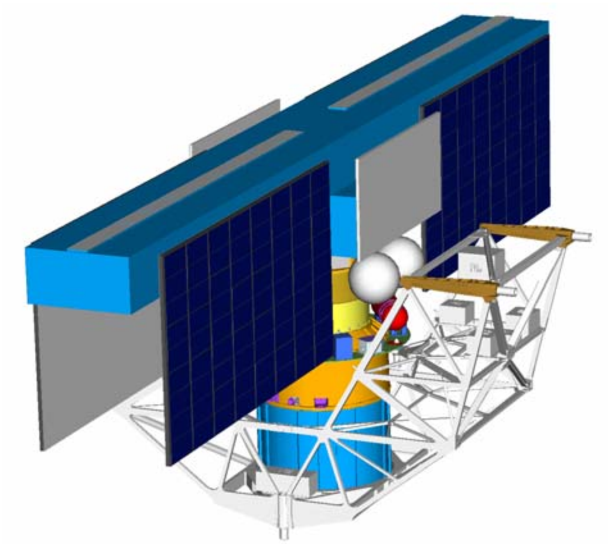
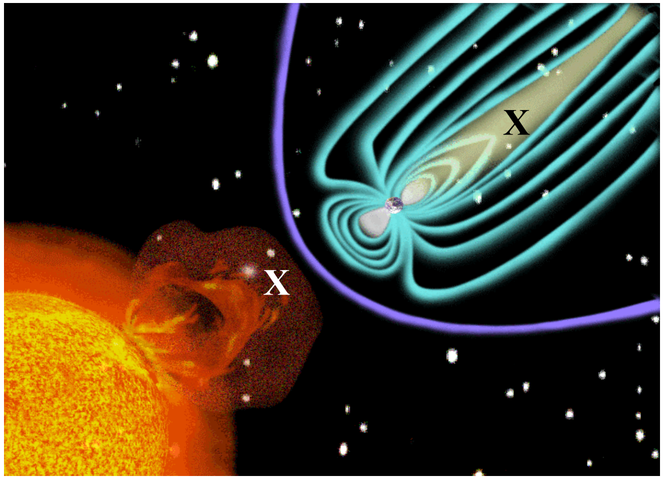
L2-View/EASI

(Earth Atmosphere Solar-Occultation Imager)

Jay Herman
Lee Feinberg
Jim Watzin



CO_2, CH_4, H_2O, O_3, O_2, N_2O



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L2-View/EASI

(Earth Atmosphere Solar-Occultation Imager)

* Solar Occultation from Lagrange-2
* Fourier Transform Imaging Spectrometer
* 10 Meter Interferometer (lightweight design)

Wavelengths: 1 – 4 microns
Resolution: 1 nm or better
Spatial Resolution: 1 to 2 km
CCD: 1K x 1K or Linear Diode Array
Available Solar Flux ~ 12 - 15% of Total Sun

L2-View (EASI): A Mission Concept
Earth Atmosphere Solar-Occultation Imager

1. **If a mission to Lagrange Point 2 (a position behind the Earth relative to the Sun) were contemplated, what science could be accomplished?**

2. **Is there unique Earth science that can be accomplished from this orbit?**

3. **Are there problems that would prevent such a mission?**

4. **Is there other unique science that can be accomplished from the same spacecraft?**

L2-View (EASI):

1. **If a mission to Lagrange Point 2 (a position behind the Earth relative to the Sun) were contemplated, what science could be accomplished?**

Ans: Measure Greenhouse Gases

CO_2, CH_4, H_2O, O_3, O_2, N_2O

2. **Is there unique Earth science that can be accomplished from this orbit?**

Ans: Produce the FIRST 3-D Mapping of Greenhouse gases

Height 2 km: Latitude 0.1^o Longitude 2^o

L2-View (EASI):

3. Are there problems that would prevent such a mission?

Ans: NO

Launch and orbit require conventional hardware
Spacecraft is derived from Triana
Instrument optics are conventional (flat mirrors)
GSFC has built in-house several IR Fourier Transform Spectrometers (e.g., CIRS on Cassini and FIRAS on COBE).

The 10 meter interferometer is new, but within today's engineering capabilities.

L2-View (EASI):

4. **Is there other unique science that can be accomplished from the same spacecraft?**

