ORIGINS Space Telescope

OST Mission Concept

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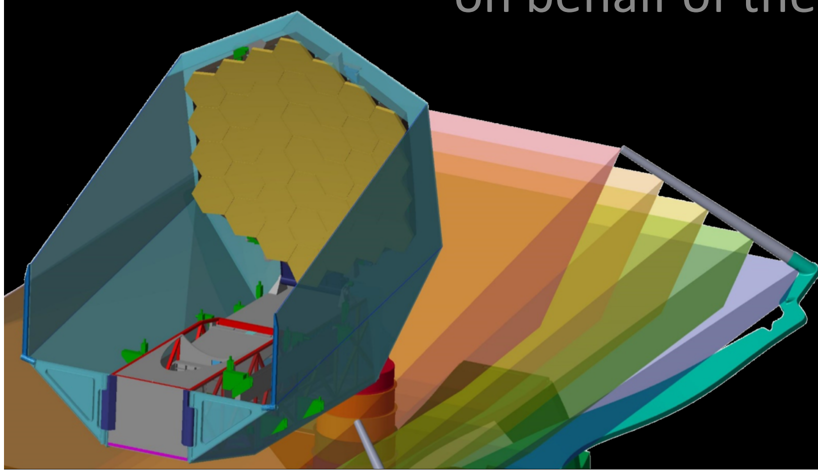
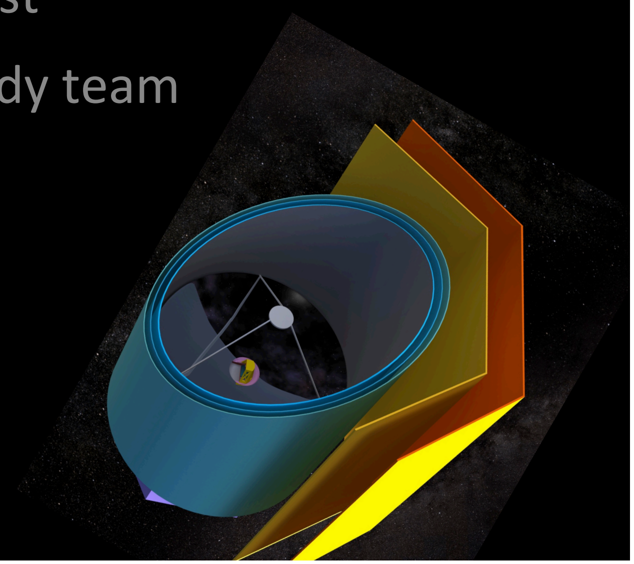
on behalf of the OST mission concept study team





Study approach

Iterate concept with STDT

Identify visionary, robust, and compelling science questions

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Derive from those questions a set of high-priority measurement requirements for the mission

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Choose a mission architecture

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Evaluate trades and develop mission point design

↓

Determine technology needs

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Estimate costs (baseline concept and options)

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Present to Decadal Survey

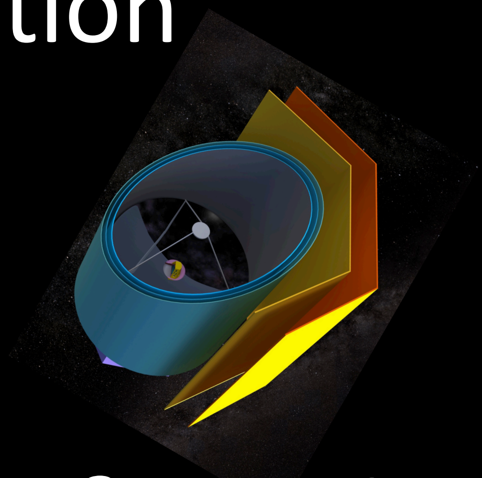
Architecture evolution

retain high-value science

constrain cost

eliminate complex deployments, reduce risk

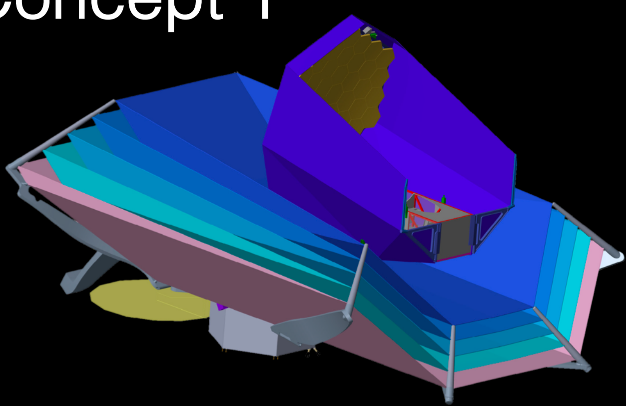
reduce size



Concept 2

optimization

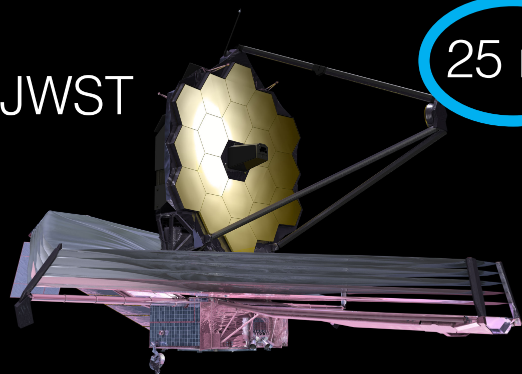
Concept 1



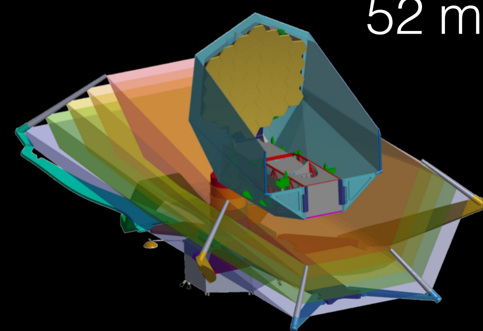
Decadal baseline concept with upscope options

