Blue Marble :
Remote Characterization of Habitable Planets

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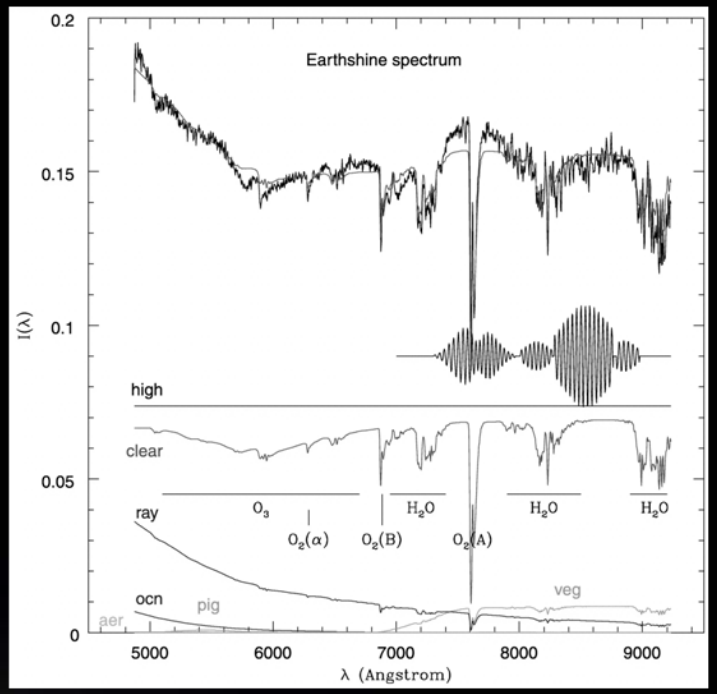
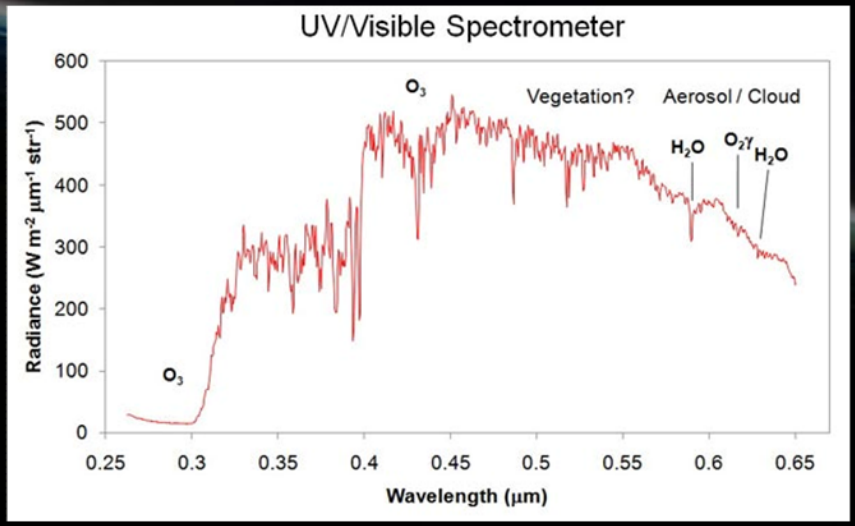
Introduction

- Search for extrasolar habitable planets has relied on models with partial ground truth
- Current theory predicts that alternative measurements may yield better data for determining exoplanet habitability
- With some instrument and trajectory design investments, a small spacecraft platform would return data on these measurements
- Mission is well suited for low cost spacecraft and launch vehicles