Ans: YES

Unique Solar Observations at high spatial resolution in the Near IR

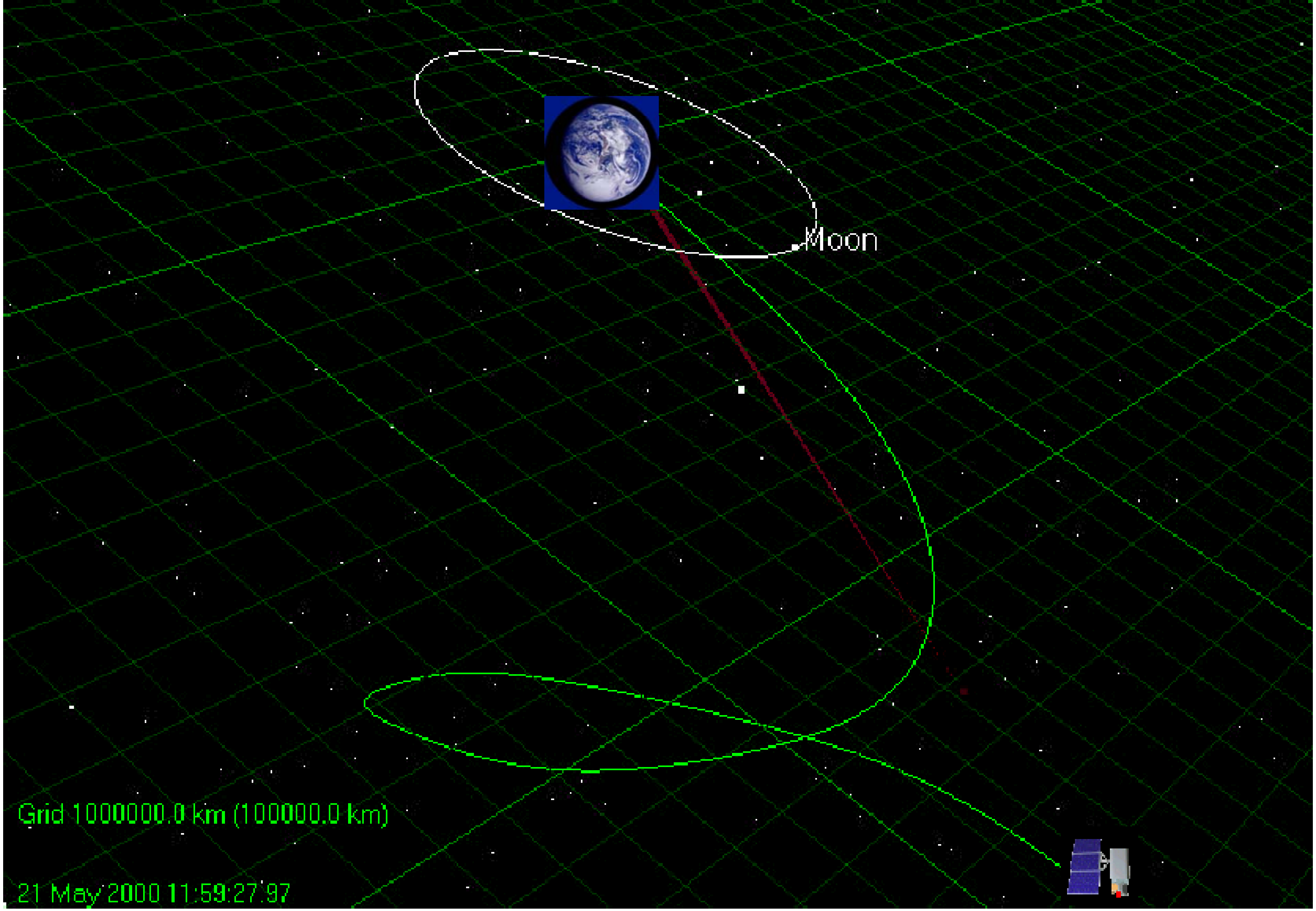
Observations of the Magnetotail

Observations of Lightning

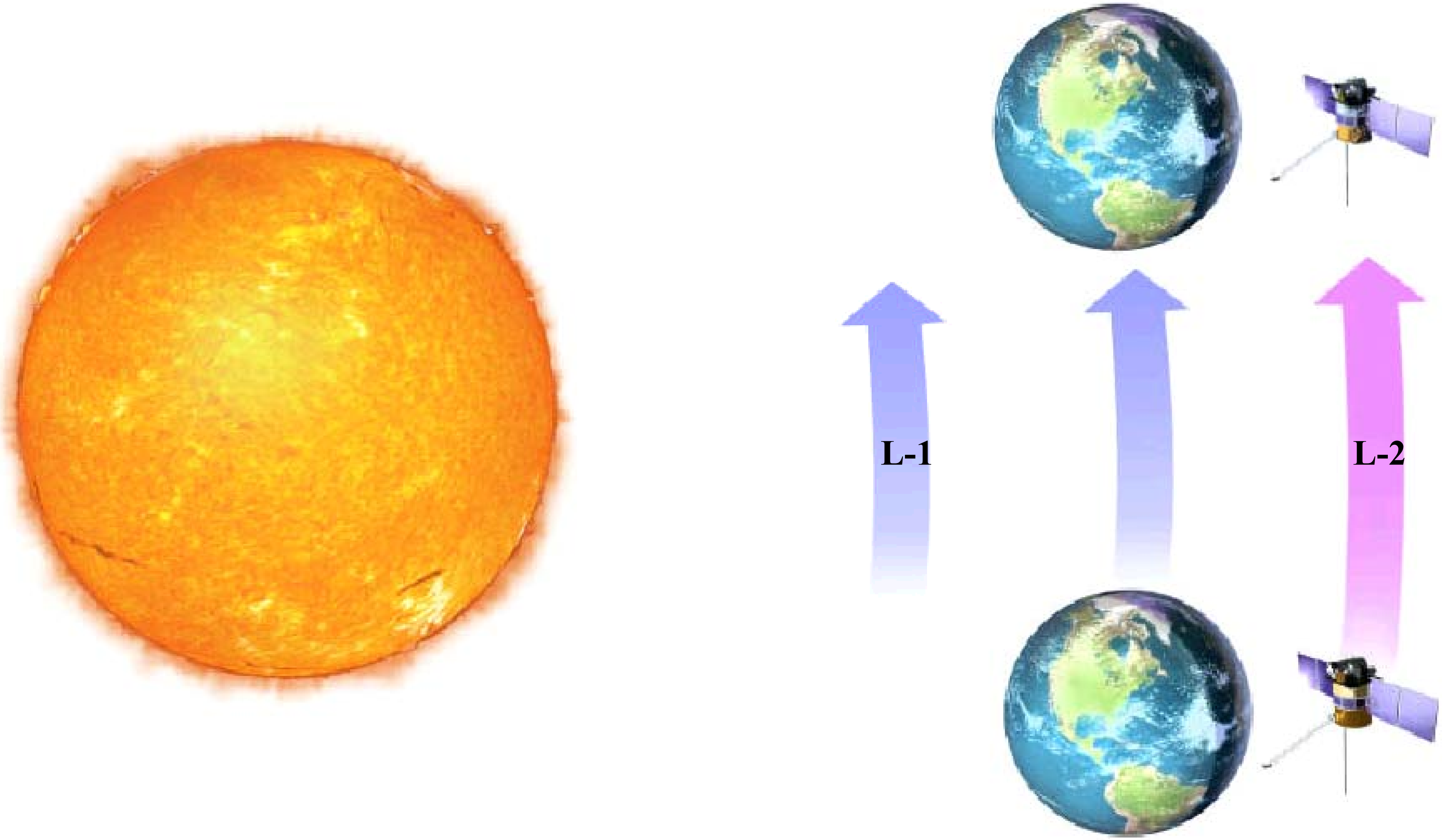
Observations of Aurora

Observation of Nighttime cloud cover

L2-View EASI Trajectory to L-2

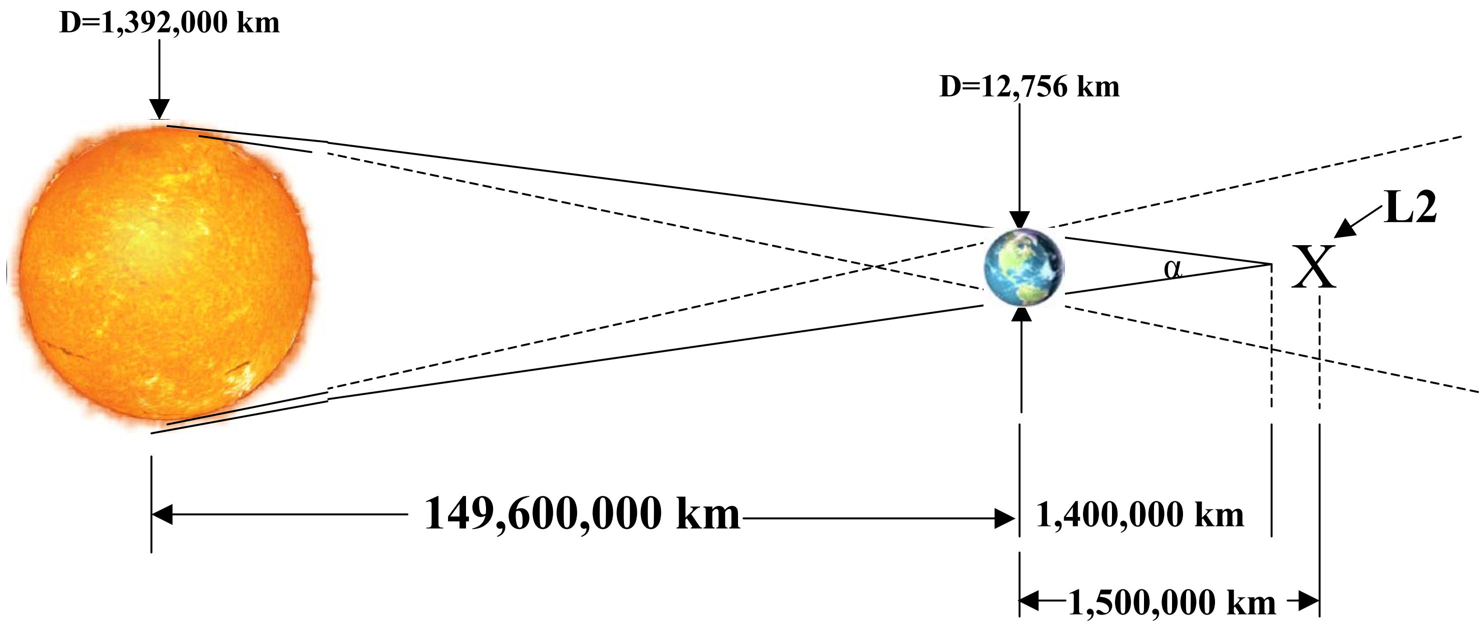


EASI Solar Occultation Mission



L-1 and L-2 points move with the Earth

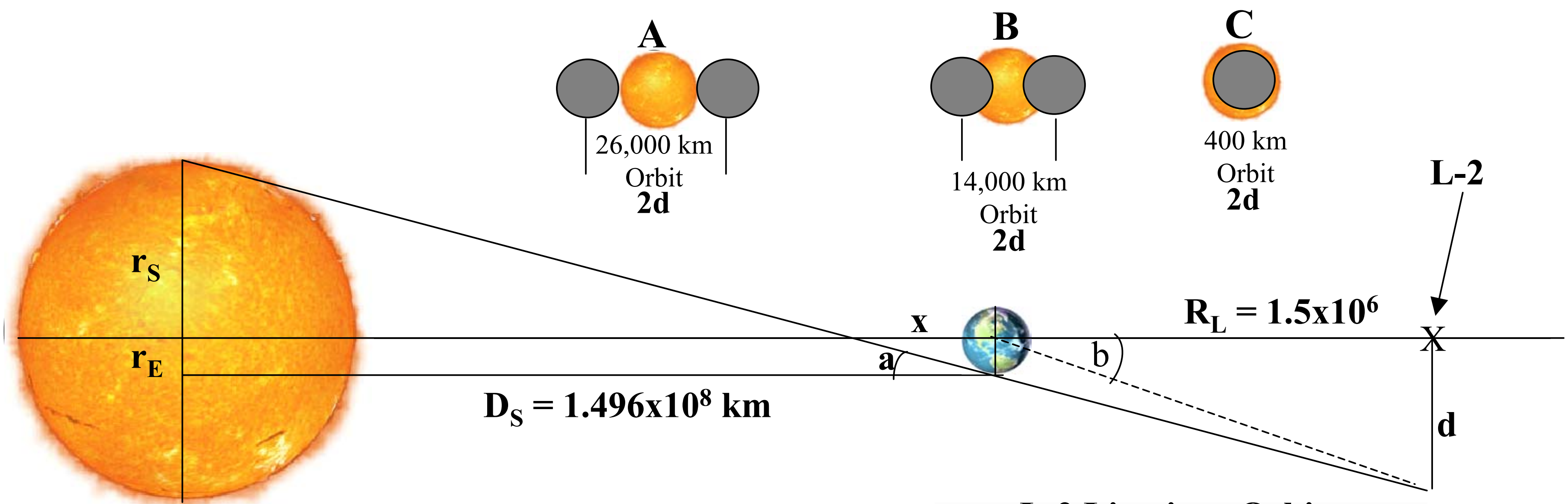
Relationship of L-2 Orbit Position to the Earth's Umbra



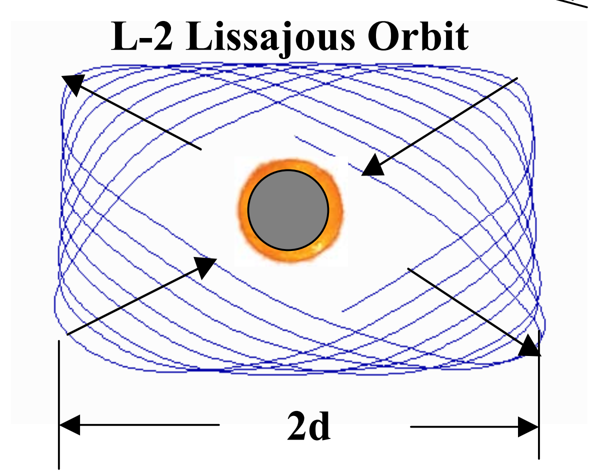
The spacecraft is always illuminated by the direct sun. This means that the atmosphere can be continuously viewed in solar occultation.

View of the Earth-Sun System from the L-2 Orbit

If the Earth's atmosphere is to always be seen against the Sun, the Lagrange orbit is close to the Sun-Earth line.