Architecture inspiration

JWST



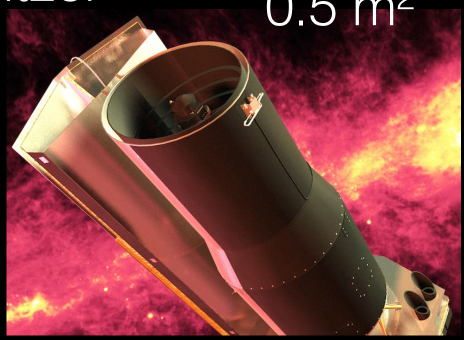
25 m²



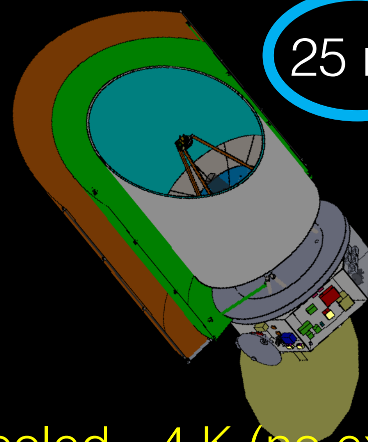
52 m²

OST Concept 1:
Open architecture

Spitzer



0.5 m²



25 m²

OST Concept 2:

- Better stray light protection
- Can demonstrate shield deployment on the ground

All concepts studied are cryo-cooled ~4 K (no expendable cryogen)

Major Architecture Trades

Telescope size
- JWST collecting area to capture transit spectroscopy from enough exoplanets

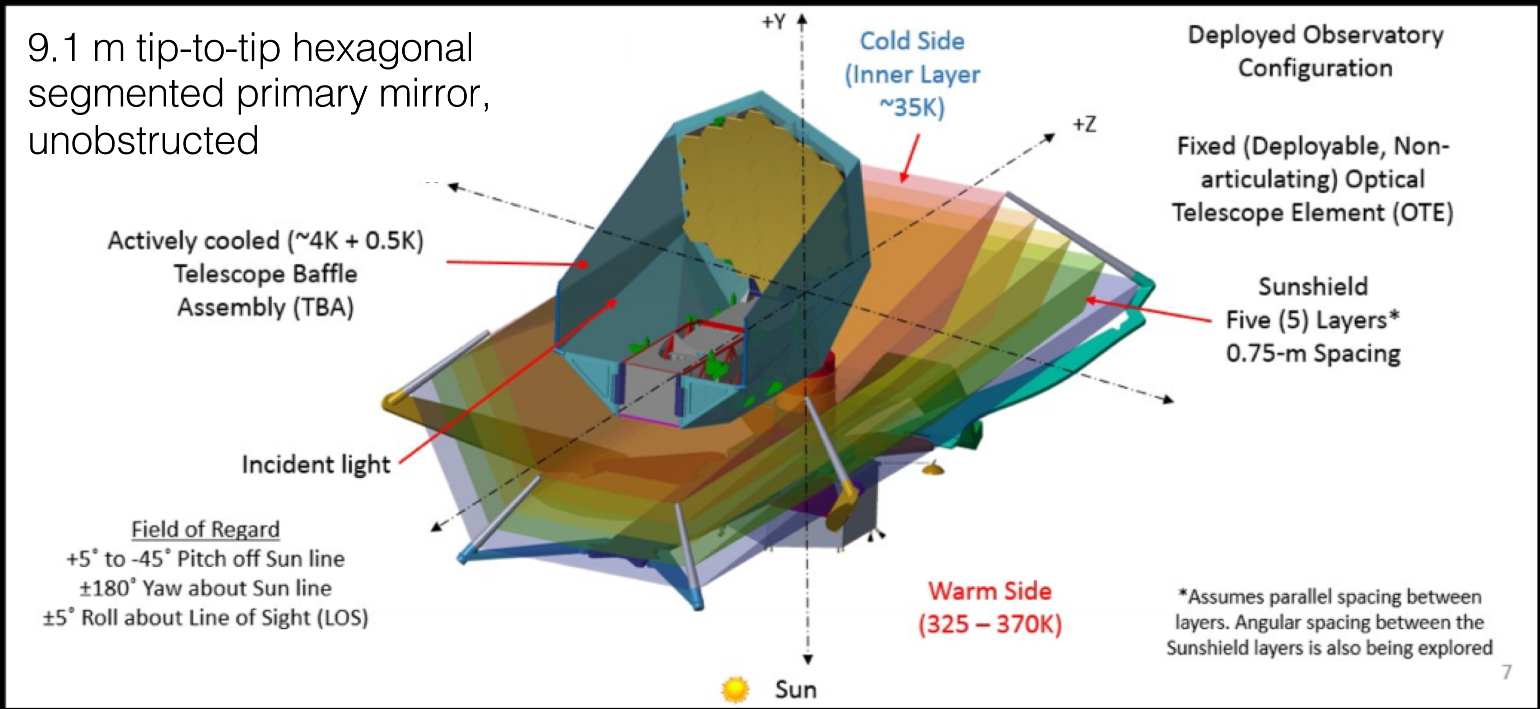
Deployed vs. Non-deployed
- Non-deployed optics for simplicity
- SLS (or BFR) required, but viewed as less risky than deployment

