Mission Systems Engineering (MSE) for the Cosmic Evolution Through UV Spectroscopy (CETUS) Space Telescope Concept

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TOPICS

- Requirements Placed on Mission
  - e.g., Science Goals, Instrument Design
- Design of Mission
  - e.g., SC Bus, LV, GS
- Conclusions

Mission Requirements

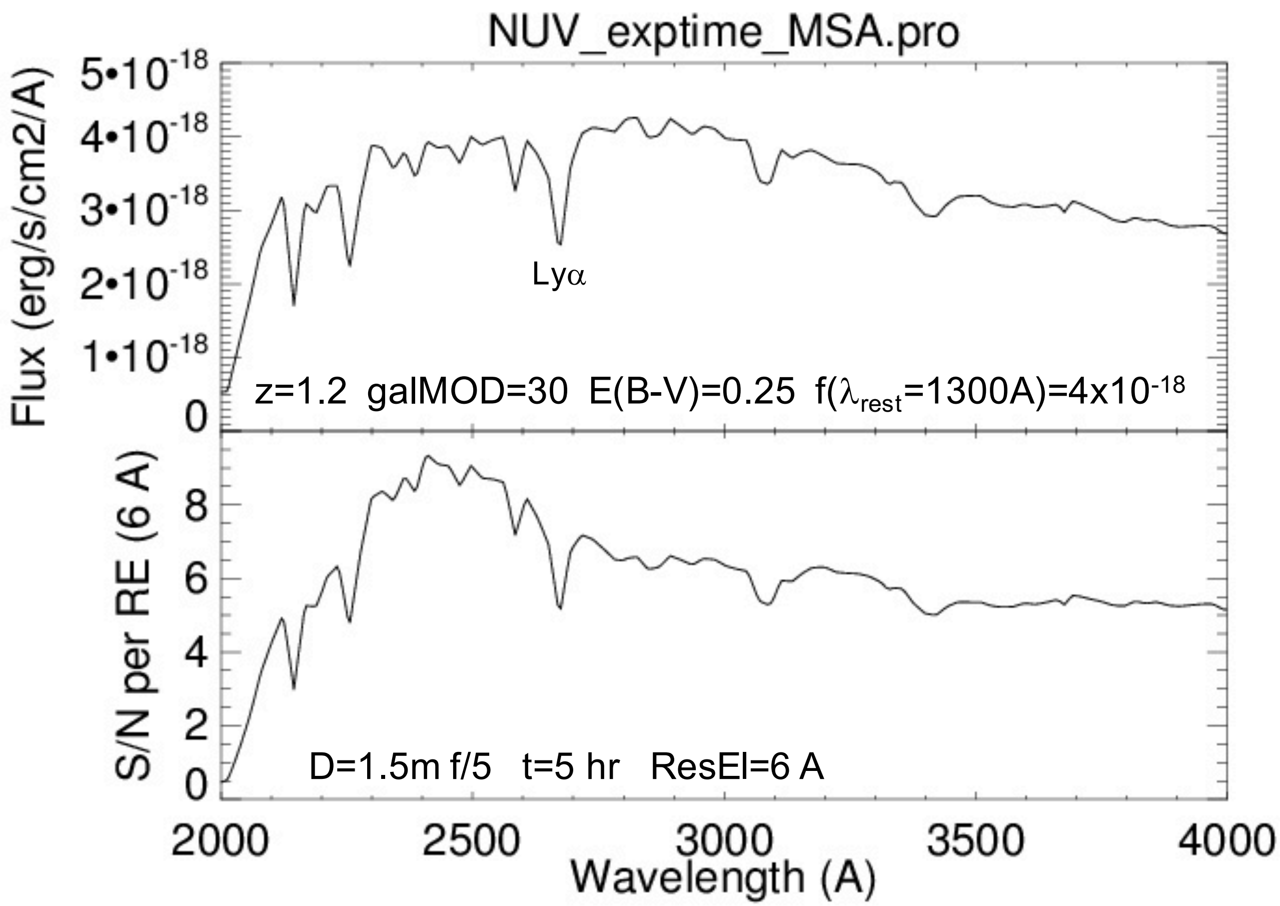
- Science Requirements
- Telescope and Instrument Design
- Measurements

CETUS is Designed to Answer Cosmic Evolution Science Questions that are associated with Galaxy Evolution

- How did the Hubble Sequence emerge?
- What explains the co-evolution of galaxies and black holes?
- What explains the turnover in the star-formation history and growth history of black-holes at z~1-2?
- How did galaxies come to look like the ones we see today?

For more details See SPIE Paper by Sally Heap, CETUS Science PI

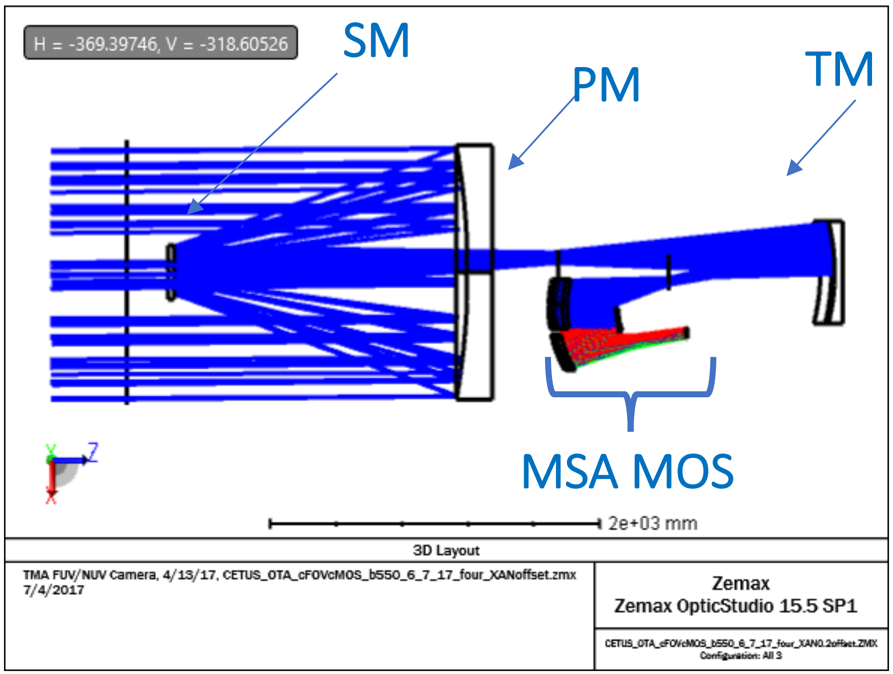
To Answer these Questions, the main CETUS Measurement Objective is to Obtain in 3 to 5 years >10^5 UV Spectra With SNR=~7 of z=~2 (i.e., very dim) galaxies



