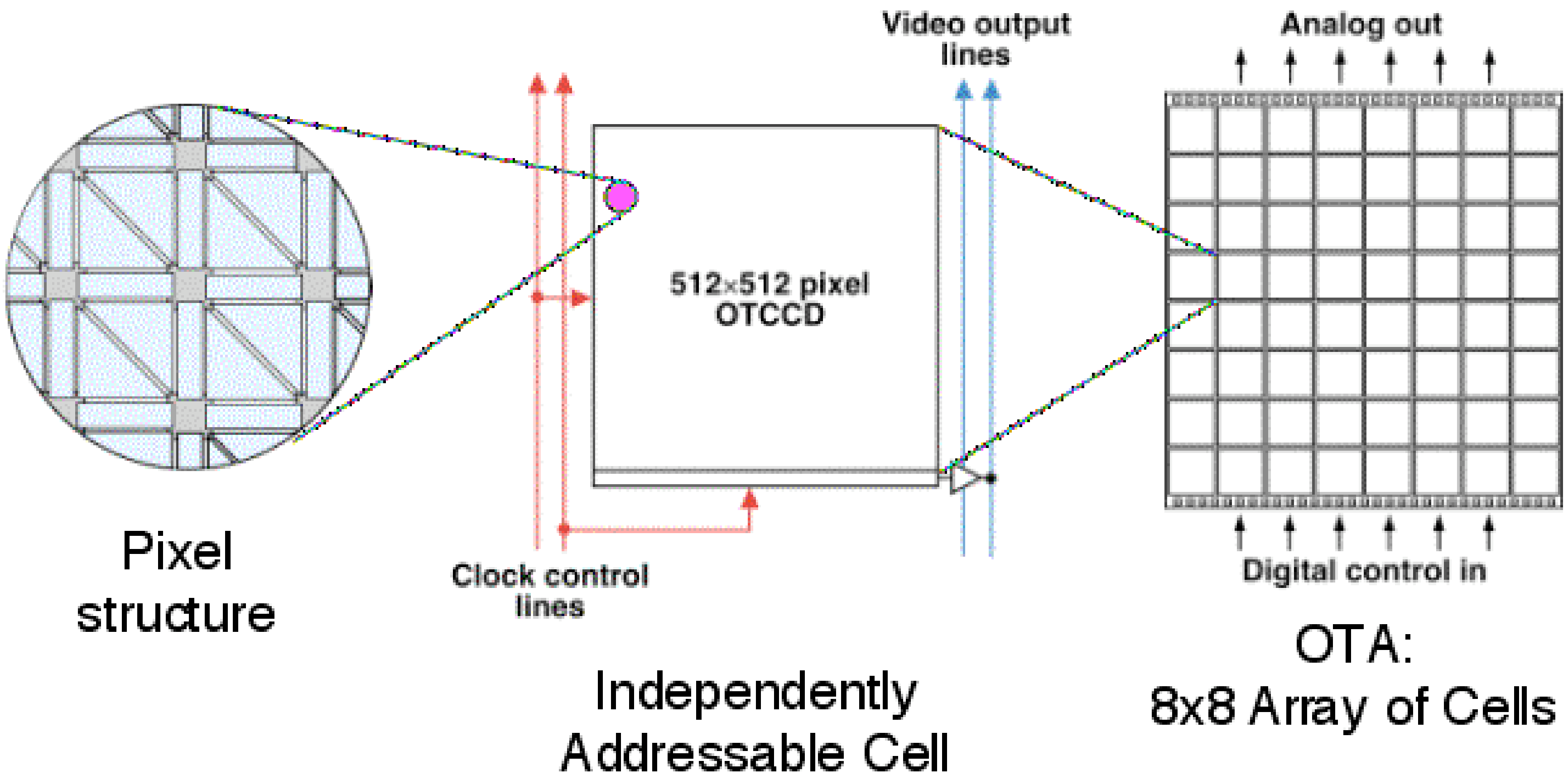
Q: Why not split the magnification more evenly between the compactor and the condenser stages?
A: Because the coma is worse than the diffraction limit if we do.

Field Angle on Sky (arcmin)	Field Angle into Condenser (arcmin)	Coma at Image Plane (arcsec)
0.5	2.0	0.063
0.75	3.0	0.084
1.0	4.0	0.112
3.0	12.0	0.338

But - given our current layout - if we minimize coma at a radius of 107” from the detector center, then coma is less than 0.1” over 63% of a 4’ x 4’ FOV.