On- vs. off-axis
- On-axis for ease of packaging

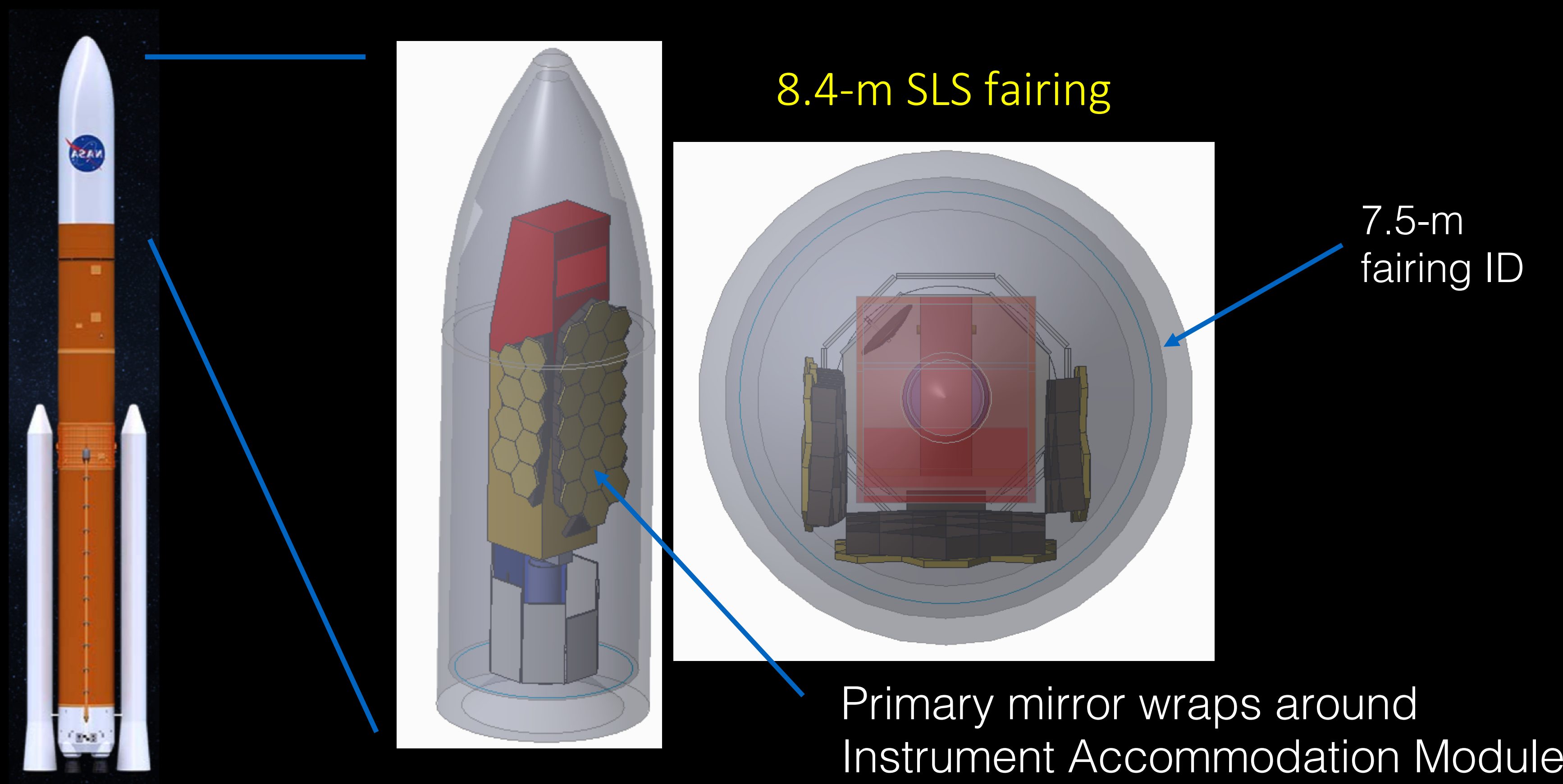
Size of primary mirror segments
- JWST size, but forming circular aperture
  - 18 segments with only two prescriptions
  - Manufacturing facilities exist

OST Concept 1

- Satisfies nearly all of the science team's "desirements"
- No cost constraint



Concept 1 stowed for launch



OST Concept 1

Concept 1 is described in the OST Interim Report

- Available on our website https://asd.gsfc.nasa.gov/firs/docs/ or
- https://arxiv.org/abs/1809.09702

Science drivers for OST C2

Design drivers

OST is a mid- and far-IR observatory whose design is driven by community-prioritized science to answer three questions:

1. How common are life-bearing planets orbiting M dwarf stars?
   - Biosignatures in the mid-infrared
2. How do the conditions for habitability develop during the process of planet formation?
   - Follow the trail of water (vapor and ice) from the interstellar medium to nascent planets
3. How do galaxies form stars, grow their central supermassive black holes, and make heavy elements over time?
   - Probe the universe deeply in key diagnostic spectral lines without the adverse effect of dust extinction

Derived requirements

The prioritized scientific objectives for OST require:

- exquisite sensitivity (e.g., 5σ sensitivity to spectral lines at10^{-20} W m^{-2} in 1 hour);
- spectroscopy with resolving power ranging from 10 to $>10^5$ in approximately order-of-magnitude increments;
- an ability to survey large areas in a reasonable observing time (e.g., a deep extragalactic "Legacy survey" covering 10 deg^2 in 1000 hours); and
- superlative stability (<5 ppm) to enable a fruitful search for biosignatures in the spectra of transiting exoplanets.

The prioritized scientific objectives do <u>not</u> require high (sub-arcsecond) angular resolution.

A cold (4.5 K) telescope equipped with next-generation detectors in high pixel count arrays can approach the astronomical background photon noise limit and satisfy the requirements.