$r_S = 6.9598x10^5$ km
$r_E = 6.373x10^3$ km



Case C is the desired
Orbit for solar occultation

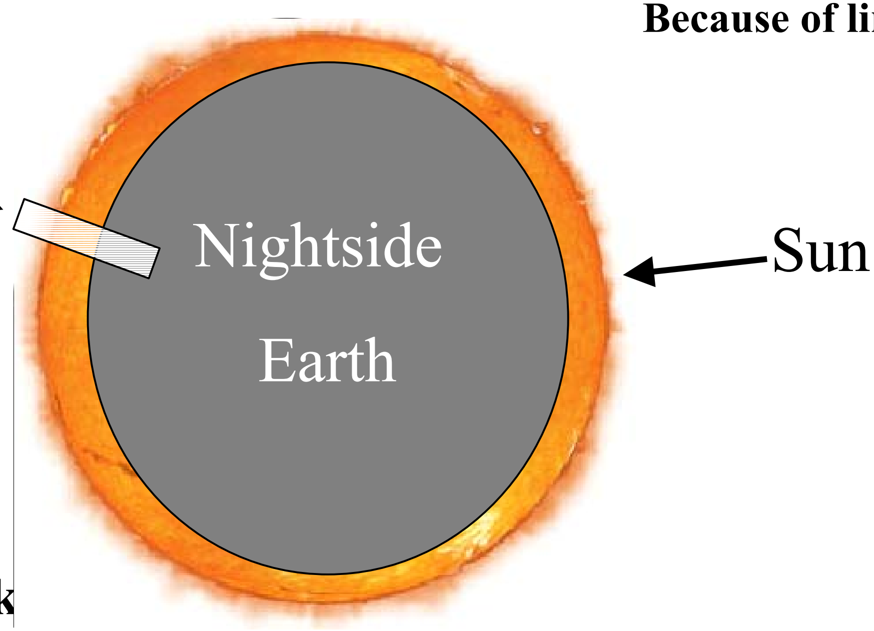
View of the Earth-Sun System from L-2

Rotatable Detector for Occultation

Detector With
Interferometer Slit
2 km altitude resolution
1 to 5 microns

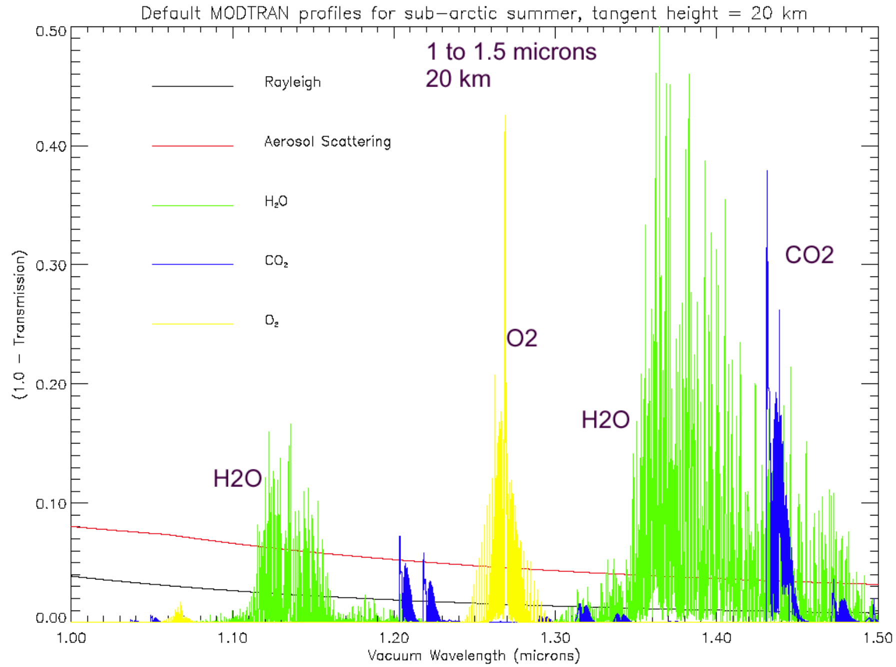
Exposed Sun Area = 15%

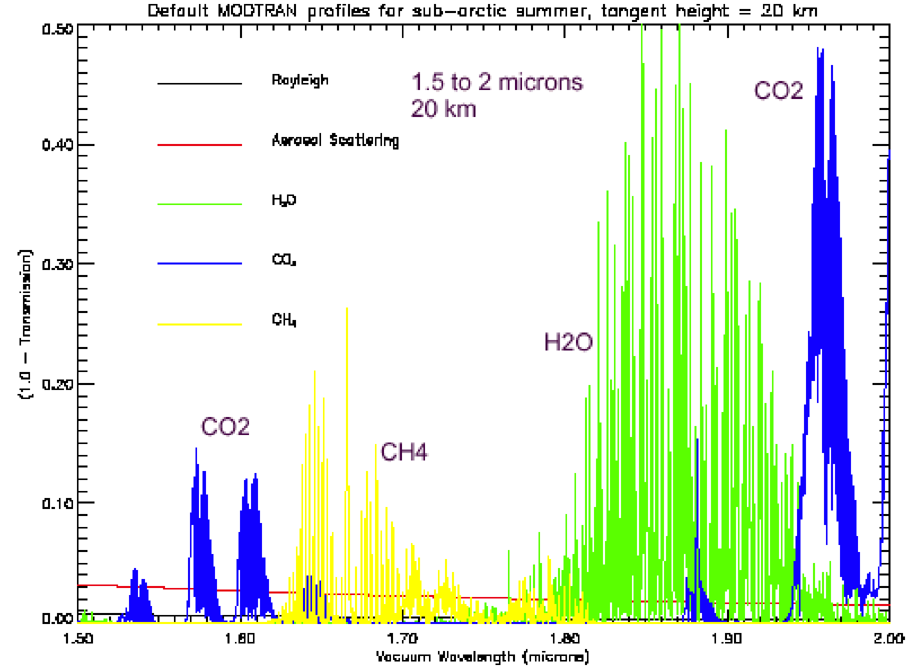
Brightness < 15%
Because of limb darkening

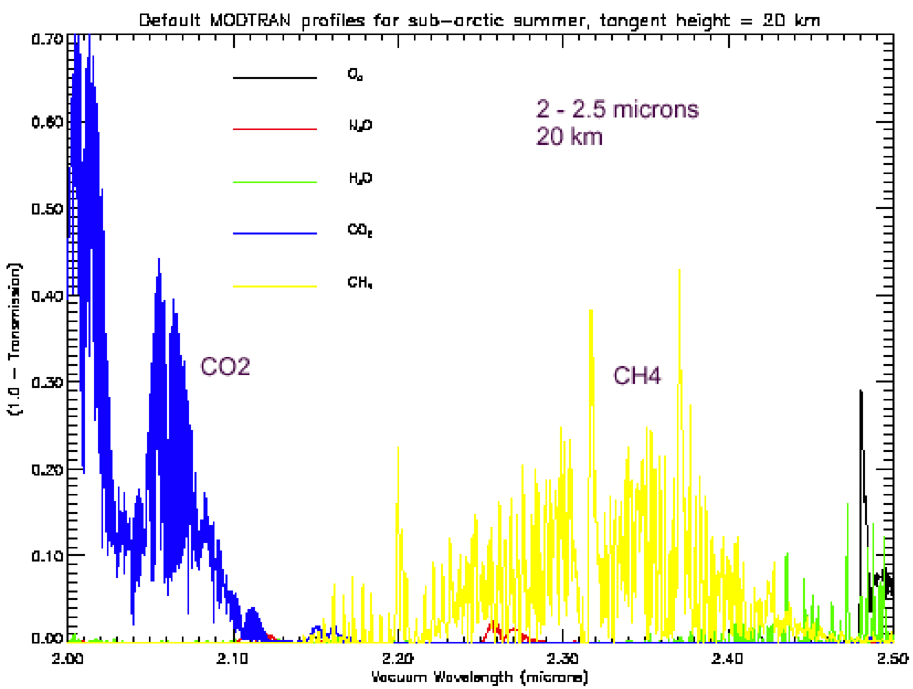


Obs. Solar Disk=53,500 k
3.8% of solar disk
Earth atmosphere=440 km

Note: The edge of the Sun is 53,500 km of the Sun's disk, but only extends 440 km above the Earth's disk