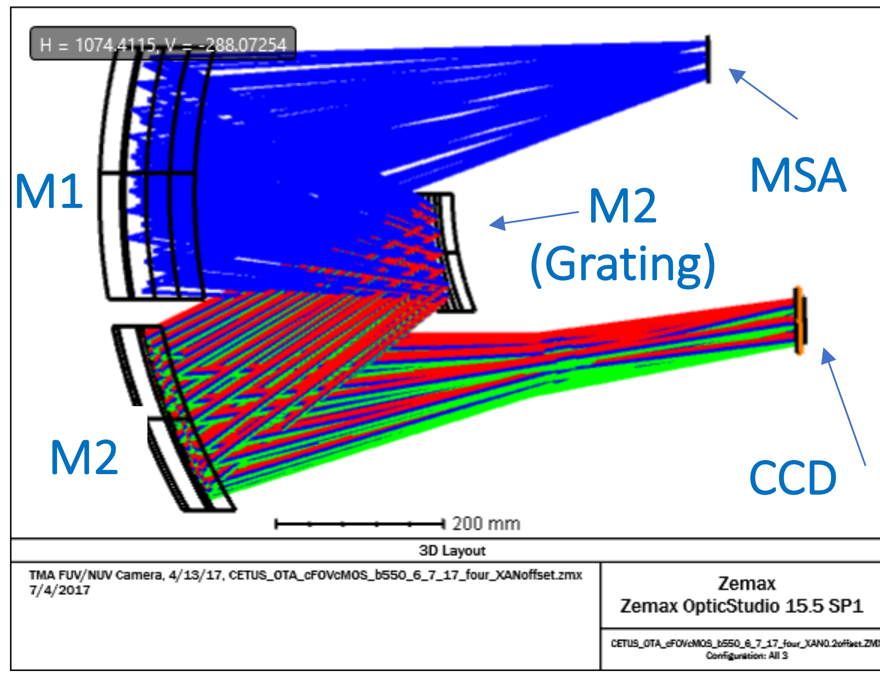
>10^5 Spectra are needed to get a sufficient number of spectra for each of the large number of galaxy categories

CETUS Concept for Obtaining Spectra:

Micro-Shutter Array (MSA) Multi-object Spectrometer (MOS)



CETUS Telescope (PM, SM, TM) with MSA MOSc



MSA MOS Details
(M1, M2, M3 operate as Offner Relay)

Wide FoV and MSA MOS Result in ~100 NUV Spectra per Image (Figures from S. Heap)

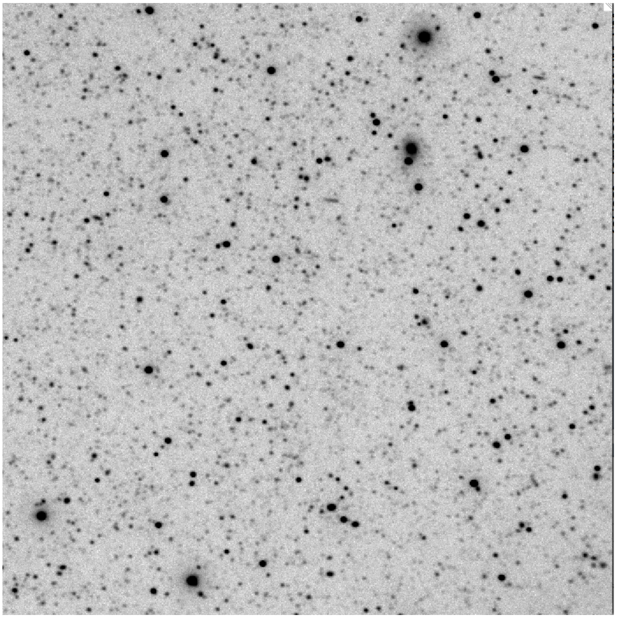
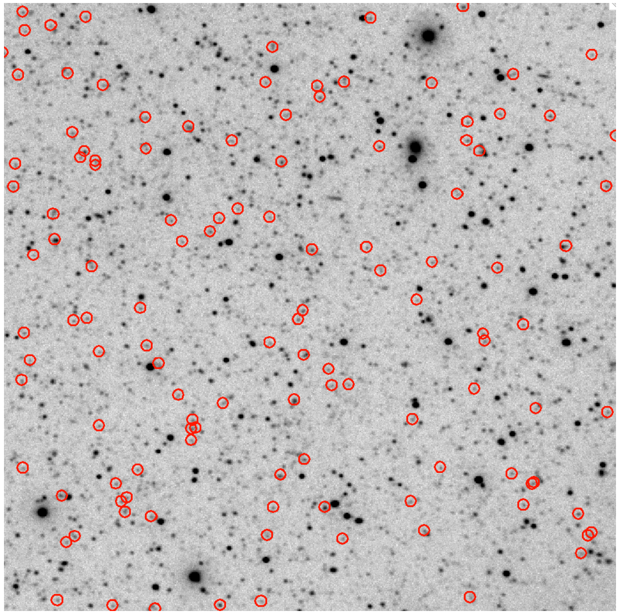
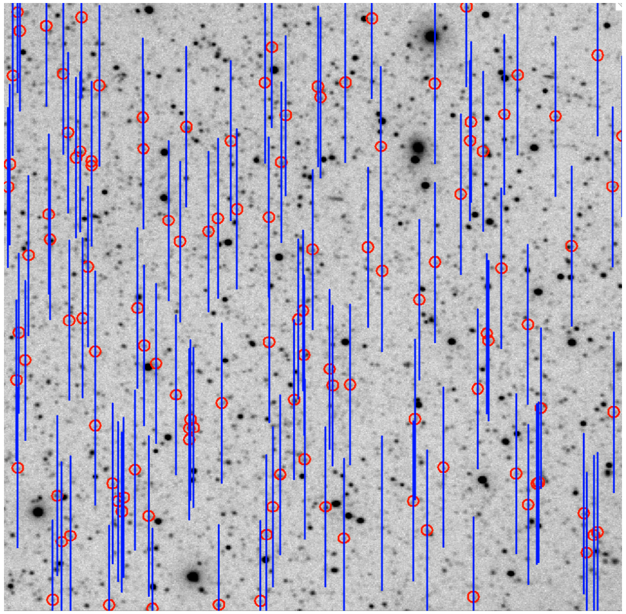