Science Investigation

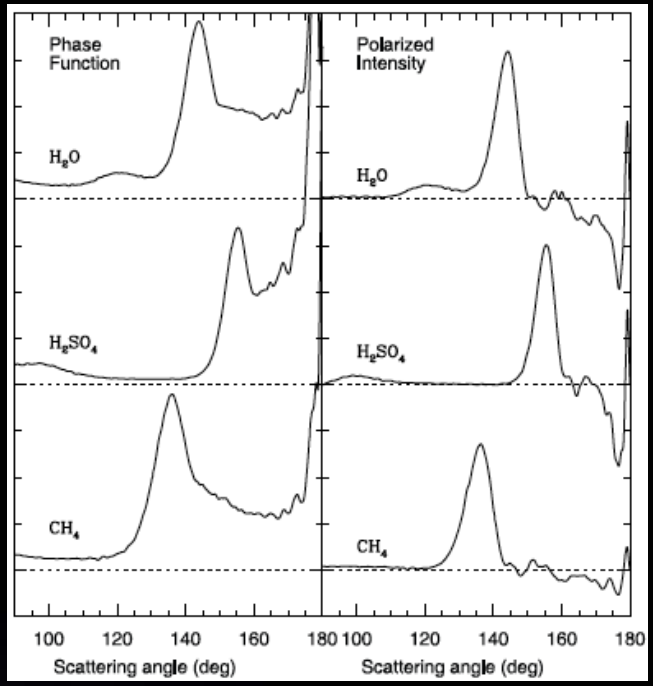
- 2008 Astrobiology Roadmap Goals 1 and 7
  - Detect and characterize habitable planets
  - Develop methods for recognizing life on distant planets
- Previous mission concepts have focused on IR bands
  - Initial studies in MWIR
  - Expanded to VIS through LWIR

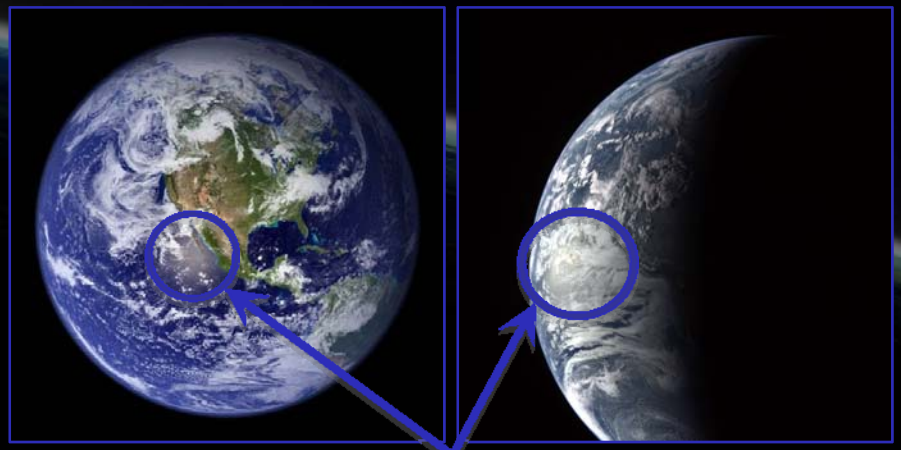




Science Investigation

- Linear and circular polarization of interest
  - Refraction index can be used to differentiate atmospheric and liquid water
  - Features of interest known in VIS through MWIR
- Illumination phase variation also of interest
- Time variation of interest





