Non-coherent LED Arrays as Ground Beacons for Small Satellite Optical Communications Systems

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Free-space optical comm offers...

- High channel capacity

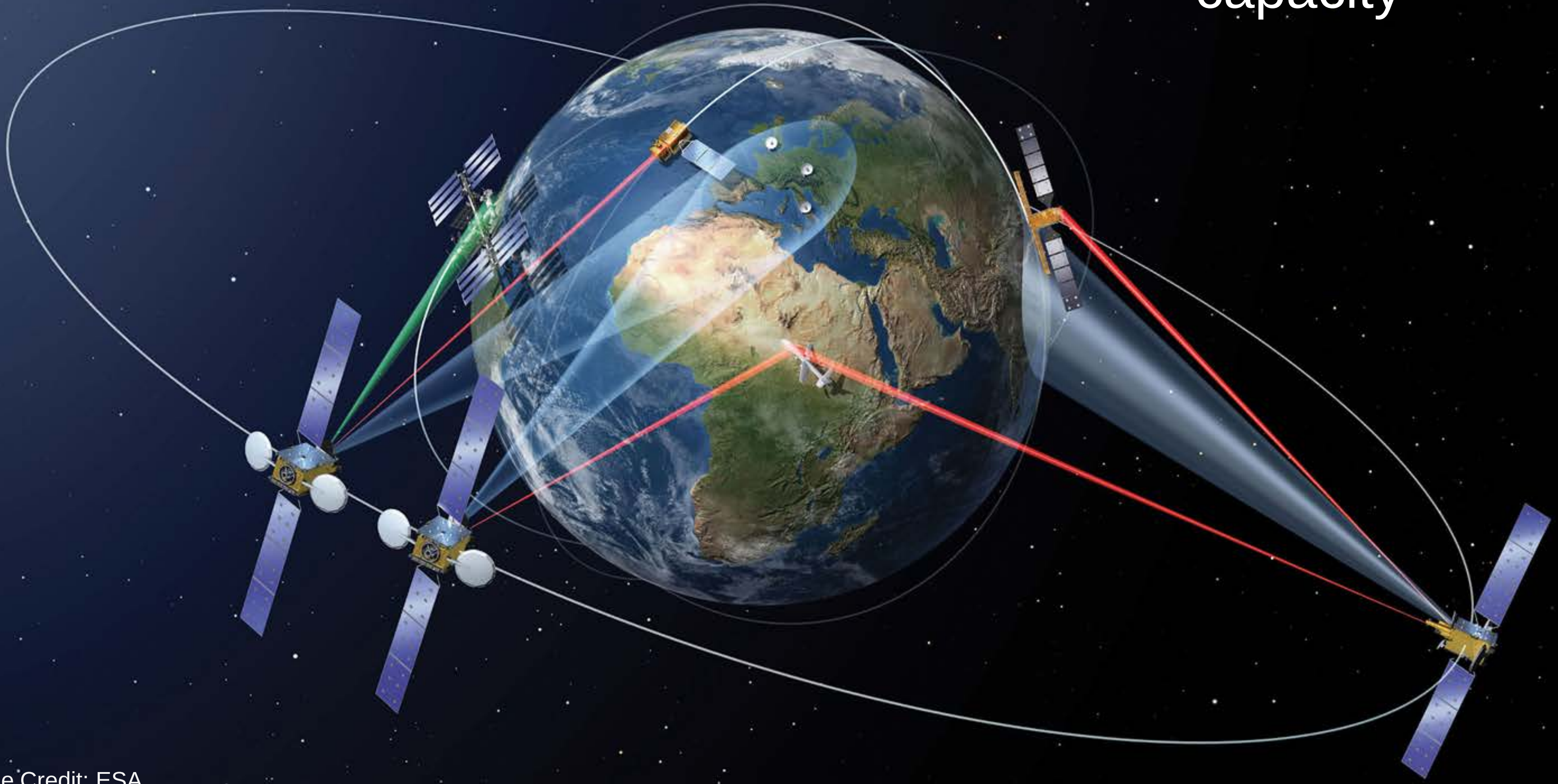
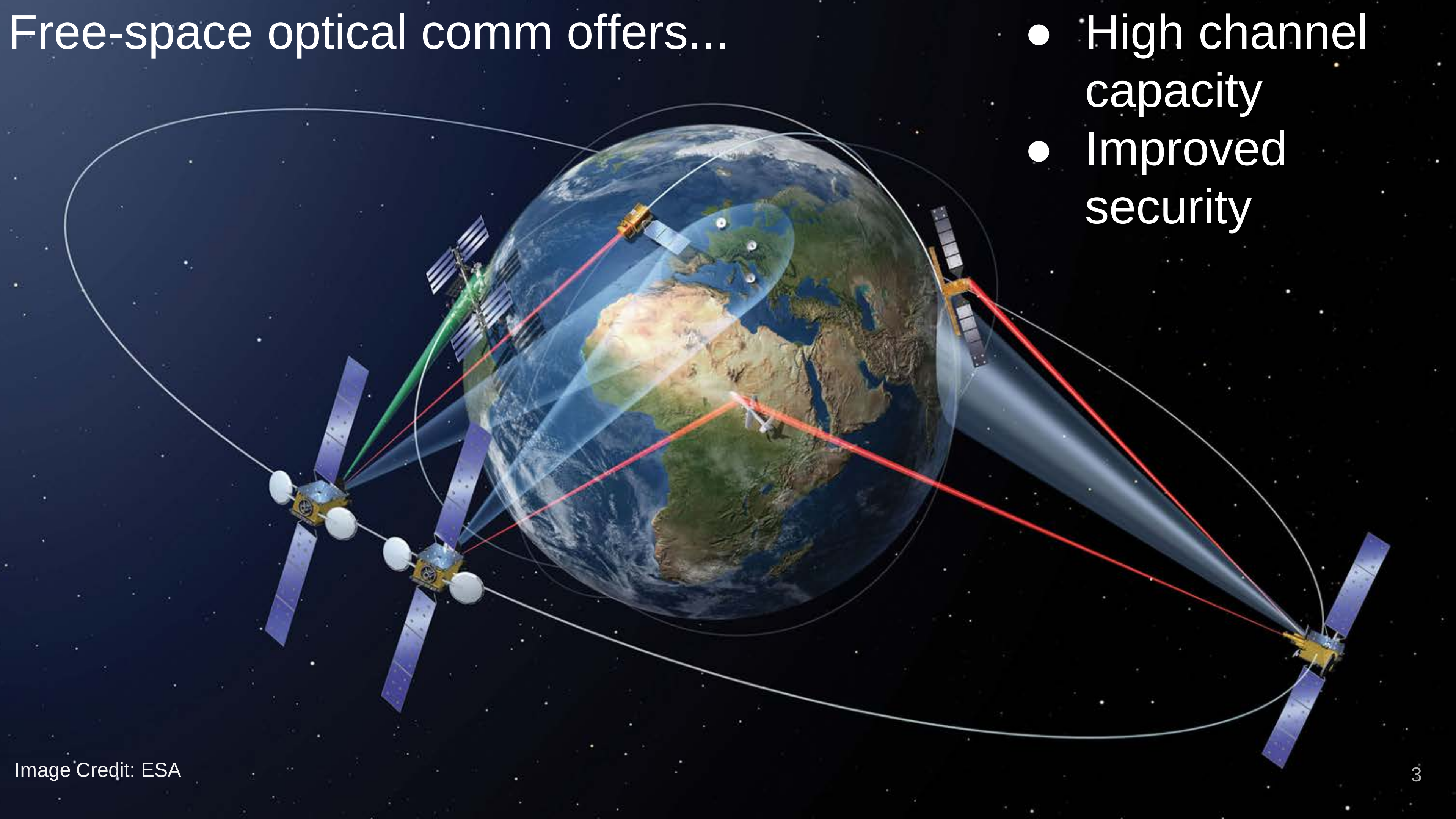
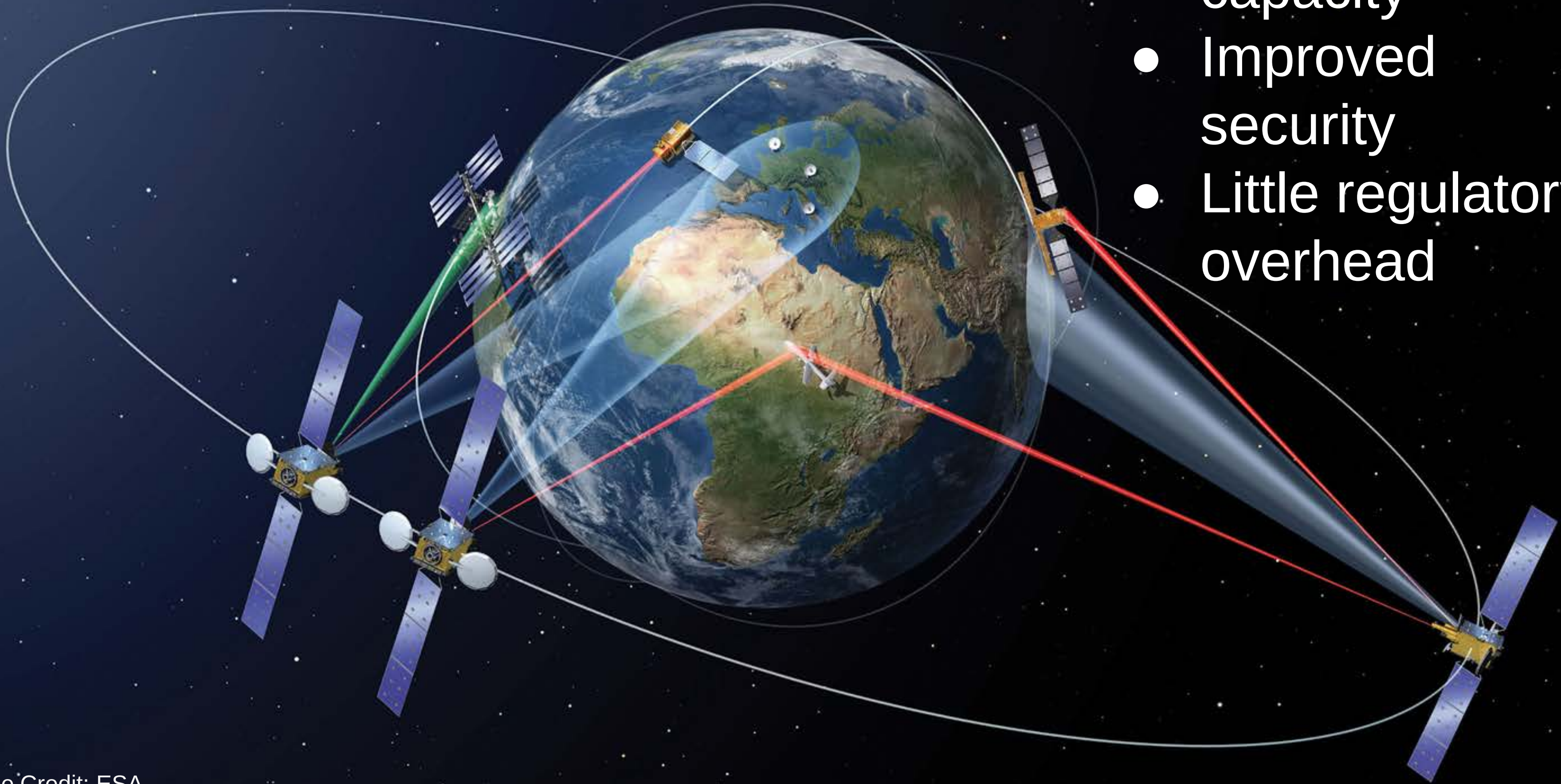