Image in MSA MOS 0.3 x 0.3 deg. FoV



Galaxies in Red Circles Selected for Spectra



Resulting Locations of Non-Overlapping Spectra on CCD

CETUS will observe PFS galaxies in HSC fields
In order to obtain UV Spectra for Galaxies that already are already well characterized with Vis Imagery and Spectra

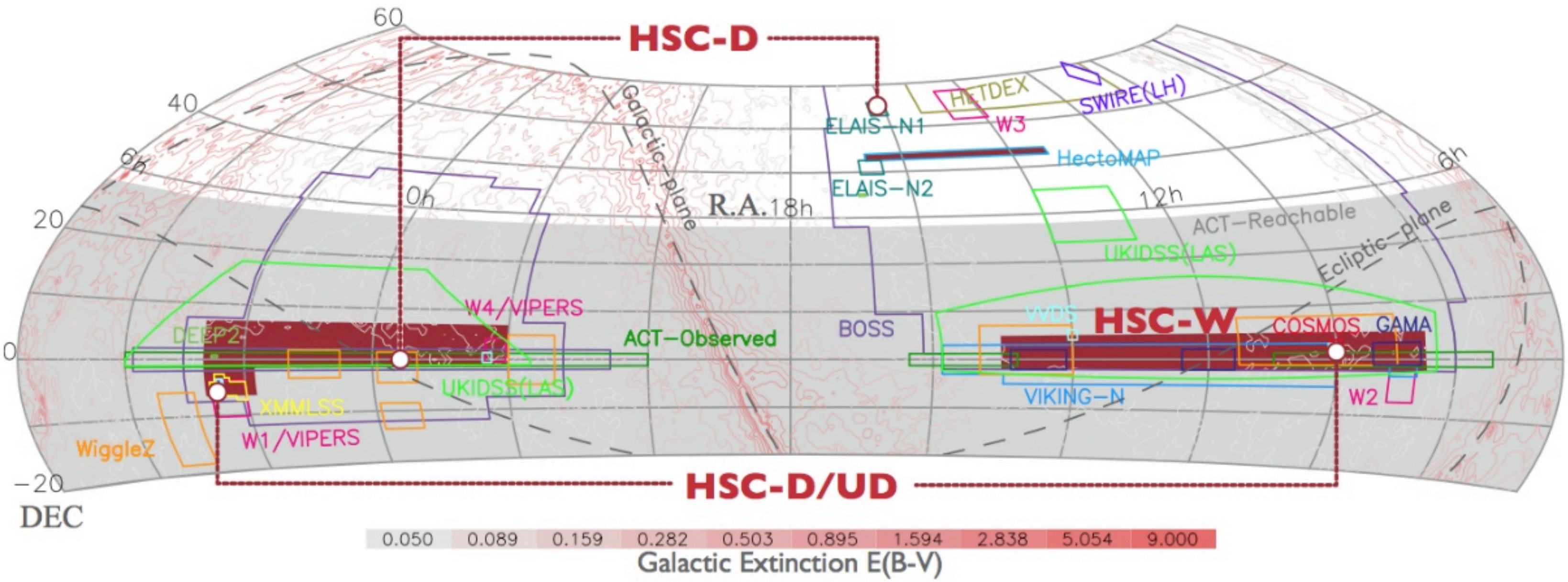


Figure 11: The location of the HSC-Wide, Deep (D) and Ultradeep (UD) fields on the sky in equatorial coordinates. A variety of external data sets and the Galactic dust extinction are also shown. The shaded region is the region accessible from the CMB polarization experiment, ACTPol, in Chile.