20 km limb view

1 to 2.5 microns

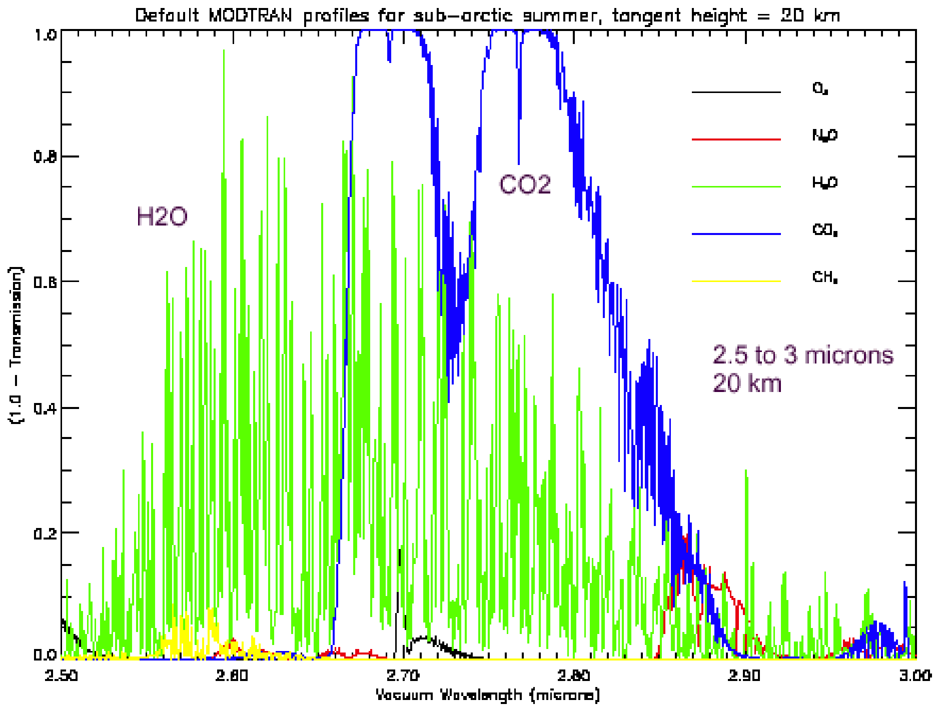
CO_2, CH_4, O_2, H_2O

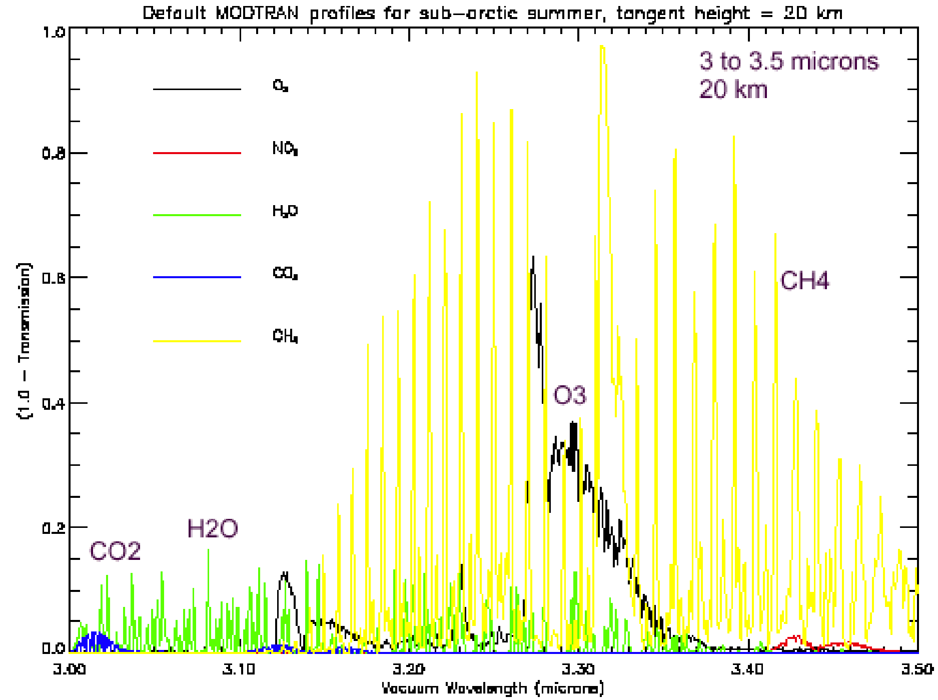
Band width 1 to 10 nm

H2O: 1.12, 1.3 microns

CO2: 1.45 microns

O2: 1.25 microns





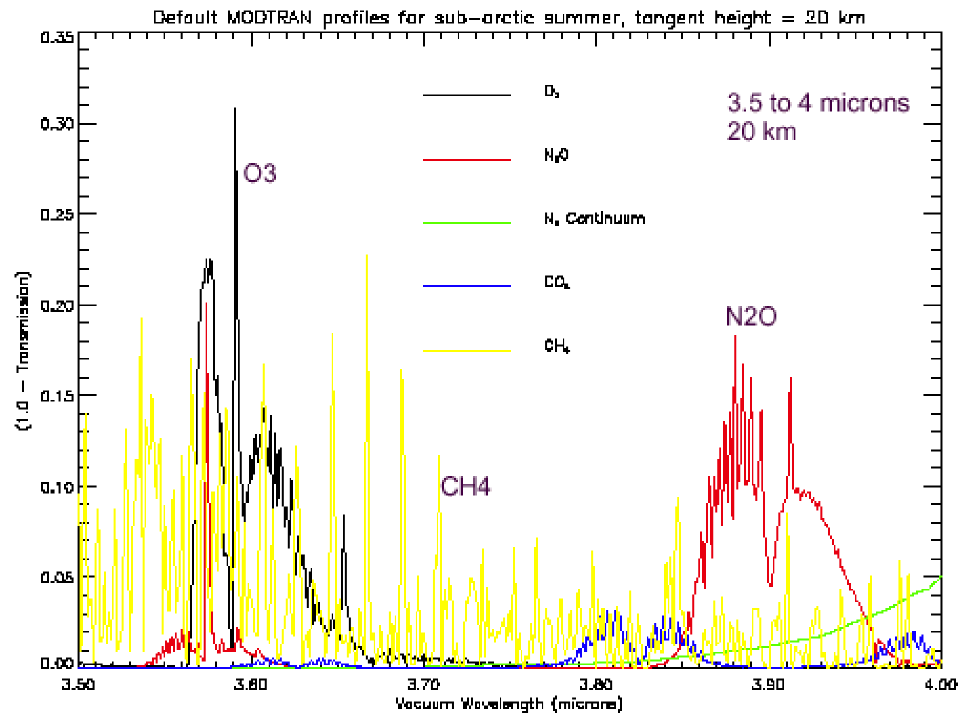
20 km

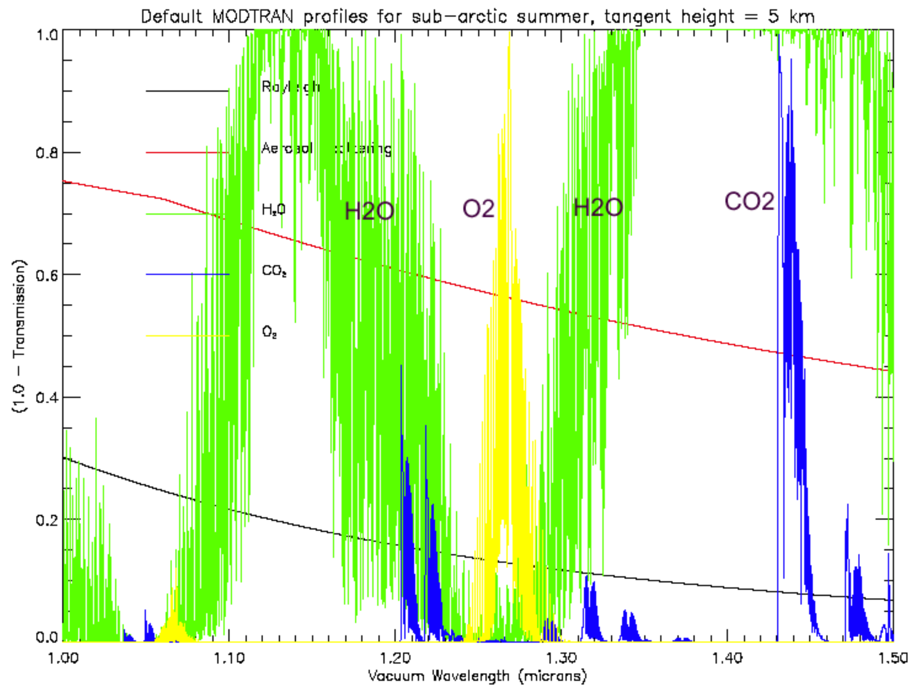
2.50 to 4.00 microns

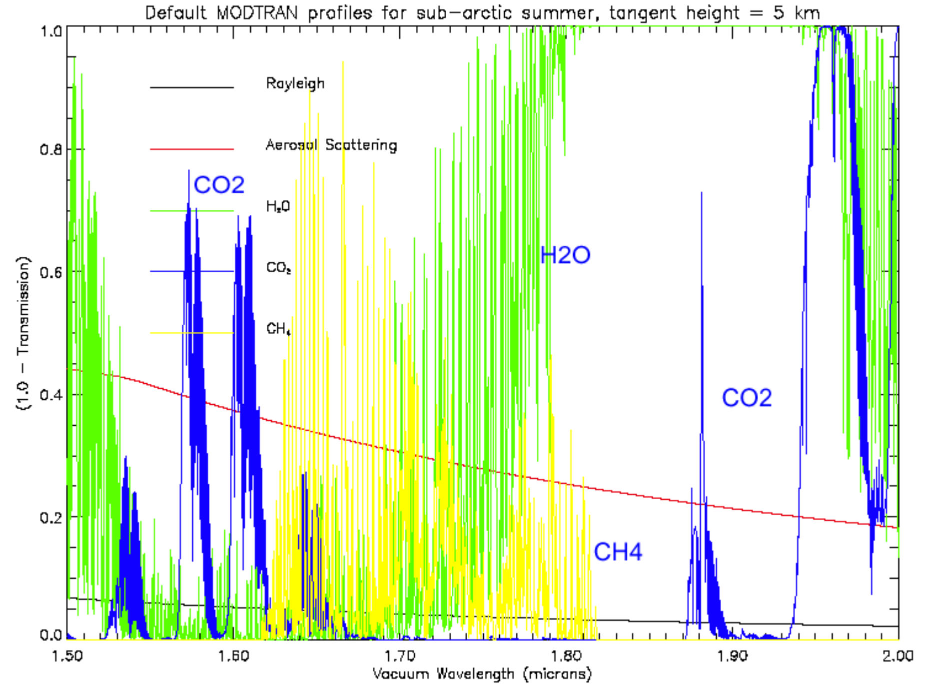
CH_4, H_2O, CO_2, N_2O, O_3

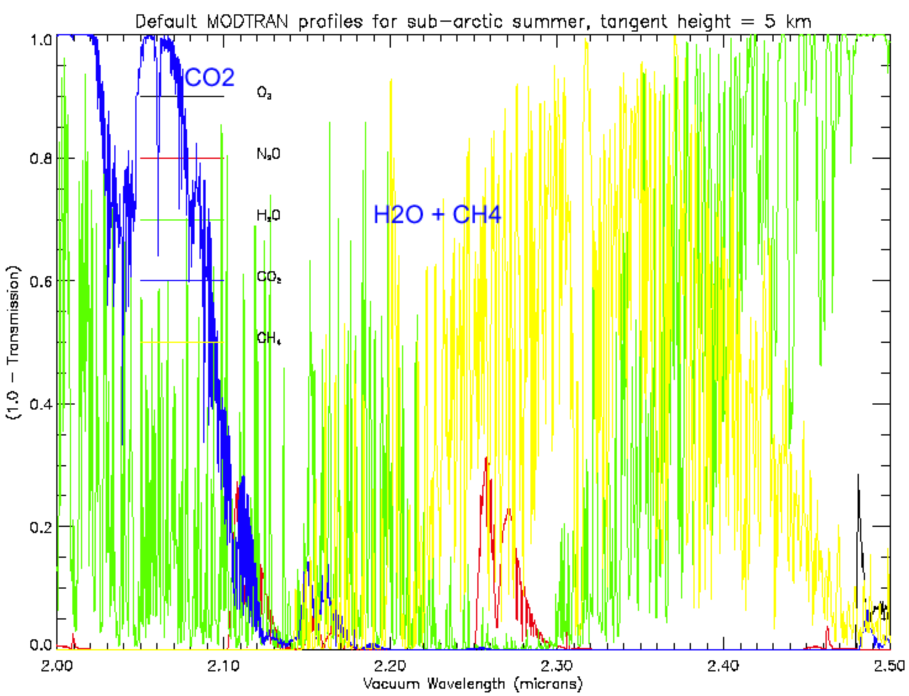
Selected bands can clearly distinguish individual species

The exact bands to use are a function of altitude. This requires a tunable spectrometer.