OST concept comparison

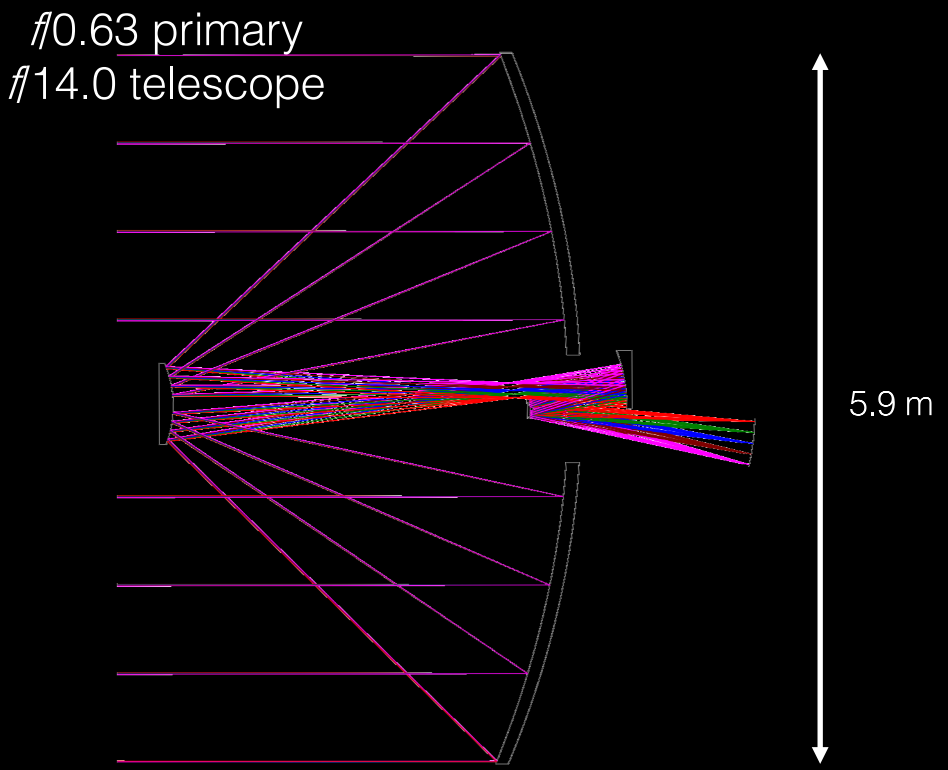
ORIGINS Space Telescope

Parameter	OST Concept 1	OST Concept 2
Wavelength range (μm)	5 - 660	5 - 588
Telescope Field of View (arcmin)	25 x 15	40 x 15
Launch Vehicle/Configuration	SLS with 8.4 m fairing	Compatible with SLS with 8.4 m fairing; Space X BFR with ~9 m fairing; Blue Origins New Glenn with ≥7 m fairing
Telescope first-order specifications		
Aperture size	9.1 m hexagonal, tip-to-tip; segmented; folded when stowed for launch, and deployed in space	5.9 m diameter (circular); no deployment
Collecting area (m^2)	52	25
f-number	*f*/12.8	*f*/14.0
Effective Focal Length (m)	116	82.6
Design form	Three-mirror anastigmat, unobstructed (off-axis pupil)	Three mirror anastigmat, on-axis pupil, 0.9 m central obstruction
Operating temperature (K)	4	4
Spatial resolution	Diffraction limited at λ = 30 μm (MISC instrument diffraction limited at 5 μm with deformable mirror)	Diffraction limited at λ = 30 μm (MISC instrument diffraction limited at 5 μm with deformable mirror)
Pointing requirements	Knowledge: 30 mas (MRSS inertial point); Control: 44 mas; Jitter: 22 mas RMS (at MISC; telescope rqmt TBD)	TBD; approximately the same as Concept 1
Instrument suite		
	Mid-Infrared Imager Spectrometer Coronagraph (MISC) • Wavelength range: 5 - 38 μm • Imaging, spectroscopy • Coronagraphy (10^{-6} contrast) • Transit Spectrometer (<10 ppm stability on a timescale of hours to days) • Study partners: JAXA, NASA ARC	**Mid-Infrared Imager Spectrometer Coronagraph (MISC)** • Wavelength range: 5 - 38 μm • Imaging, spectroscopy • Transit Spectrometer (5 ppm stability, with a goal of 1 ppm, on a timescale of hours to days) • Study partners: JAXA, NASA ARC
	Medium Resolution Survey Spectrograph (MRSS)	**Origins Survey Spectrometer (OSS)**

OST instruments by concept

Instrument suite	Concept 1	Concept 2
	Mid-Infrared Imager Spectrometer Coronagraph (MISC) • Wavelength range: 5 - 38 μm • Imaging, spectroscopy • Coronagraphy (10^{-6} contrast) • Transit Spectrometer (<10 ppm stability on a timescale of hours to days) • Study partners: JAXA, NASA ARC	**Mid-Infrared Imager Spectrometer ~~Coronagraph~~ (MISC)** • Wavelength range: 5 - 38 μm • Imaging, spectroscopy • Transit Spectrometer (5 ppm stability, with a goal of 1 ppm, on a timescale of hours to days) • Study partners: JAXA, NASA ARC
	Medium Resolution Survey Spectrograph (MRSS) • Wavelength range: 30 - 660 μm • Multi-band spectroscopy • Study partner: JPL	**Origins Survey Spectrometer (OSS)** • Wavelength range: 25 - 588 μm • Multi-band slit spectroscopy, with all bands in one slit; ~100 diffraction-limited beams per slit • FTS mode provides R = 43,000 x (112 μm/λ) • High-resolution mode provides R = 325,000 x (112 μm/λ) • FTS and High-res modes in single diffraction-limited beam • Study partners: JPL, NASA GSFC
	High Resolution Spectrometer (HRS) • Wavelength range: 25 - 200 μm • High-resolution, high-sensitivity spectroscopy • Study partner: NASA GSFC	
	Far-infrared Imager and Polarimeter (FIP) • Wavelength bands: 40, 80, 120, 240 μm • Broadband imaging • Field of view 2.5’ x 5’, 7.5’ x 15’ • Differential polarimetric imaging • Study partner: NASA GSFC	**Far-infrared Imager and Polarimeter (FIP)** • Wavelength bands: 40, 80, 120, 240 μm • Broadband imaging • Field of view 13.5' x 9' @ 120 and 240 μm, 4.5' x 3' @ 40 and 80 μm • Polarization sensitivity: 0.1% in linear and circular; ±1° in pol. Angle • Study partner: NASA GSFC
	Heterodyne Receiver for OST (HERO) • Wavelength bands: 63 - 66, 111 - 641 μm • Multi-beam high-resolution spectroscopy • Study partner: European consortium	**Heterodyne Receiver for OST (HERO)** • Wavelength bands: 617 - 397 μm; 397 - 252 μm; 252 - 168 μm; and 168 - 111 μm • R = 10^5 - 10^7 spectroscopy • Instantaneous FoV: 2.1' x 2.1' @ 480 μm; 1.3'x1.3' @ 300 μm; 0.8'x0.8'@ 200 μm; 0.6'x0.6' @ 130 μm • Study partner: European consortium