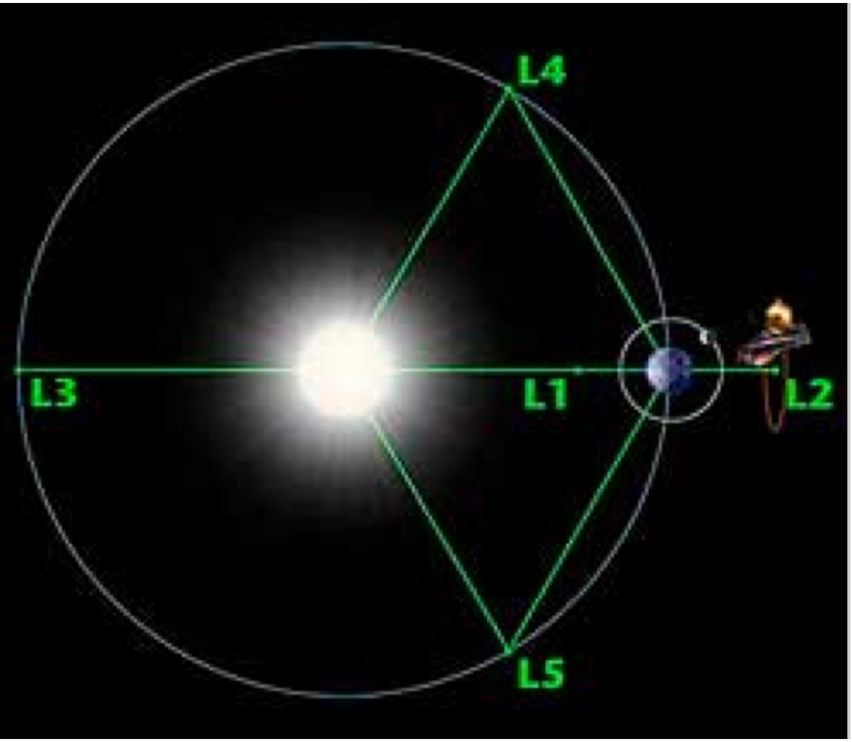
PFS will target: 16 deg^2 in the HSC Deep survey for J<23.4 mag of which 2.6 deg^2 in the HSC UltraDeep mag-limited survey

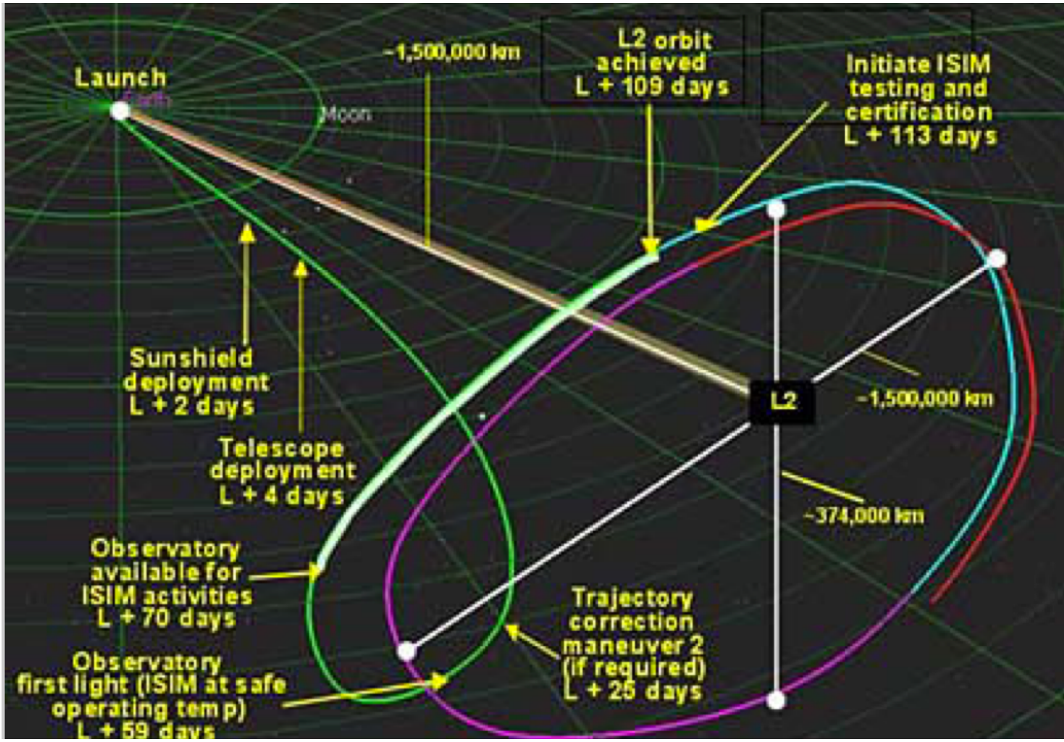
Mission Design Elements

- Orbit and LV
- Mechanical
- Thermal
- ACS
- Power
- Comm (including OD)
- C&DH

CETUS will Orbit the Sun-Earth L2 Point

(in a manner similar to JWST as shown below)





SEL2 Orbit allow CETUS to view HSC Fields almost constantly
With manageable requirements on LV & Comm

CETUS LV Concept (Falcon 9) is Cost-Effective and Has Adequate Performance and Fairing size

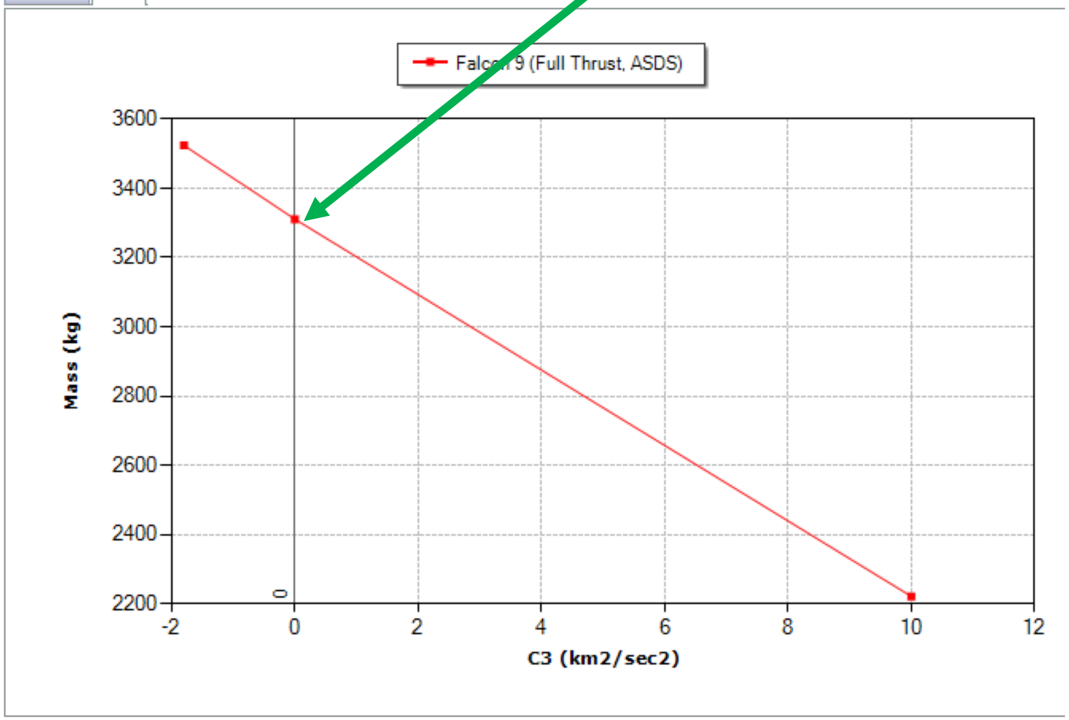
JWST-like SEL2 Orbit
Requires a C3 of about
$-0.7\ km^2/sec^2$,
Allowing a Falcon 9
PL Mass of <=~3,400 kg