Polarized glint effects

Adapted from Williams and Gaidos, 2008

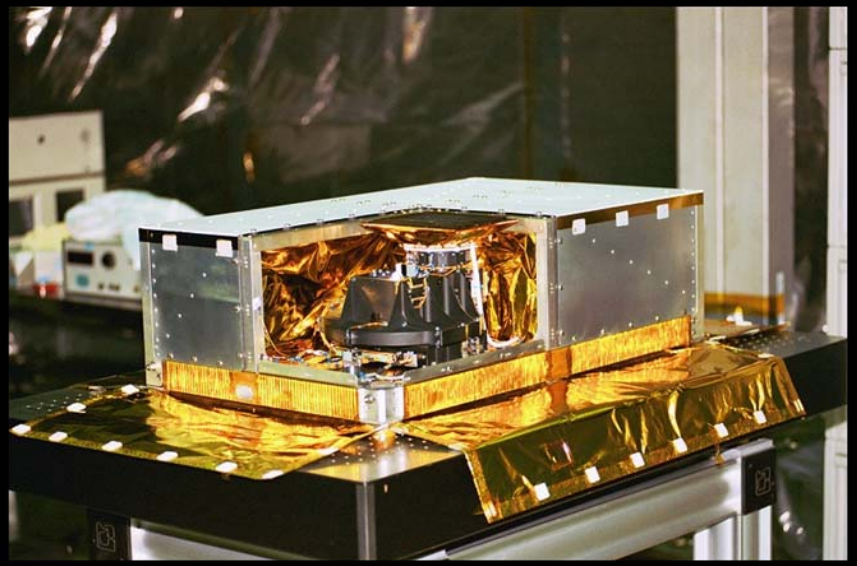
Preliminary Requirements Trace

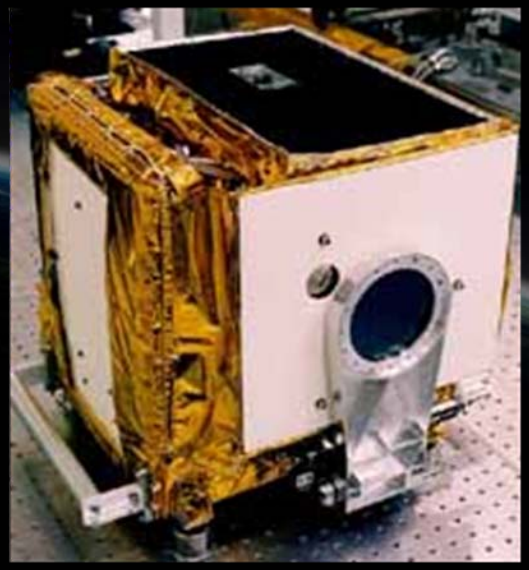
Science Objective	Science Measurement	Instrument	Instrument Requirements	Mission Requirements
Obtain linear spectroscopy of full Earth Obtain circular spectroscopy of full Earth	• Observe at least 98% of earth disc • Observe in VNIR wavelengths • Observe full 360° phase angle • Observe over full range of Earth seasons	Spectropolarimeter / Polarizing Imager	• Rotate instrument about boresight at 0.5 to 1 rpm • Collect 8 - 12 samples per spacecraft rotation • Instrument bandpass from 350 to 900 nm	• Mission distance from Earth > 200,000 km • Orient spin axis to <15 arc-min error • Observe Earth in 360° angle per season • Mission lifetime > 1 year
Obtain polarized imagery of full earth	• Observe at 4 bands		• Observe 400, 570, 650, and 760 nm • Resolution of at least 400 x 400 pixels • FPA readout rate of 5 to 20 Hz	
Obtain infrared spectroscopy of full earth	• Observe in M/LWIR band	IR Spectrometer	• Instrument bandpass from 5 to 20 microns • <125 nm resolution	• Mission distance from Earth > 200,000 km
Obtain infrared imagery of full earth	• Observe in M/LWIR band	IR Imager	• Resolution of at least 128 x 128 pixels • Imager bandpass from 5 to 20 microns • FPA readout rate of 5 to 20 Hz	• Mission distance from Earth > 200,000 km
Obtain ground truth imagery	• Observe in 3 colors	Visible Camera	• Instrument bandpass from 350 to 900 nm	• Mission distance from Earth > 200,000 km

Primary Objectives
Secondary Objectives
Tertiary Objective

Instrumentation

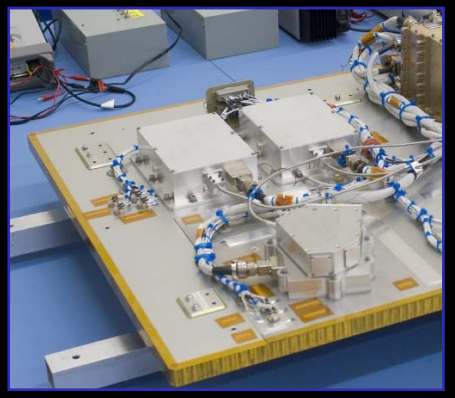
- Spectropolarimeter and imaging polarimeter provides primary science
  - Observe 4 bands from 400 to 760 nm
  - Collect 8 – 12 samples around 360° rotation angle
  - FPA readout rate of at least 5 Hz
- Represents development item
  - POLDER-2 / MICAS serve as surrogates