OST Concept 2 telescope



Three-mirror (TMA) selected over two-mirror system

- Larger FoV
- Improved imaging performance
- Incorporate Field Steering Mirror

On-axis selected over off-axis

- Easier to package in fairing
- Easier fabrication/testing – more symmetric segments

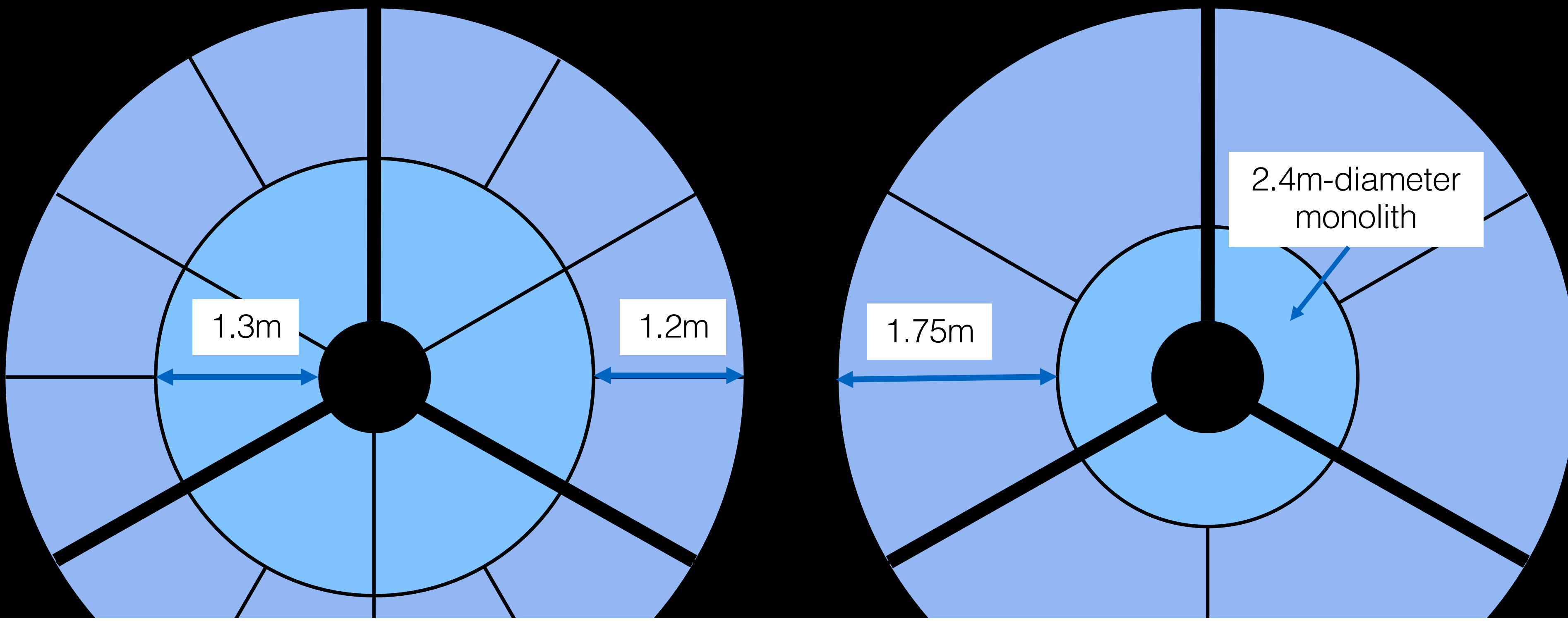
Circular pupil selected over elliptical or rectangular

- Cleaner/symmetric PSFs

Primary mirror segments

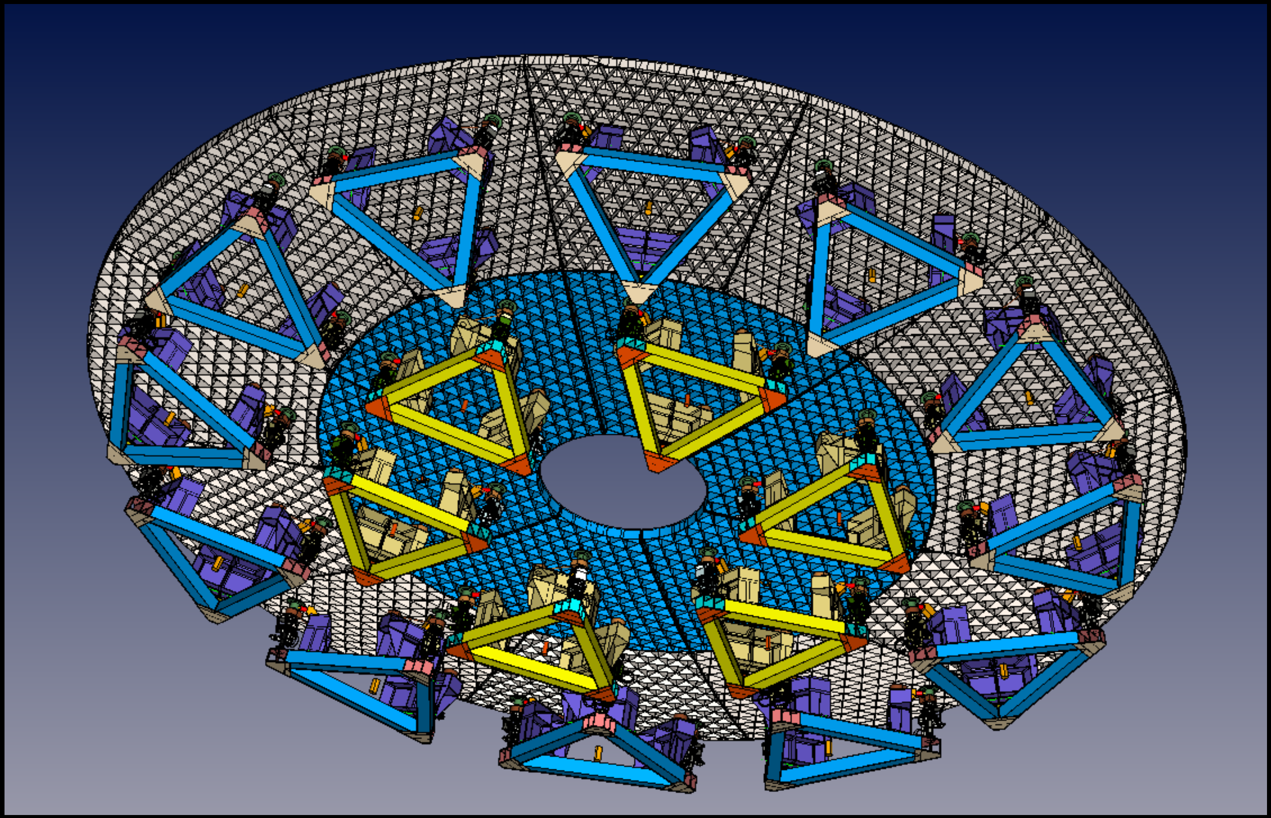
Option 1a: replace Herschel-sized (3.5m) monolith w/ six segments. 12 segments in outer ring.