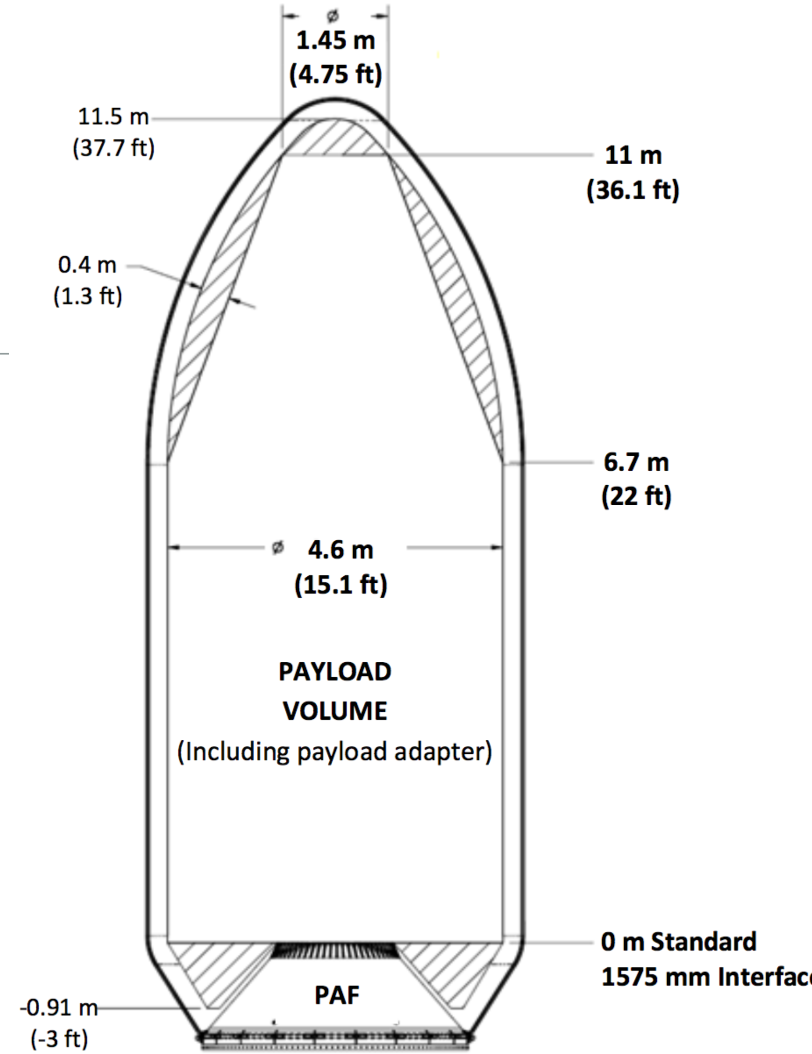
Performance Query

Orbit Class:	High Energy
Graph Type:	C3 (km2/sec2) vs. Mass (kg)
C3 (km2/sec2):	0