Hosted Payload Mission: CCD Detectors for a UV Imaging Telescope

We are considering a modification of the PanSTARRS Orthogonal Transfer (OT) CCDs from MIT/LL. The CCID64 detector consists of an 8 x 8 array of 600 x 600 pixel CCDs, each with OT capability. Pixel size is 10 μm, total detector area is 4800 x 4800 pixels, about 5 cm x 5 cm, or just over 4' at a platescale of 0.05" per pixel.



Hosted Payload Mission: CCD Detectors for a UV Imaging Telescope

- QE: At 100 -200 nm, very short photon interaction depths, only about 10 μm into the Si substrate. MBE to treat the backside and AR coating will be critical to get QEs > 25%.

- Pros and cons vs. Multi-Channel Plates:

  - OTCCDs can remove jitter with no moving parts. MCPs can time tag photons to allow post-processed reconstructions of jitter-free images. BOTH require an accurate pointing reference signal.

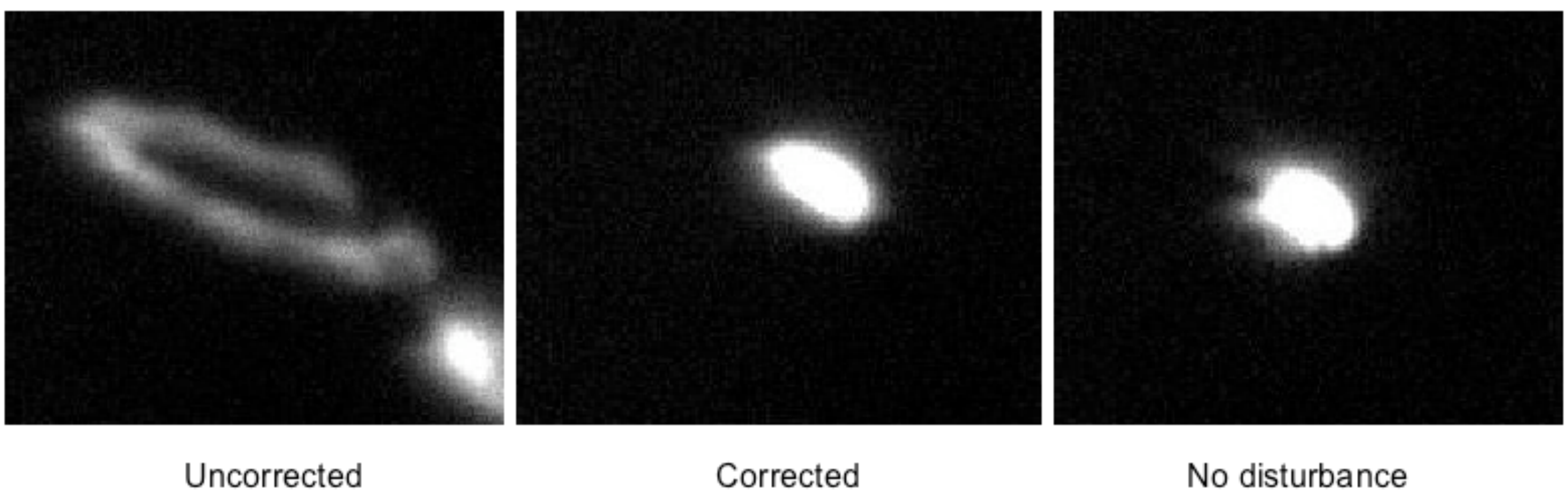
  - OTCCDs are not solar blind. Could be a fatal flaw.

  - The size of the telescope scales with the effective pixel size of the detector. Need to have an effective spatial resolution of 10 μm or less from the MCP.

Hosted Payload Mission: Pointing and Tracking for a UV Imaging Telescope

We plan to use a three-stage pointing system.

- STAR-2 bus pointing (towards Earth): RMS of 0.01°.
- OTCCD: Loses charge off the edges, but ± 0.5" correction preserves 87% of the detector area.
- The difference between 0.01° (36") and 0.5" can easily be made up by an intermediate stage, a fine steering mirror.



Previous SPIE result (Kraut et al. 2008): An FSM from Left Hand Design achieved 20 dB of correction.

Summary

- Hosted payloads on commercial satellites in GEO provide many launch opportunities.
- Satellite operators are trying to encourage the hosted payload model (*i.e., it might really happen*).
- UV telescopes make a compelling mission on a satellite the size of an Orbital Sciences STAR-2 bus.
- Tough problems of fitting the optical layout within the size and mass constraints look solvable.
- Pointing and tracking looks solvable.
- Still need to do an end-to-end SNR simulation with MCPs and CCDs to make a valid comparison between detectors.