Image Credit: ESA


Free-space optical comm offers...
High channel capacity
Improved security
Image Credit: ESA

Free-space optical comm offers...



- High channel capacity
- Improved security
- Little regulatory overhead

Image Credit: ESA

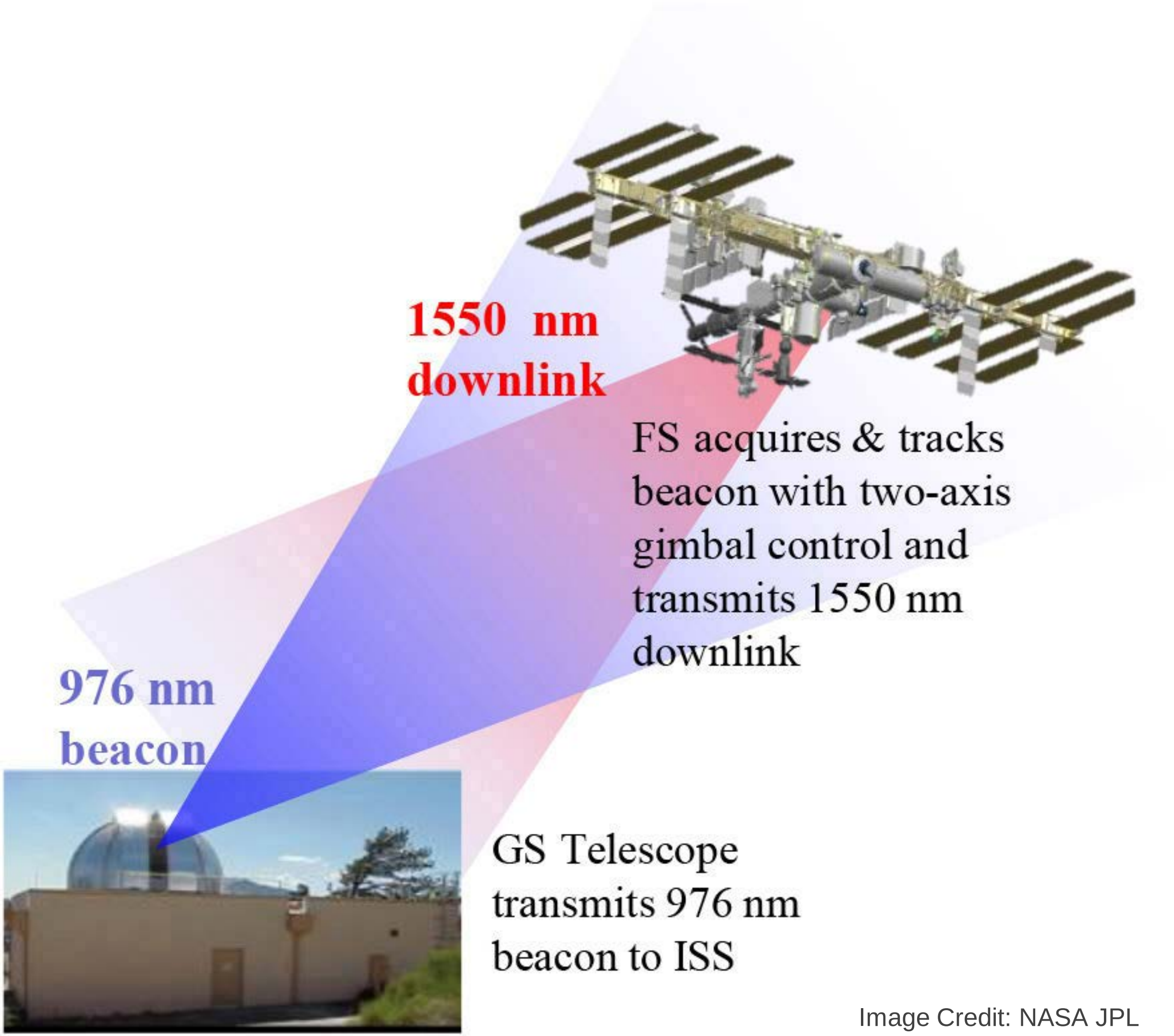
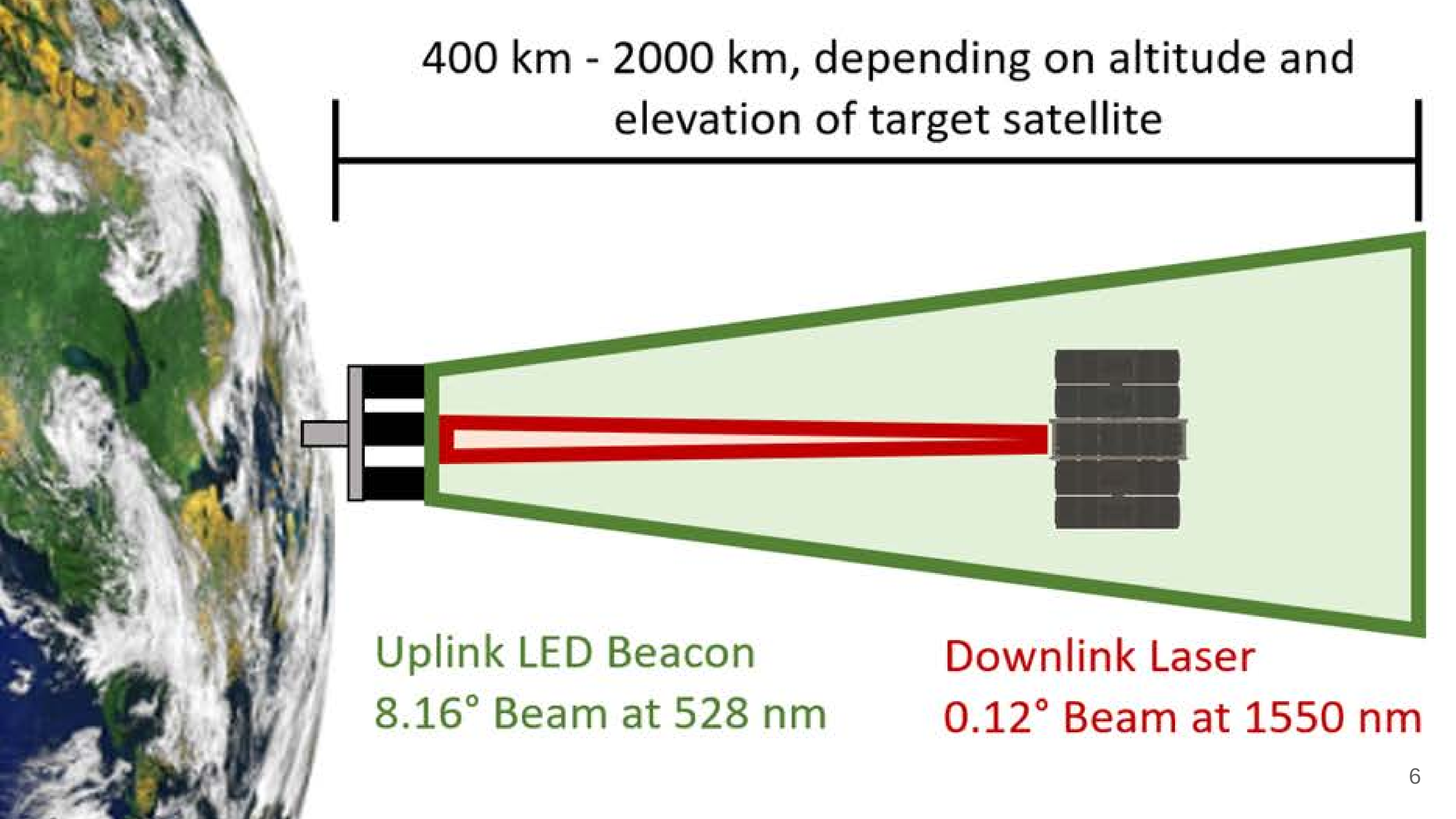