Option 2a: Hubble-sized (2.4m) monolith surrounded by ring of six segments.



3 dof segment actuation

Only need to adjust piston, tip and tilt.



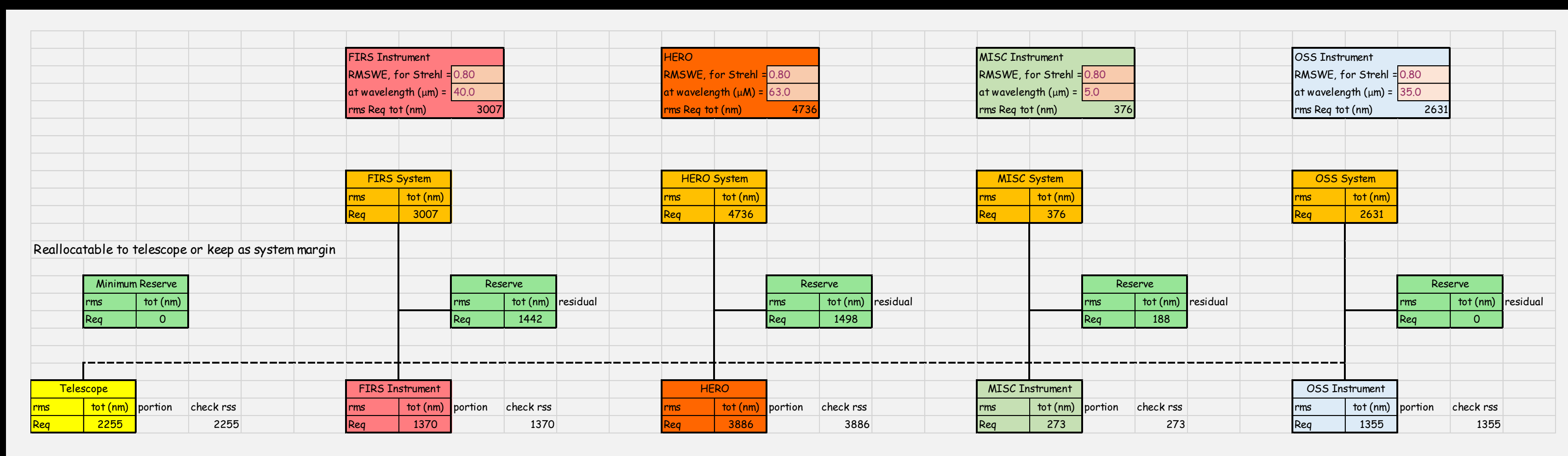
OST Concept 2 error budget

Shows how we take advantage of the relaxed WFE tolerance.

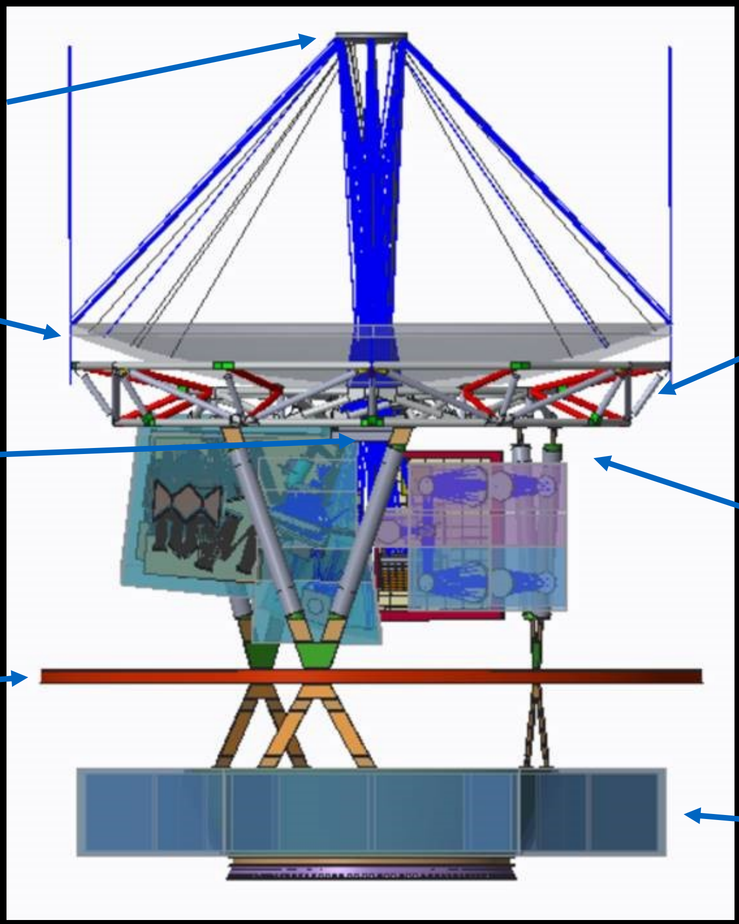
- No cryo-null figuring

Deepen Budget as architecture matures

- Includes alignment of telescope optics and instruments
- low, mid, high allocations
- Break out thermal and dynamic terms
- Focus allocation