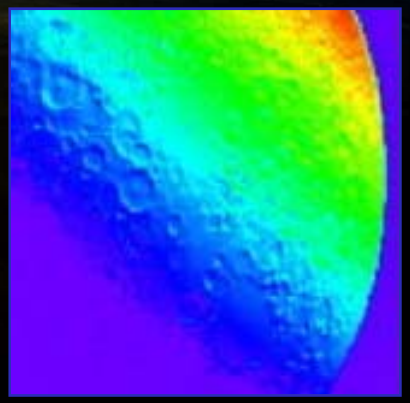




Instrumentation

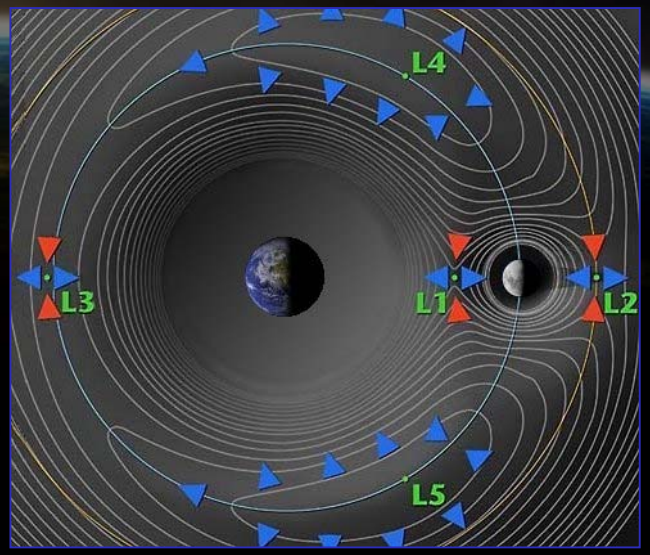
- Secondary instruments drawn from LCROSS mission
  - NIR spectrometer
    - Extend to MWIR
  - NIR, VIS, MIR cameras
- Excellent preliminary results obtained





Mission Design

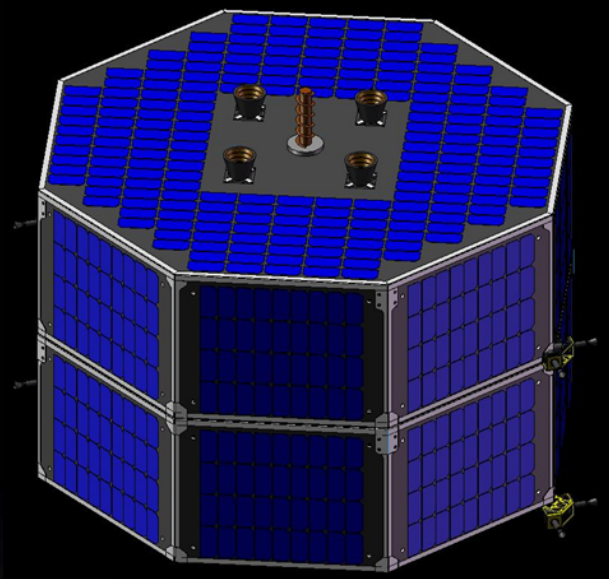
- Desired orbit distance leads to Lunar or Lunar Lagrangian orbits
  - Lunar interference and complexity remove L2, L3
  - L1, L4, L5 considered acceptable destinations



- To simplify instrument design, spacecraft designed to spin about boresite
- Spin axis precession required for Earth imaging
  - Continuous spin, reorient with thrusters
  - Spin – despin with single reaction wheel and reorient with thrusters

Spacecraft Design

- Simple deep-space bus
- Derivative of LADEE bus
- Co-boresighted, fixed instruments
- Dual mode bipropellent system for injection
- Fixed arrays for power generation
- 15 arc-min spin axis control
- X band RF system with fixed antennas



Launch and Operations

- Launch mass compatible with Minotaur I, Minotaur IV and Falcon 1E vehicles
  - Launch from CCAFS
  - Falcon 1E primary
    - Best match to launch mass
  - Minotaur IV backup
    - Excellent margin may allow co-manifest
- Mission operations directed at ARC MOC with Deep Space Network contacts