L2-View/EASI

(Earth Atmosphere Solar-Occultation Imager)

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Nightside Earth

CO₂, CH₄, H₂O, O₃, O₂, N₂O
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

\[ \text{CO}_2, \text{CH}_4, \text{H}_2\text{O}, \text{O}_3, \text{O}_2, \text{N}_2\text{O} \]

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° Longitude 2°
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
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.

$r_S = 6.9598 \times 10^5 \text{ km}$

$r_E = 6.373 \times 10^3 \text{ km}$

$D_S = 1.496 \times 10^8 \text{ km}$

$R_L = 1.5 \times 10^6$

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
CO₂, CH₄, O₂, H₂O
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$_2$O, CO$_2$, N$_2$O, 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
\(\text{CH}_4, \text{H}_2\text{O}, \text{CO}_2, \text{N}_2\text{O}, \text{O}_3\)
\(\text{CH}_4: \ 2.58 \ \text{microns}\)
\(\text{N}_2\text{O}: \ 3.85 \ \text{microns}\)
\(\text{O}_3: \ 3.28, 3.60 \ \text{microns}\)
Sensitivity to Change @ 1570

Instrument:  1/3 %

Total: CO₂  0.2% at 5 km
or 1 part in 500
0.4% at 10 km
2% at 20 km
EASI and Triana Synergy

EASI: $1.5 \times 10^6$ km
Triana: $1.5 \times 10^6$ km
From Earth

BowShock: $5 \times 10^4$ 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 CO₂, H₂O, CH₄, O₃, N₂O, O₂

Altitude 2 km Resolution
Latitude 0.1°
Longitude 2°

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

- Flat Mirror
- Shutter
- Rigid Composite Bar
- Interferometer and Imaging Package

10 Meters

0.7m

0.2m
EASI Mirror-Boom Assembly

- Sunlight
- Open
- Closed Shutters
- Tip-Tilt Mirrors
- 10 Meter Boom
- Interferometer and Imaging Package
- Sunlight
- Open
Advanced L2 Mission Architecture
Using Wide-field Imaging Interferometry

Spatial Resolution = \lambda / B
B = Collecting Baseline = 10 meters

Active Delay Line for Michelson

Incoming Light

Sample Pair of Collecting Mirrors

Boom

Simplified Diagram of Interferometer and Imaging Package

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

**Outer Layer**
- Silverized Teflon ($\alpha_s = 0.25$)

**Inner MLI Blanket**
- low $e^*$ (0.015)

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

**Graph**
- Time (HR) vs Temperature (°C)
- Heater Control Band
- PSS Panel
- Sun vs No Sun
- Temperature Range: 18.0 to 21.0 °C
- Temperature Intervals: 0.5 °C
GSFC Spatial-Spectral Imaging Interferometry Roadmap

1 Km
40 meter
8.5 meter
.5 meter

Aperture

1 year 7 years 15 years 20+ years

Time from Present

10 meters at L-2
Earth Viewing
0.25 Arc Sec at $1\mu$
EASI

20 meters
Astronomy
0.12 arc sec at $1\mu$
SPIRIT

0.5m
Laboratory
WIIT

1 km
Astronomy
0.02 arc sec at $1\mu$
SPECS
## Technology Readiness:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Current</th>
<th>Challenge</th>
<th>Risk</th>
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<tbody>
<tr>
<td>1-D Spatial-Spectral Interferometer + Algorithms (2-D algorithms desirable)</td>
<td>.5m Wide Field Imaging Interferometer Testbed in Build (funded by IR+D, ROSS)</td>
<td>Extension to large 10 meter aperture for space flight</td>
<td>MED</td>
</tr>
<tr>
<td>Light-weight beam splitters Low vibration shutters</td>
<td>New Disk shutter</td>
<td>Lightweight Low vibration</td>
<td>Low</td>
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<tr>
<td>Extremely stable 10 meter lightweight truss</td>
<td>SIM composite material truss</td>
<td>Vibration/thermal control to avoid complex metrology</td>
<td>MED</td>
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<tr>
<td>Repeatable tip-tilt mirrors Delay lines Near IR detectors Light flat mirrors</td>
<td>Current Techn. CIRS Heritage Current Techn. Current Techn.</td>
<td>Need flight qualified Modify for Near IR Tailored readout desirable Flat pass band for BS</td>
<td>LOW</td>
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L2-View EASI Spacecraft and Instrument

Rigid Composite Interferometer Bar with 20 mirrors stowed internally and accessed using pairs of shutters

Stowed Solar Array 26 m²

Fourier Transform Instrument and Electronics

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