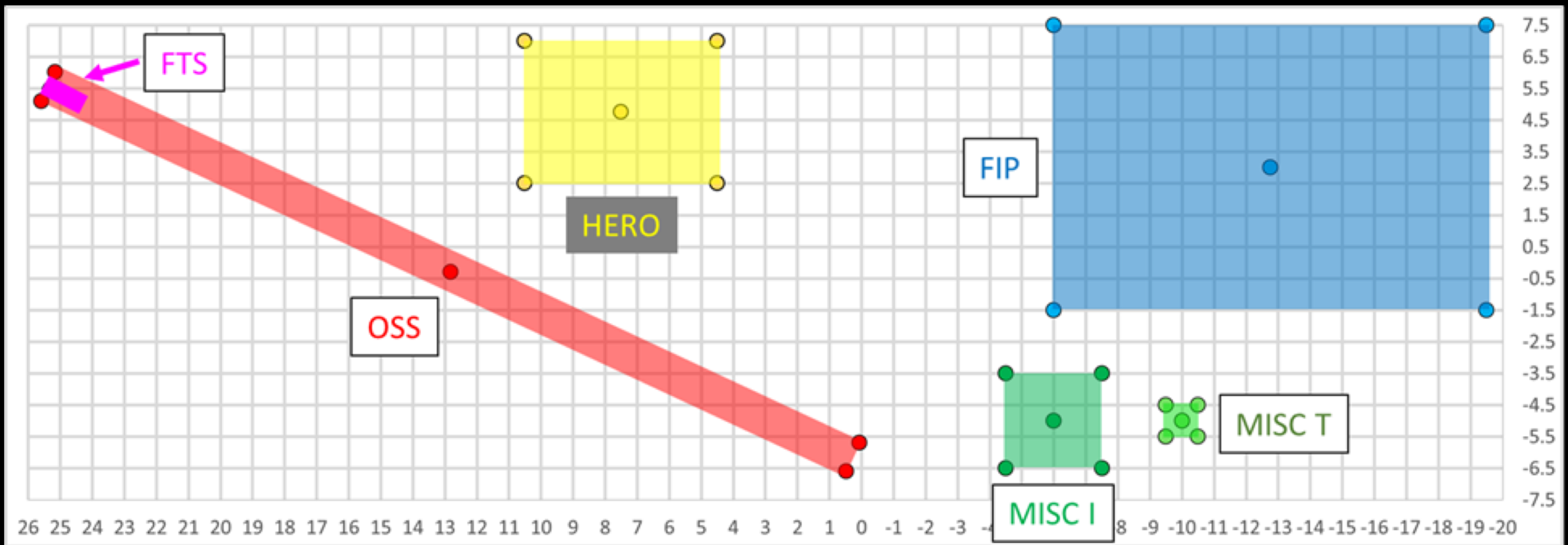
OST Concept 2



Baseline mission concept

- 5.9 m diameter telescope, same collecting area as JWST
- MISC Transit Spectrometer (2.8 – 20 μm)
- OSS instrument with all 6 bands, FTS, and etalon, with half the original number of pixels (reduced spatial dimension)
- FIP instrument with 50 and 250 μm channels, polarization, and half the original number of pixels
- Temperature increased from 4 to 4.5 K - modest cost saving, but reduces risk and relaxes detector NEP requirement
- Dropped the heterodyne instrument, HERO, and the MISC imager, but maintain volumes allocated to these items
- Descoped items become upscope options
- Changes have only a modest impact on the highest priority science