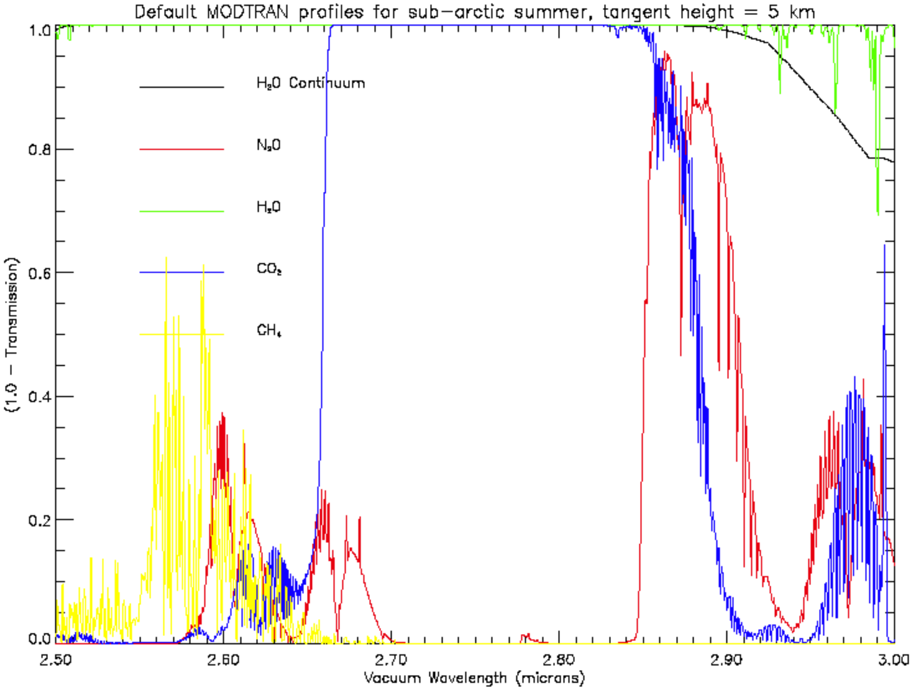


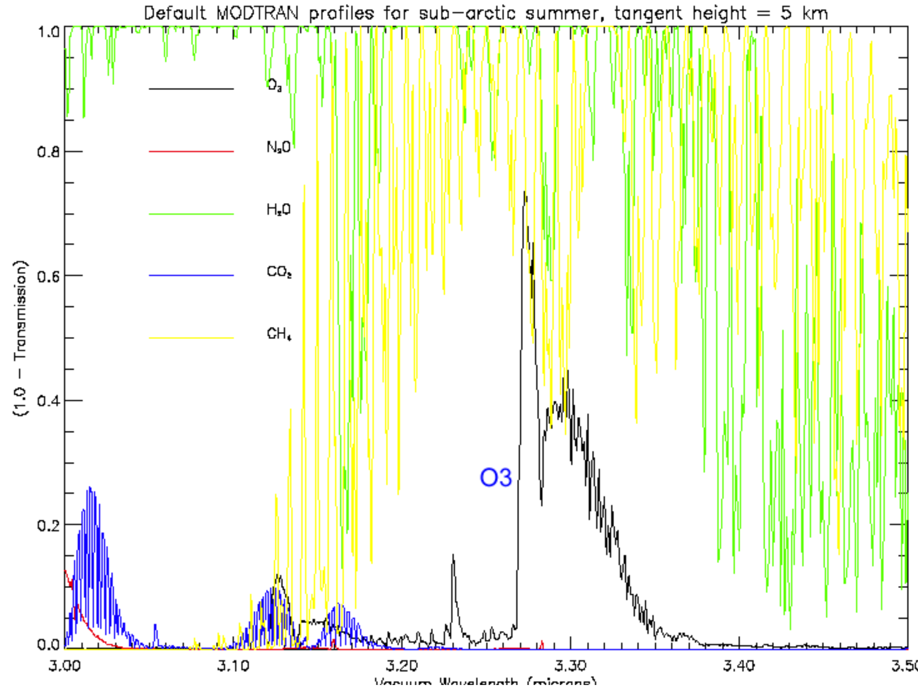


5 km limb view

1 to 2.5 microns

H2O: 1.3 microns
CO2: 1.45 microns
O2: 1.25 microns



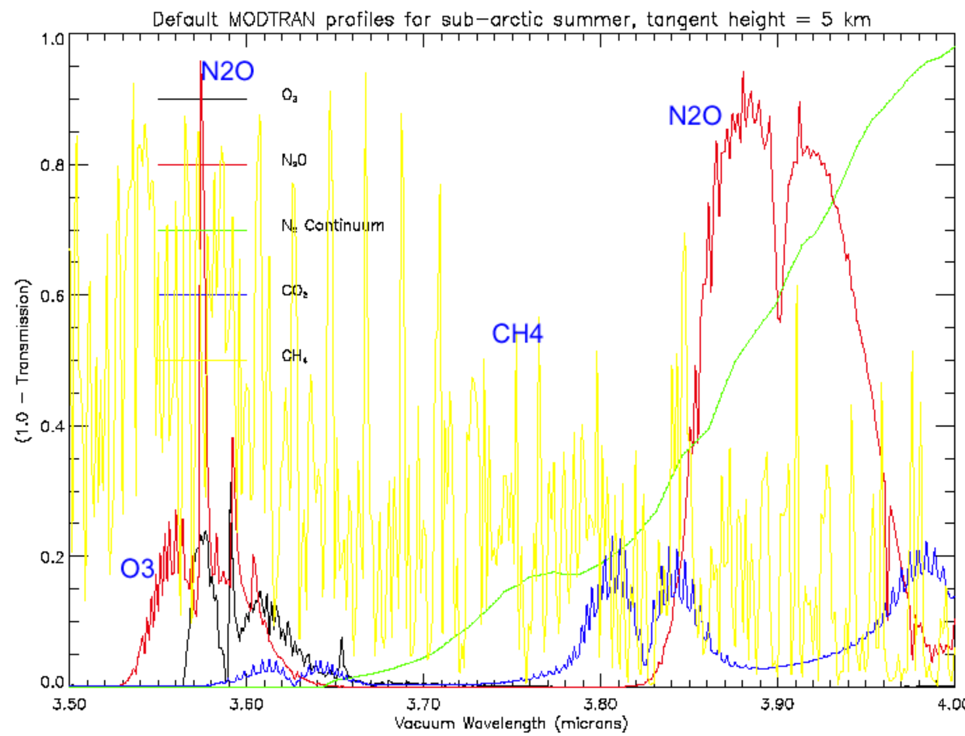


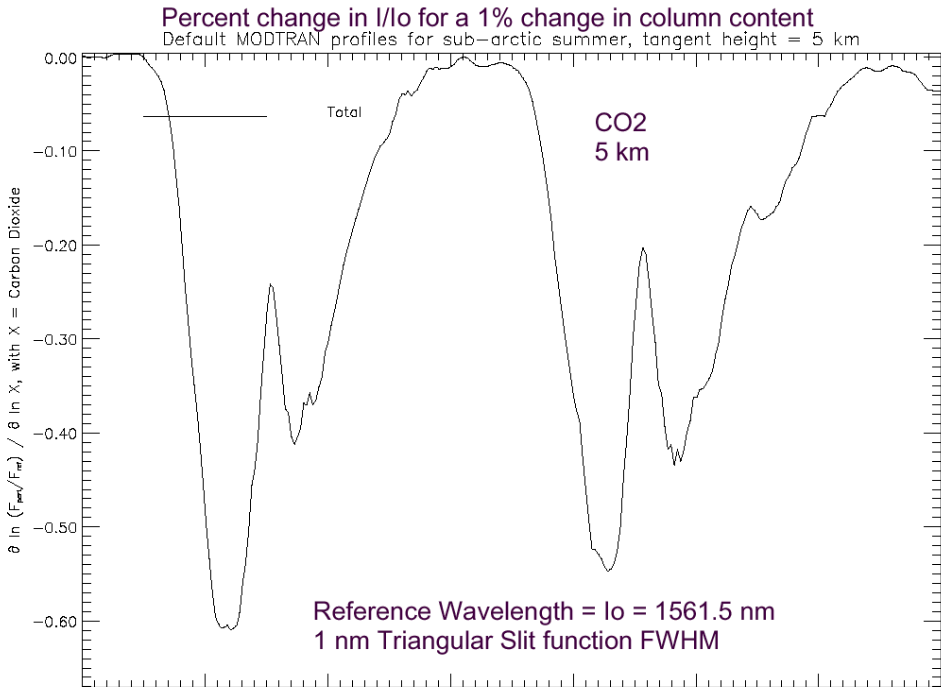
5 km

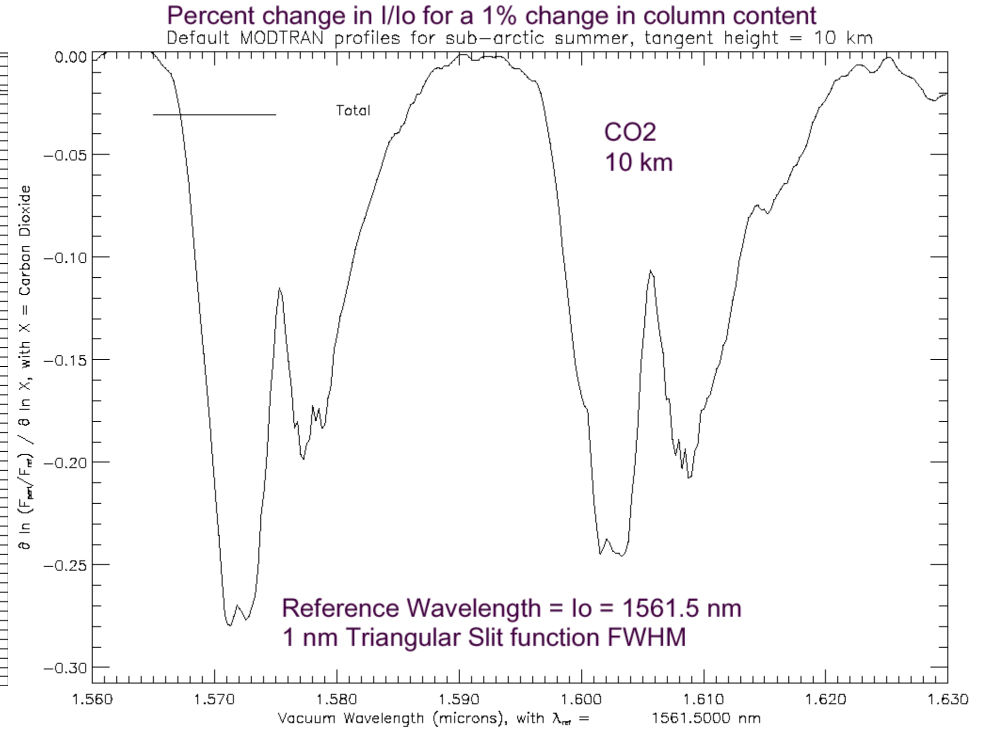
2.50 to 4.00 microns

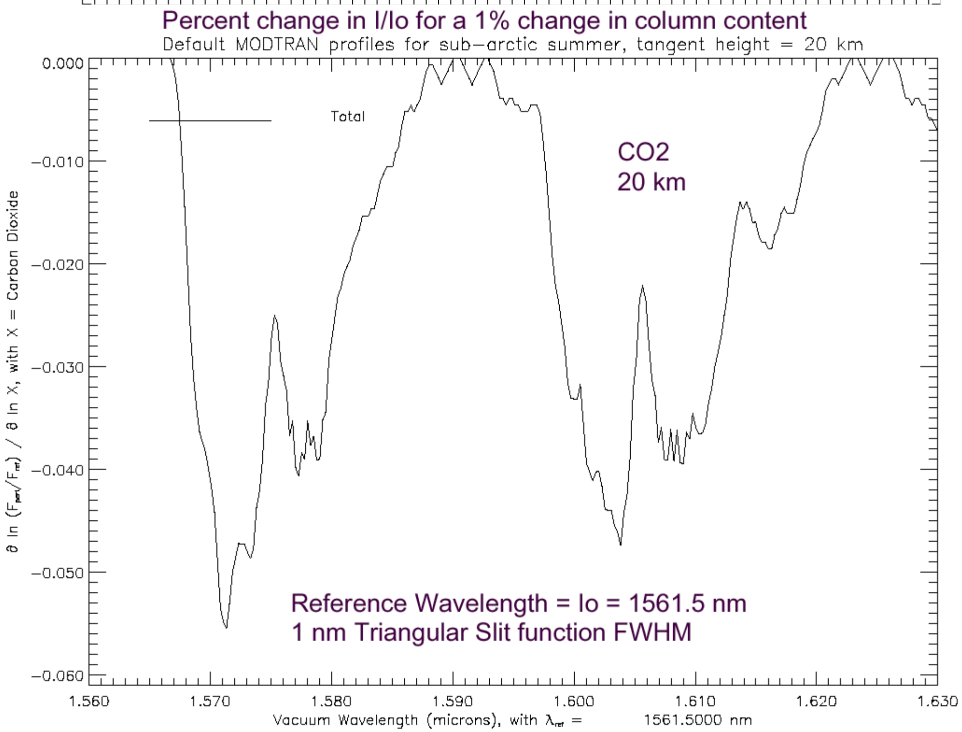
CH_4, H_2O, CO_2, N_2O, O_3

CH_4: 2.58 microns
N_2O: 3.85 microns
O_3: 3.28, 3.60 microns









Sensitivity to Change @ 1570

Instrument: 1/3 %

Total: CO_2 0.2% at 5 km

or 1 part in 500

0.4% at 10 km

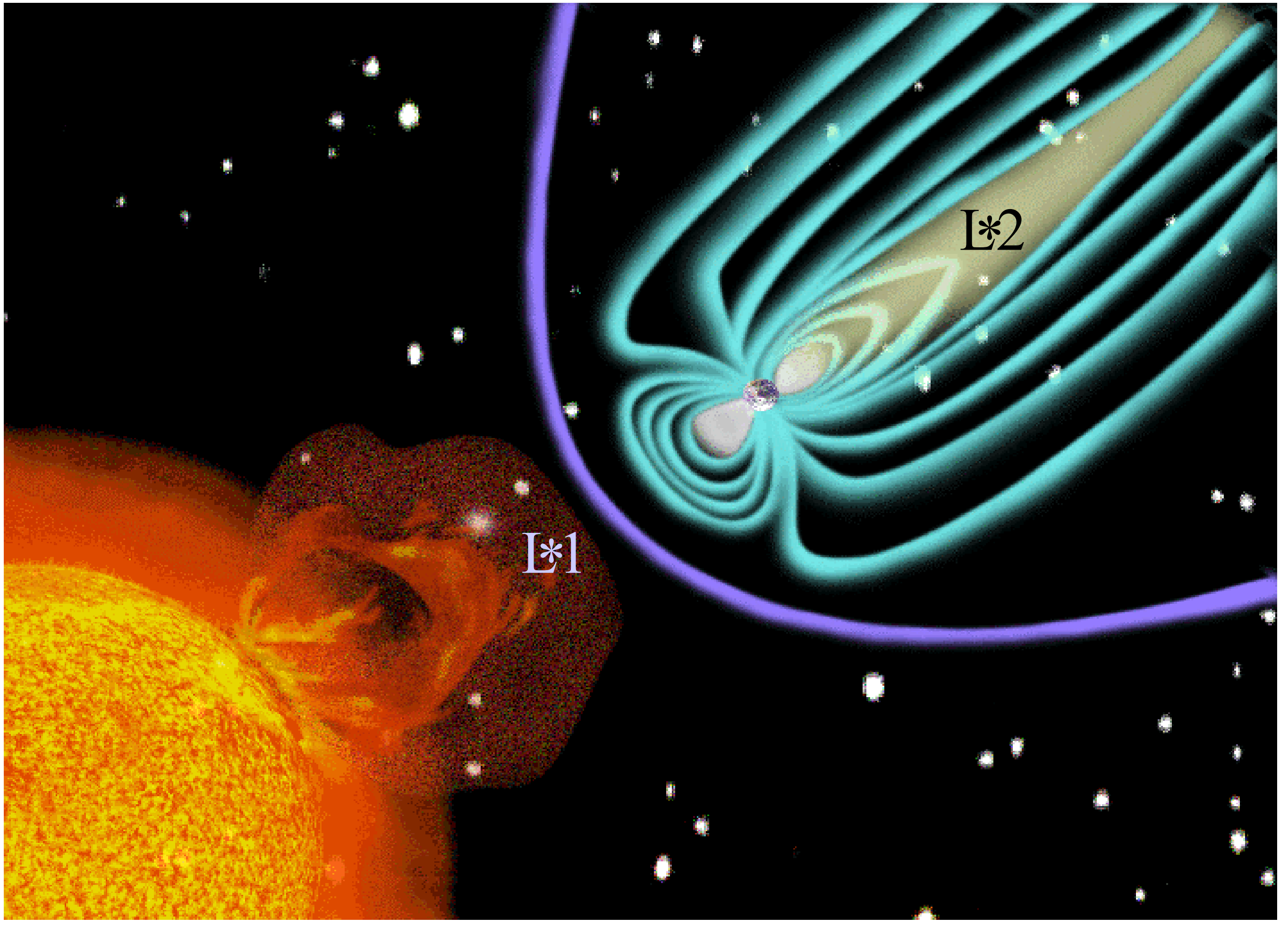
2% at 20 km

EASI and Triana Synergy

EASI: $1.5x10^6$ km
Triana $1.5x10^6$ km
From Earth

BowShock $5x10^4$ km

Day and Night Obs of Clouds for Climate Studies



EASI and Triana can make unique observations of Solar disturbances outside of the Bowshock and within the Magnetotail.