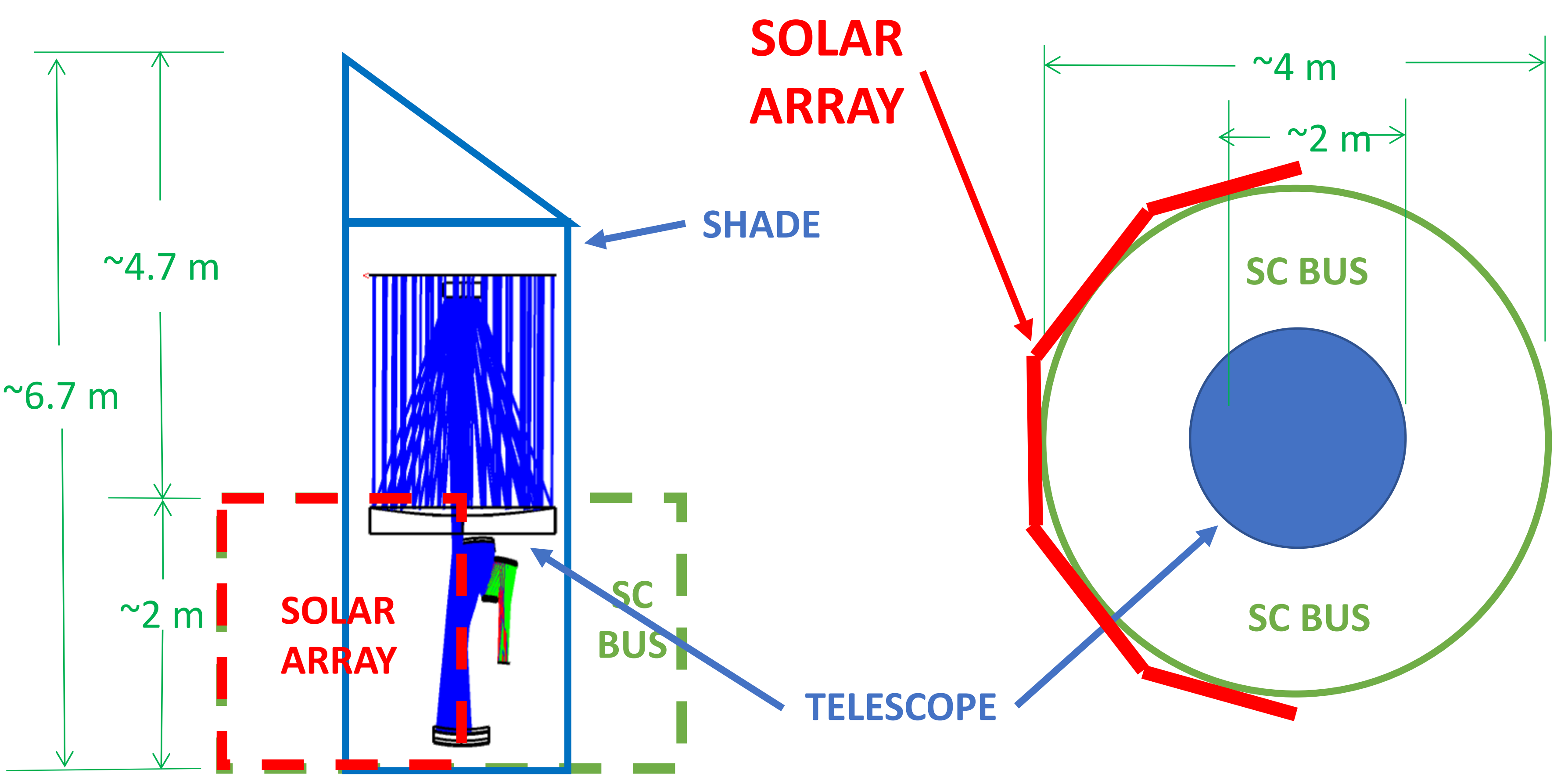
Clear Vehicles | Create New Query | Change Query Parameters | Generate Report

Results | Plot





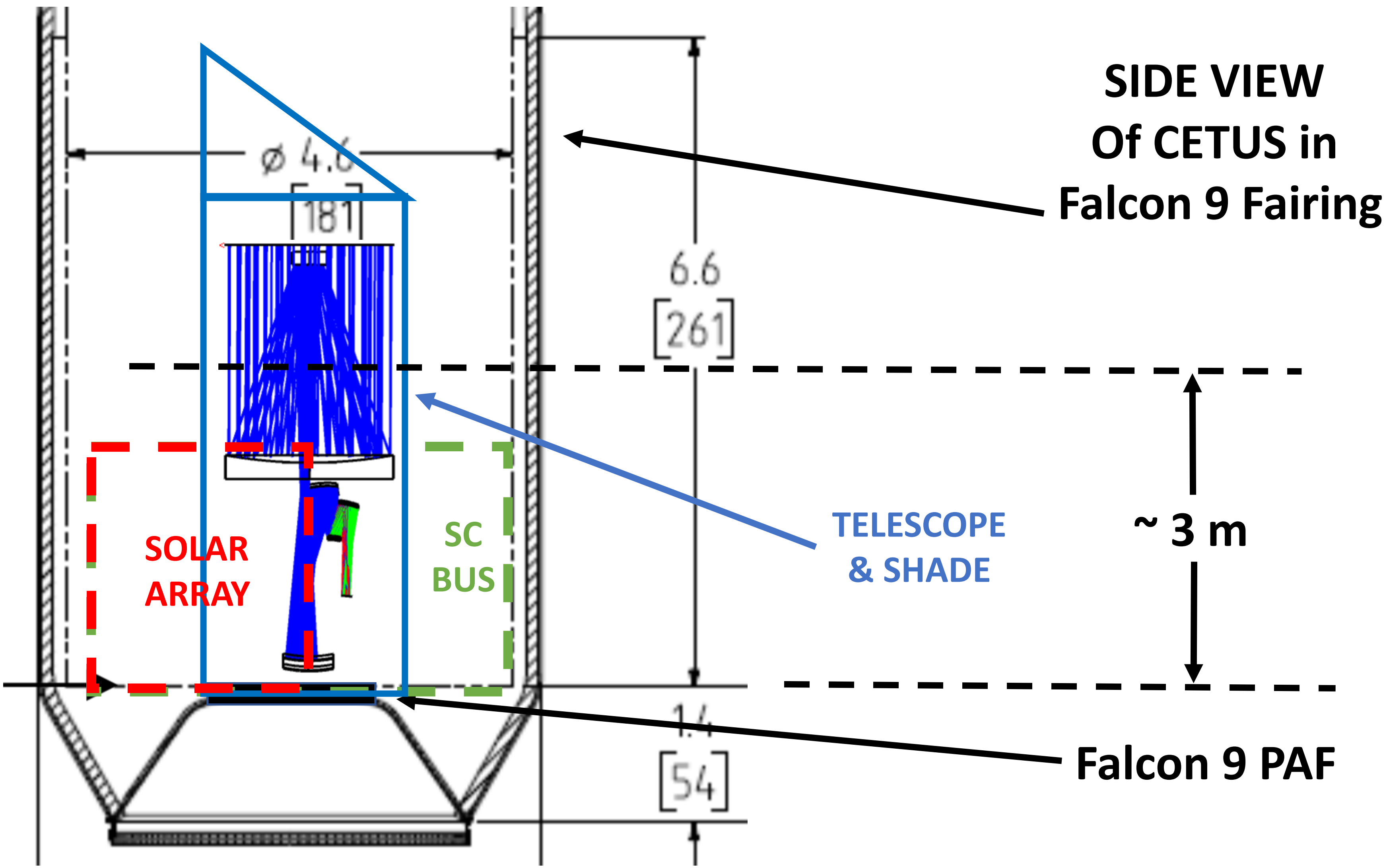
Overall Length of CETUS Telescope and Shade May Require Donut-Shaped SC Bus to meet F9 limit on PL C.G. Height