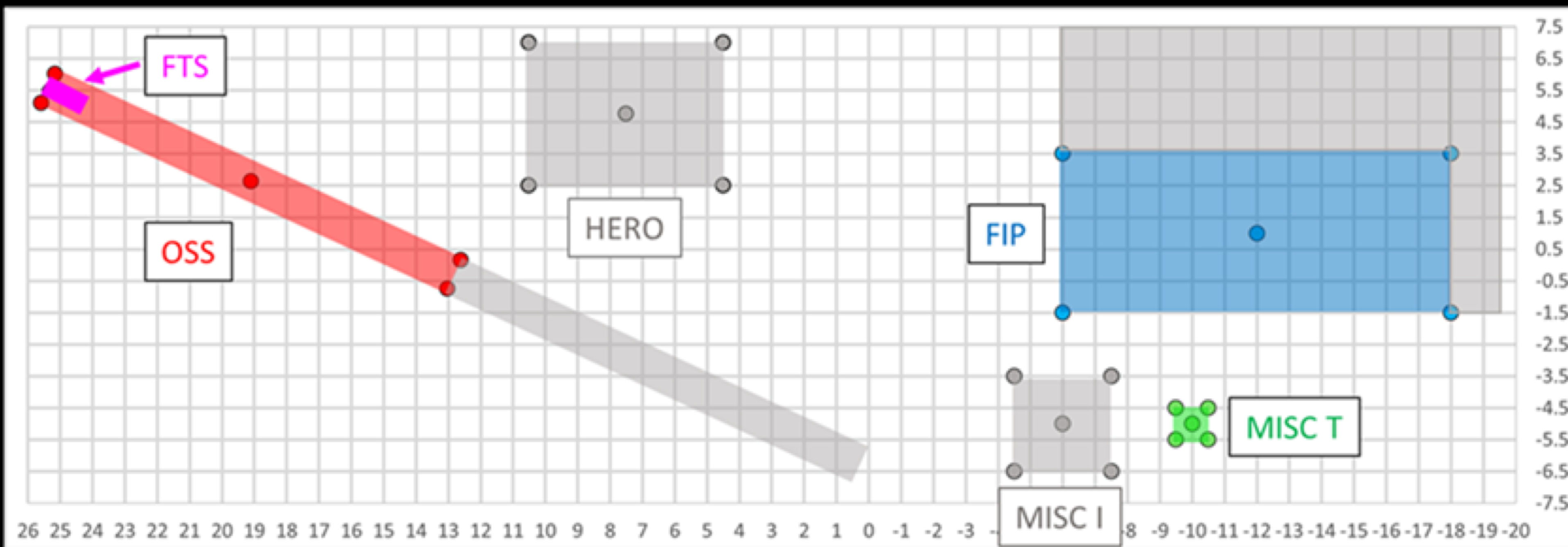
OST Field of View: Concept 2



OSS – Origins Survey Spectrometer
HERO – Heterodyne Receiver for OST
FIP – Far-IR Imager/Polarimeter

MISC – Mid-IR Imager and Spectrometer (WFI = Wide-field Imager; TRA = Transit Spectrometer)

OST Field of View: Baseline



OSS – Origins Survey Spectrometer
HERO – Heterodyne Receiver for OST
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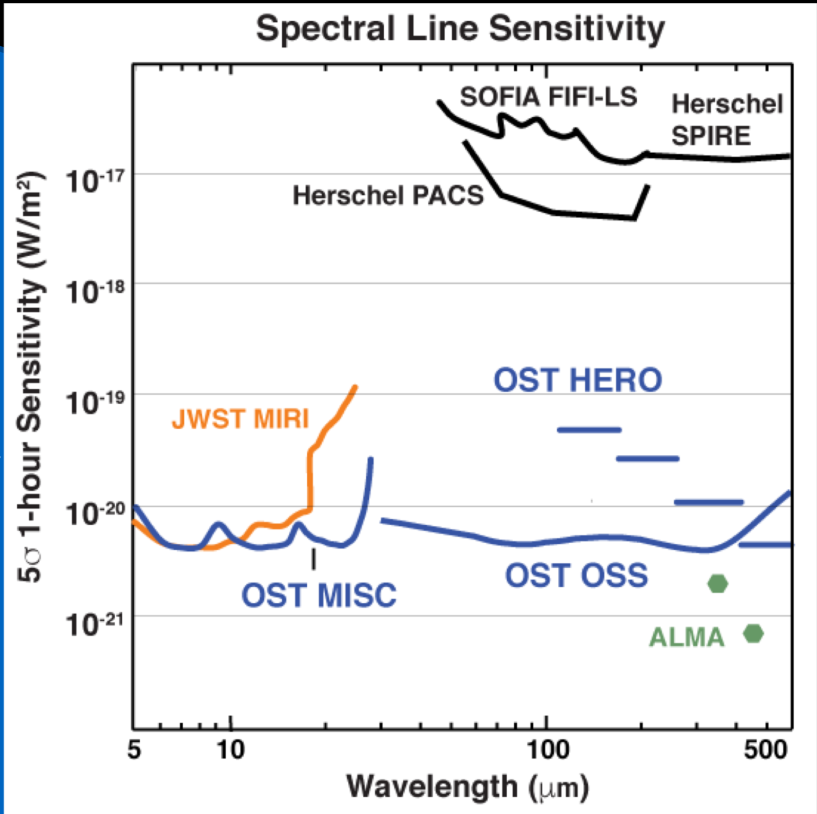
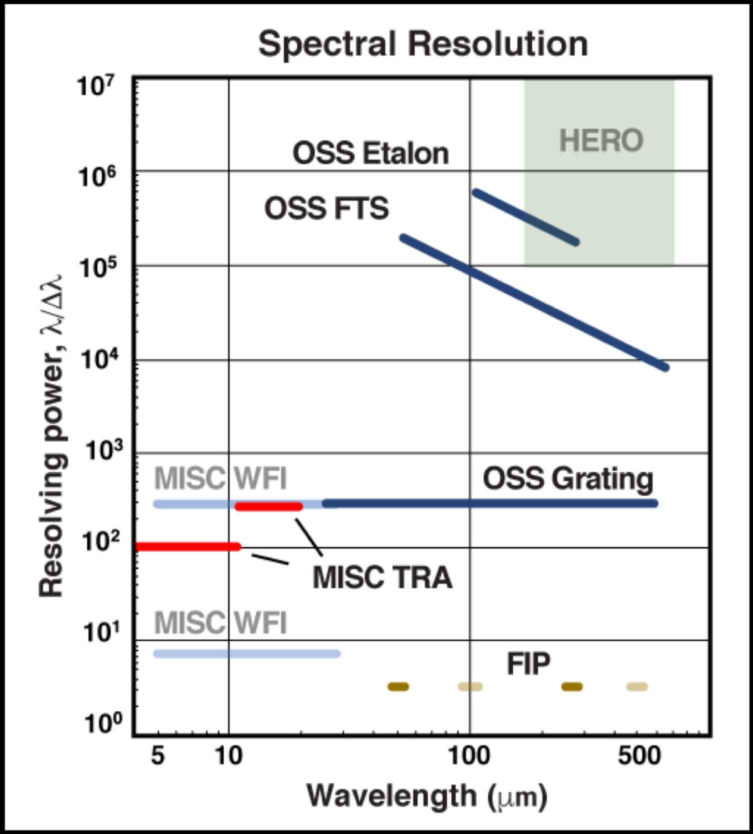
OST sensitivity

Equivalent differenc
optical telescope to
1000x sensitivity



OST is about 3 orders of magnitude more sensitive than Herschel, thanks to its cold temperature and next-generation detectors.

OST spectral resolution



OST's instruments collectively provide the required spectral resolution.

The OST study team will present a scientifically compelling, <u>low-risk</u>, executable mission concept to the 2020 Decadal Survey.