L2-View/EASI Imaging Solar Occultation of the Earth from L-2

Additional Science:

Measurements the Earth's magnetotail

- **Magnetic field, electron, proton and alpha velocity**
- **View of the aurora**
- **Correlations with measurements at L-1**

Lightning: Observations of full night disk to observe the frequency and location of lightning.

Full disk observations of clouds and surface features at 4 microns.

Spectral mapping of the solar limb, observations of solar granulation, and other solar features (sunspots, flares).

L2-View: EASI
Earth Atmosphere Solar-Occultation Imager

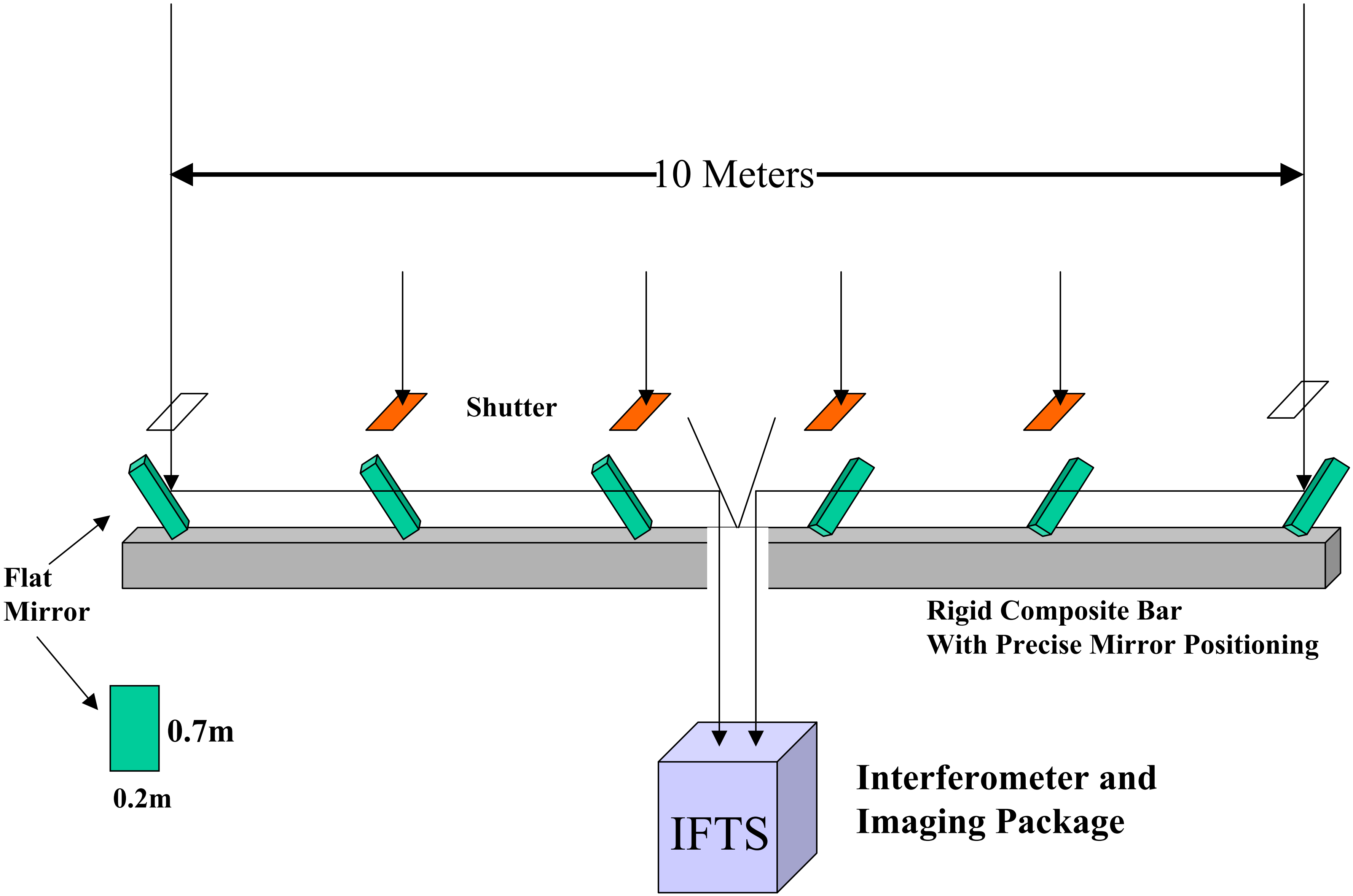
Goals: Measure altitude profiles for 5 major Greenhouse Gases for the entire Earth and the atmospheric pressure profile

Produce a 3-D Map of the distribution of
CO_2, H_2O, CH_4, O_3, N_2O, O_2

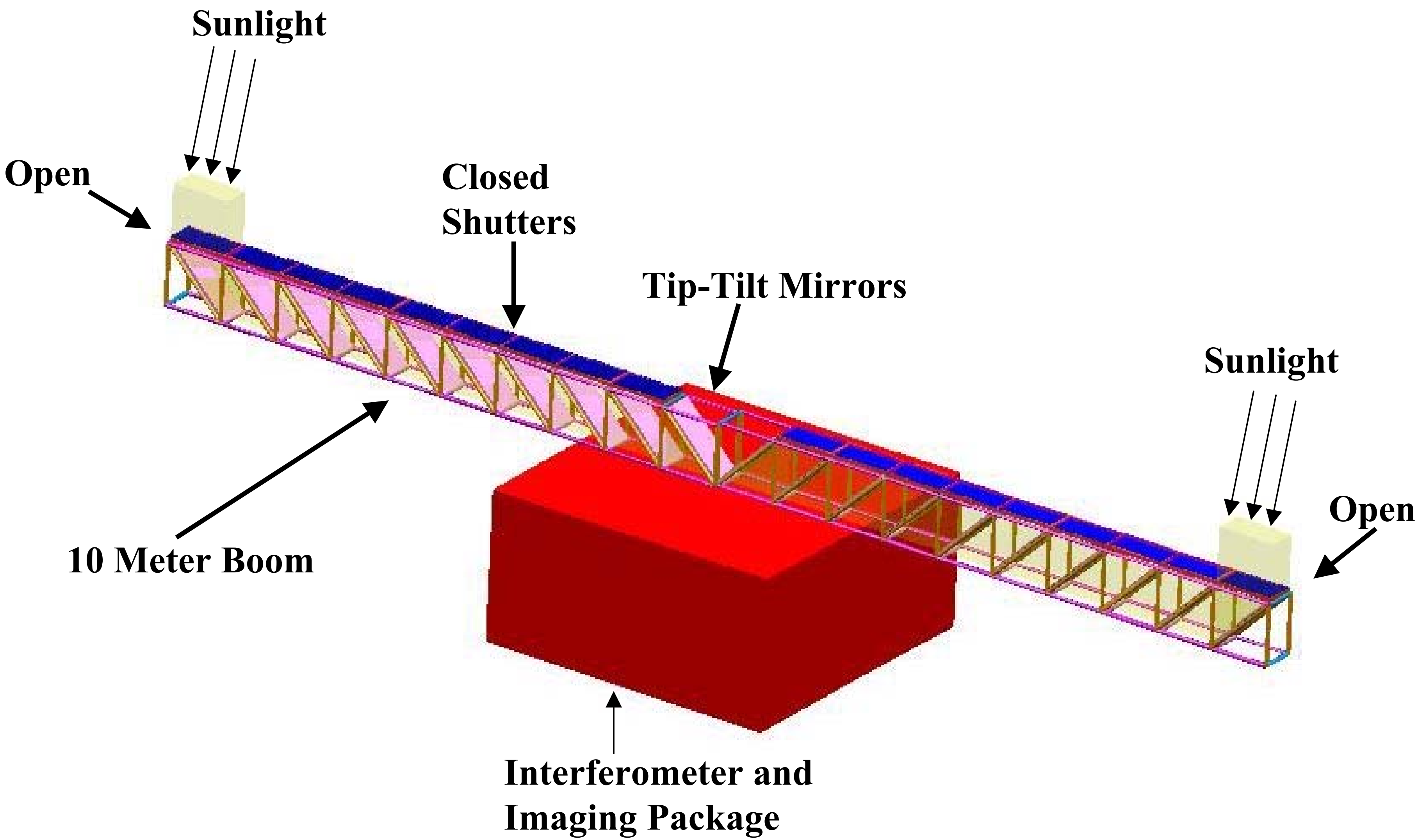
Altitude 2 km Resolution
Latitude 0.1^o
Longitude 2^o