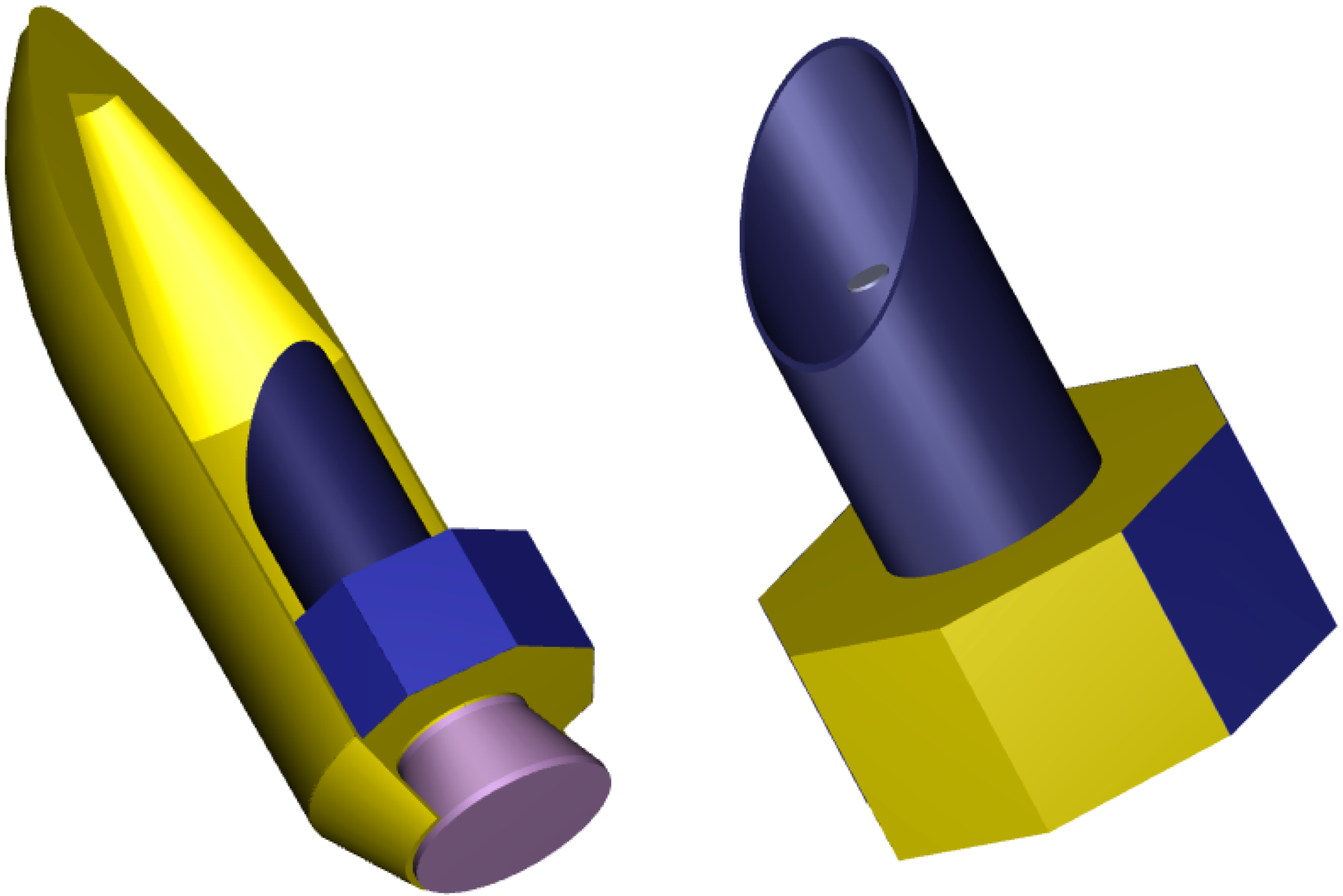
SIDE VIEW

TOP VIEW

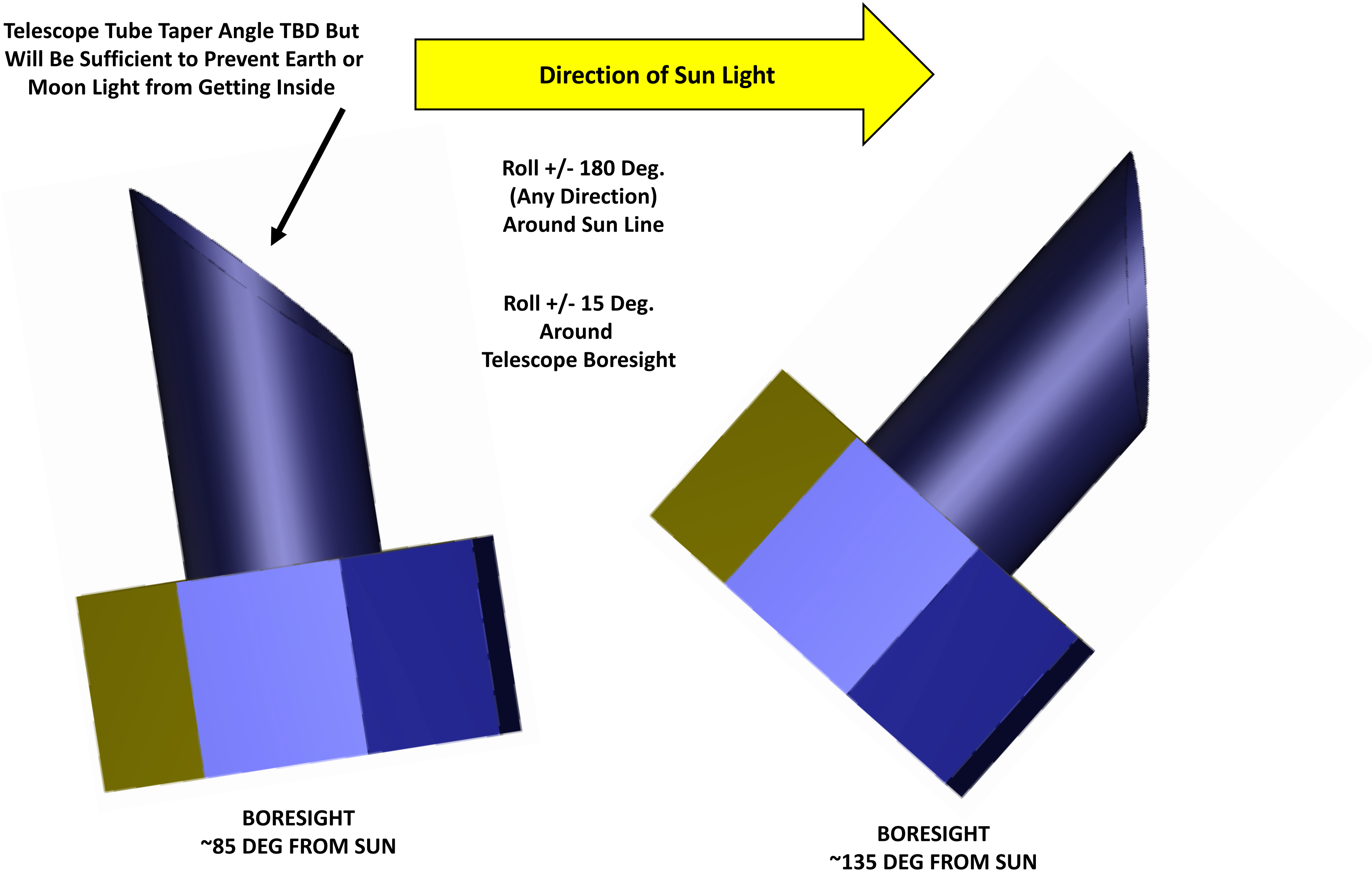
F9 limit of 3 m on PL C.G. Height when using Light PAF



CETUS Stowed in Fairing (left) and after Separation (right)



CETUS Field of Regard (FoR)



JWST Design for Communications from SEL2 Orbit is much more capable than CETUS Requires, can therefore probably be down-scaled, and is expected to be less expensive in future

- 58.8 GB Onboard Solid State Recorder (SSR)
- 0.6 m-aperture High Gain Antenna (HGA)
- DSN 34-m aperture Ground Stations
- Ka-band downlink at up to 3.5 MBps (28 Mbps)
- Two 4-hour contacts per day
- >=28.6 GB can be down-linked per contact

JWST DSN Ground Station

https://www.nasa.gov/directorates/heo/scan/news_dss-36_operational.html

34 meter
Beam Waveguide (BWG)
Antenna

Located in:
Goldstone, California
Canberra, Australia
Madrid, Spain

(Separated by approximately 120 degrees of longitude to ensure that any spacecraft in deep space can communicate with at least one station at all times as the Earth rotates)

CETUS Duration Requirements for Obtaining 10^5 Spectra & Downlinking Science Data

Parameter	Value
Number of SNR ~7 Spectra Desired	>=100,000
Number of SNR ~7 Spectra Produce-able per 24 Hour Day	~240
Number of SNR ~7 Spectra Produce-able per Year	~90,000
Number of SNR ~7 Spectra Produced per Year after consideration of duty cycle and non-survey observations	~30,000
Number of years required to obtain desired number of spectra	**~3**
Average Science Data Rate after adjusting for duty cycle and lossless compression (bps)	~10^5