Technical Challenges:
- Fly large aperture (10 meter) interferometer
- Extensive use of lightweight materials
- Highly controlled orbit at L-2
- High data rate with advanced antenna design

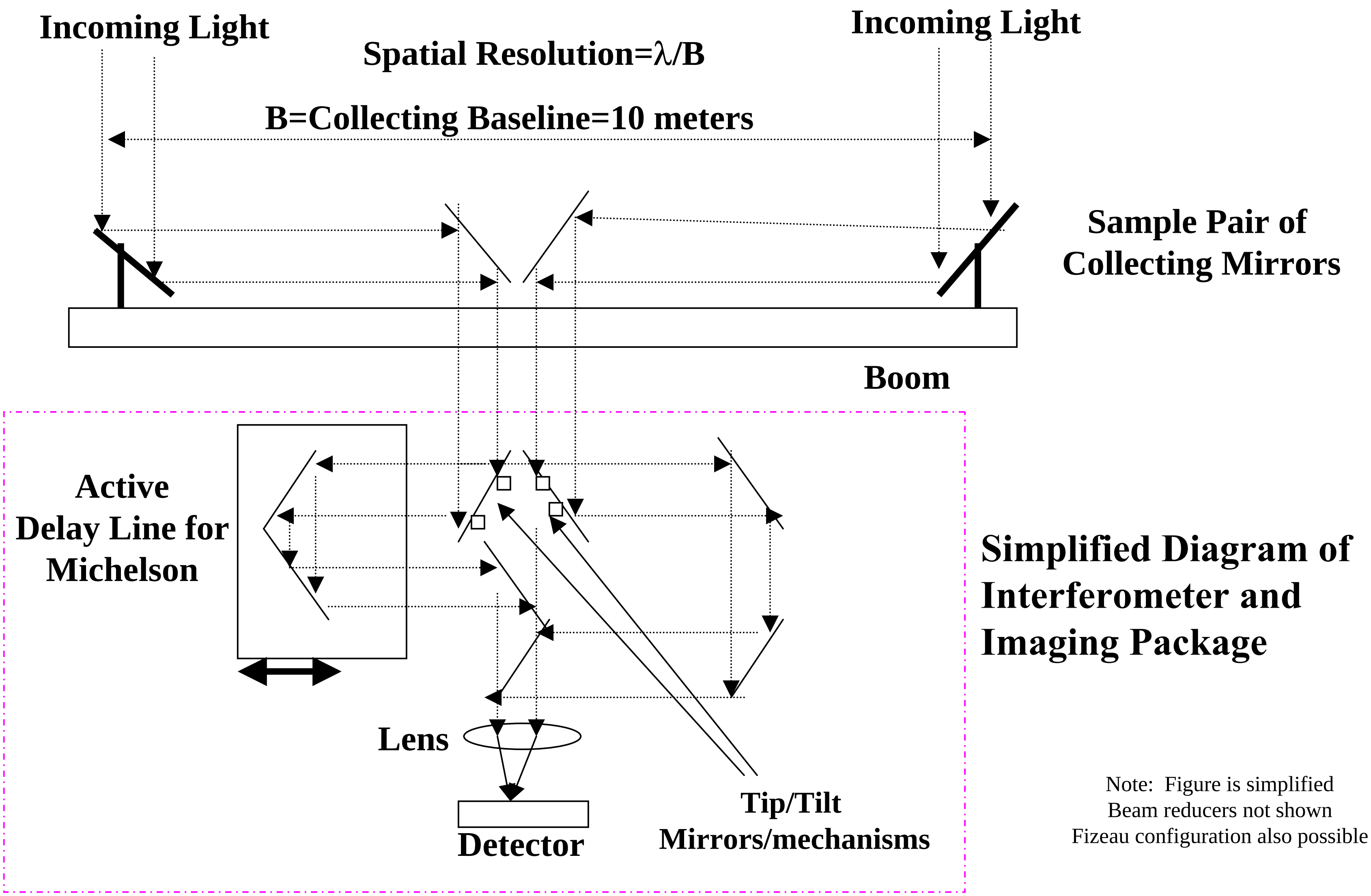
Block Diagram of EASI Interferometer With Beam Entering An Imaging Fourier Transform Spectrometer



EASI Mirror-Boom Assembly



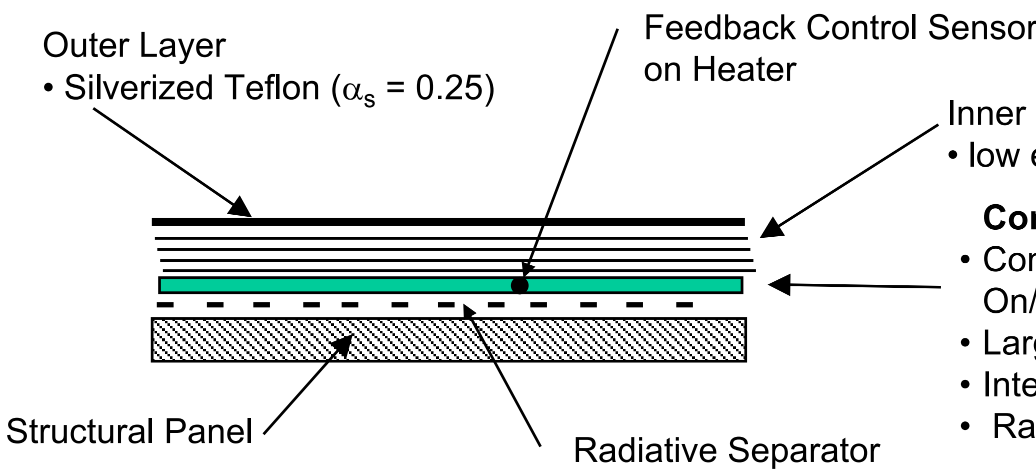
Advanced L2 Mission Architecture Using Wide-field Imaging Interferometry



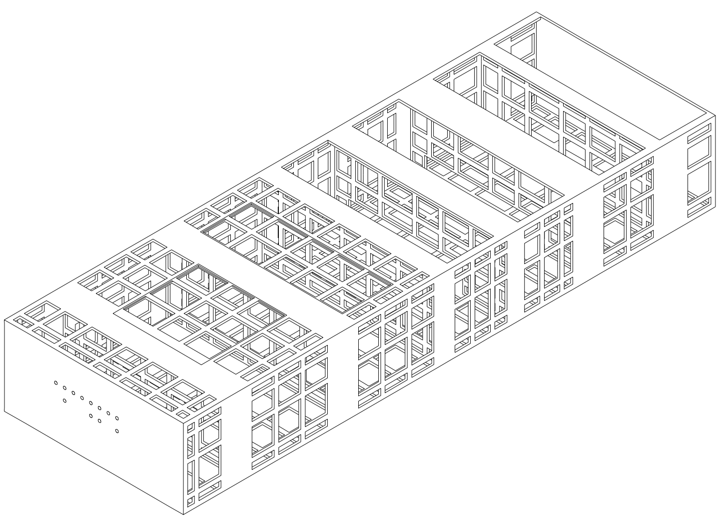
Note: Figure is simplified
Beam reducers not shown
Fizeau configuration also possible

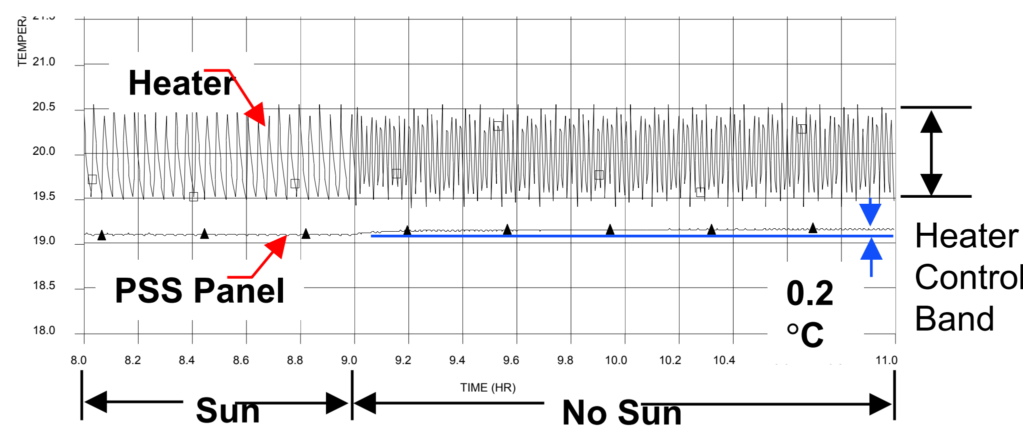
Boom Technology Has Heritage on SIM

- The thermal control environment will be much more stable than SIM
  - SIM requires supporting many different pointing angles relative to sun
  - SIM boom technology should easily meet our requirements
  - SIM approach to isolate reaction wheel vibrations should also work

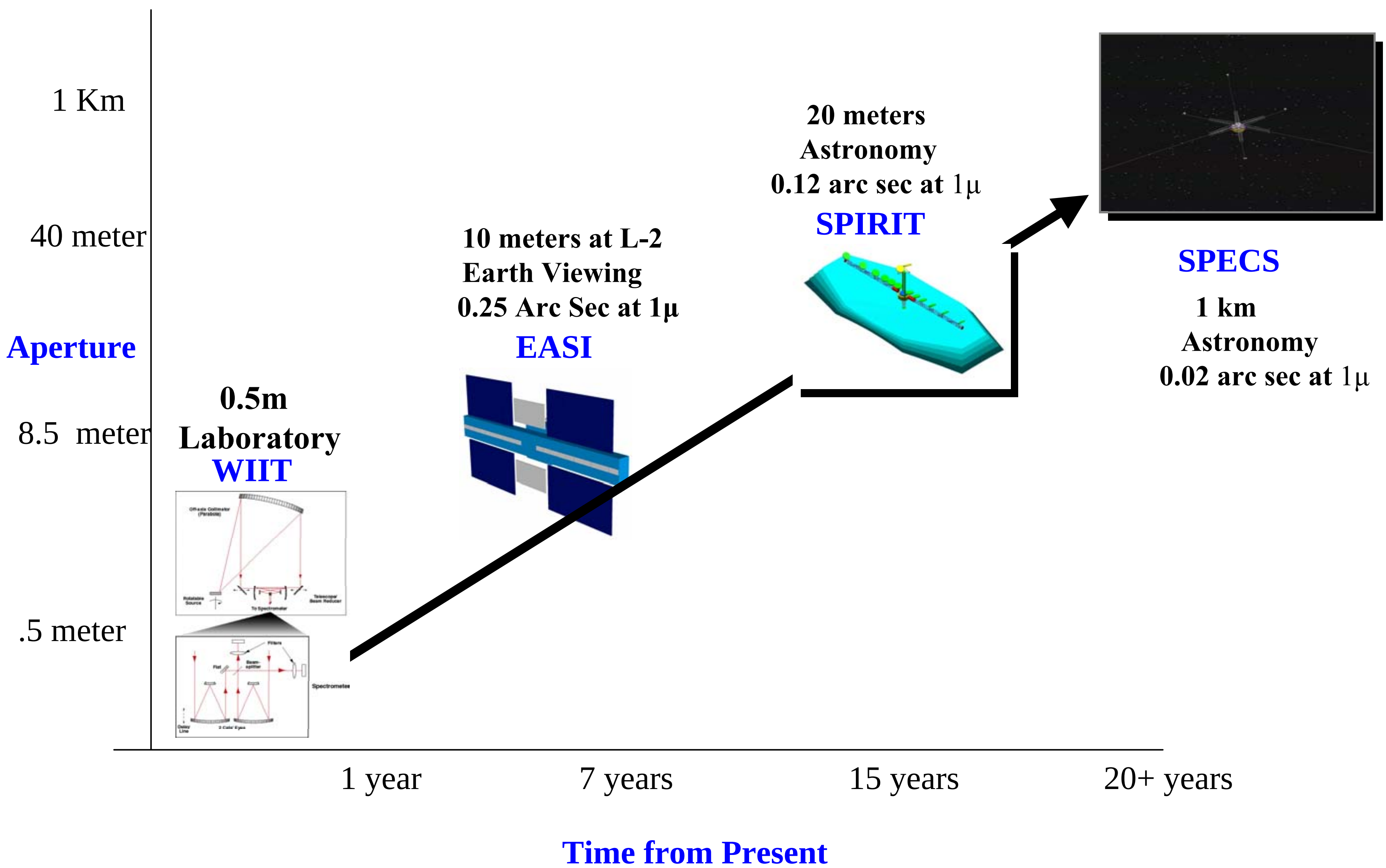


Control Heater
- Computer controlled On/Off Deadband < 1°C
- Large Area, Low Power Density
- Integral Feedback Control Sensors
- Radiative Thermal Coupling to Panel





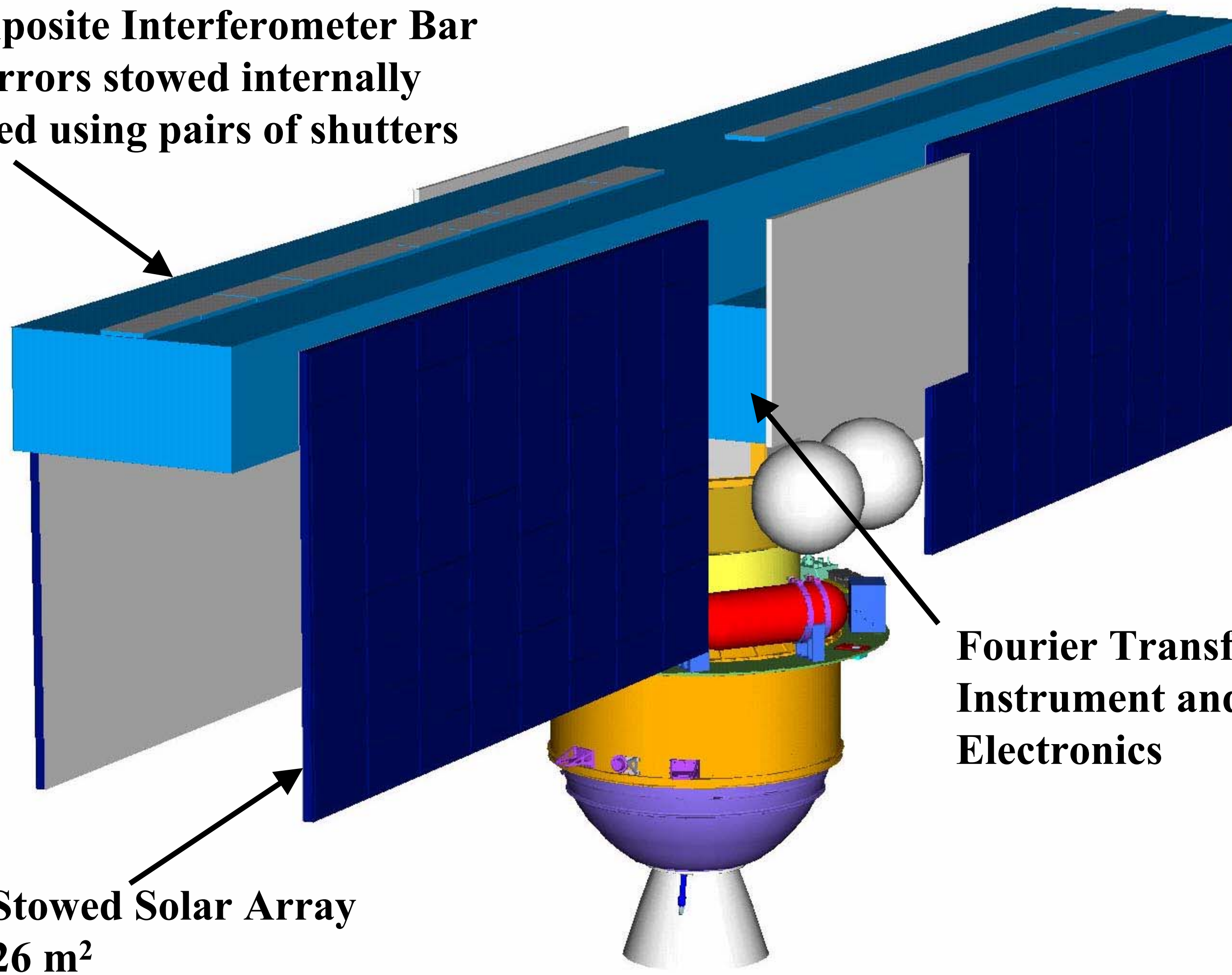
GSFC Spatial-Spectral Imaging Interferometry Roadmap



Technology Readiness:

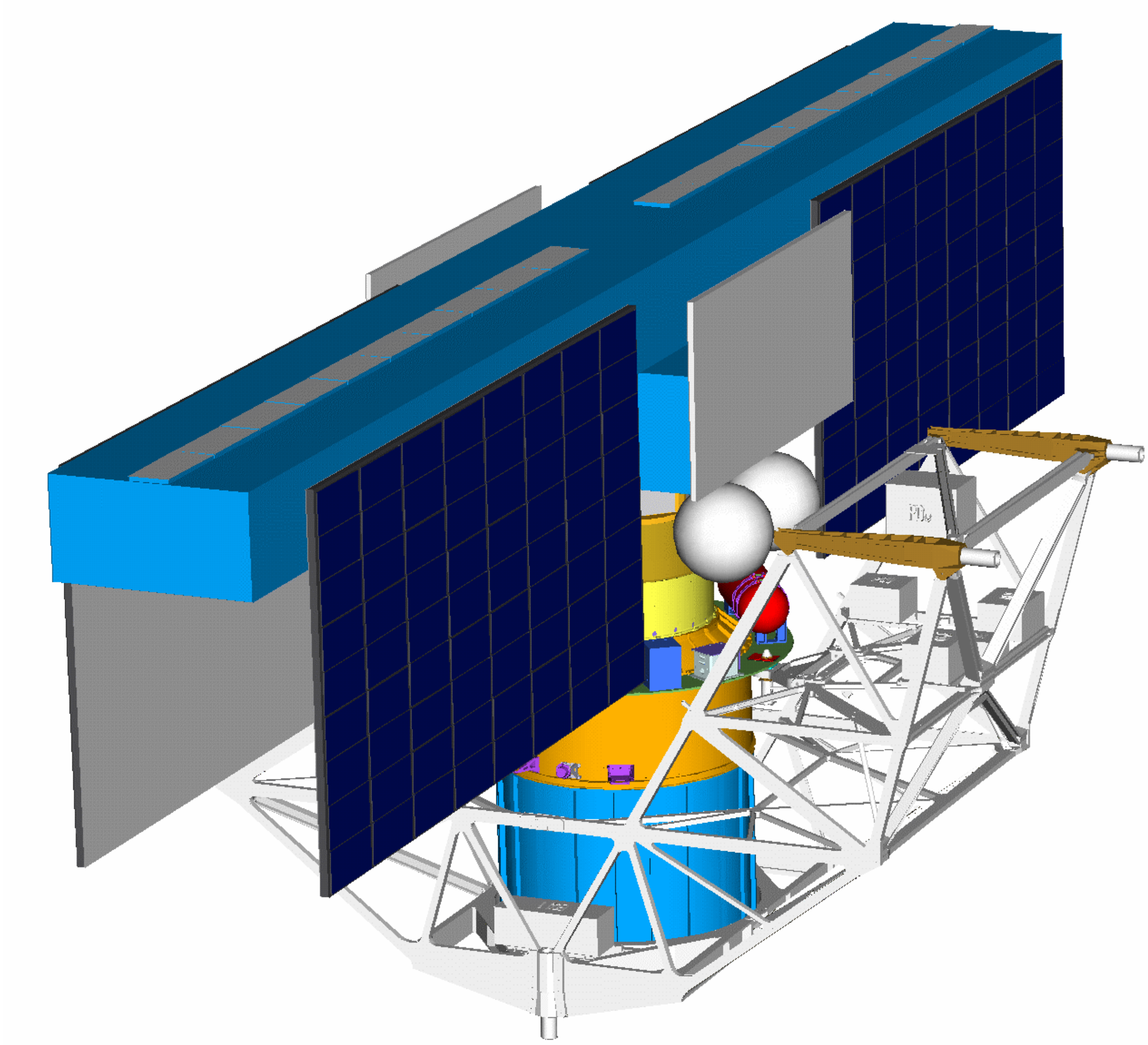
Technology	Current	Challenge	Risk
1-D Spatial-Spectral Interferometer + Algorithms (2-D algorithms desirable)	.5m Wide Field Imaging Interferometer Testbed in Build (funded by IR+D, ROSS)	Extension to large 10 meter aperture for space flight	MED
Light-weight beam splitters Low vibration shutters	New Disk shutter	Lightweight Low vibration	Low MED
Extremely stable 10 meter lightweight truss	SIM composite material truss	Vibration/thermal control to avoid complex metrology	MED
Repeatable tip-tilt mirrors Delay lines Near IR detectors Light flat mirrors	Current Techn. CIRS Heritage Current Techn. Current Techn.	Need flight qualified Modify for Near IR Tailored readout desirable Flat pass band for BS	LOW LOW LOW LOW

L2-View EASI Spacecraft and Instrument



EASI Stowed Configuration on Triana-Heritage Gyroscopic Upper Stage

EASI Instrument and Spacecraft Mounted in Shuttle Carrier



Instrument Spacecraft And Carrier Mounted in Shuttle Bay