Average Science Data Rate after adjusting for duty cycle and lossless compression (Bits per week)	~10^{11}
JWST Ka-Band Downlink Data Rate into DSN 34 m GS (bps)	~3×10^7
CETUS Downlink time per week at JWST rate (sec)	~3×10^3
CETUS Downlink time per week at JWST rate (hr)	**~1**

Other CETUS SC Bus Subsystem Concepts

- Thermal Control
  - Straight forward given that CETUS is in constant sunlight at ~ 1 AU and has modest rotations (85 to 135 from sun, +/-15 deg about boresight)
  - Radiators on anti-sun side will always see deep space

- Propulsion
  - Modest Delta V requirements (MCC on way to SEL2, SK in SEL2 orbit, momentum unloading
  - Looks doable with only hydrazine mono-prop

- ACS
  - RWA on SC Bus
  - ST, IMU, FGS on instrument optical bench
  - ~1 arc-sec control required (Kepler equivalent, ample heritage)

- Power
  - Estimate of 1 to 2 kW required
  - F9 5-meter faring permits very large SC Bus size, which provides more than adequate area for simple, fixed, body mounted SA

- C&DH
  - Only does SC Bus HSK (Inst computer will do any req'd science data compression)
  - Modest sized SSR

Conclusions

- Preliminary CETUS Mission Design Defined
- No Major Challenges yet uncovered
- Mostly a Simple, High Heritage-Conventional Design
  - Good news for cost control
- Impact of less-conventional items
  - Donut shaped SC Bus still allows conventional components
  - More analysis needed to determine if Celestial Navigation (Cel-Nav) rather than ground tacking can be used for Orbit Determination (OD)
- Meeting Probe-Class Total Mission Cost Constraint (<=~$1B) looks feasible

The CETUS Team

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