Image Credit: NASA JPL

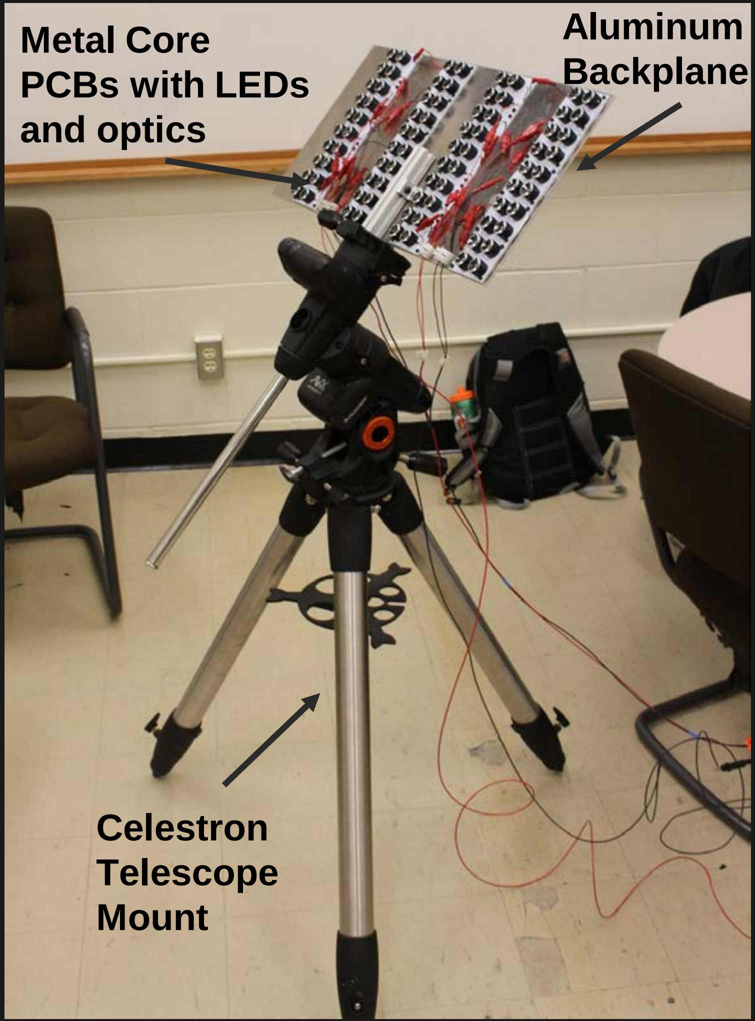
- Pointing, Acquisition, and Tracking (PAT) is difficult
- Existing systems (such as OPALS) rely on a beacon laser from the receiver
- OCTL: 10 Watts, 1 mrad FWHM, 976 nm beacon laser
- Laser beacons are expensive, immobile, and require coordination with the Laser Clearing House and the FAA

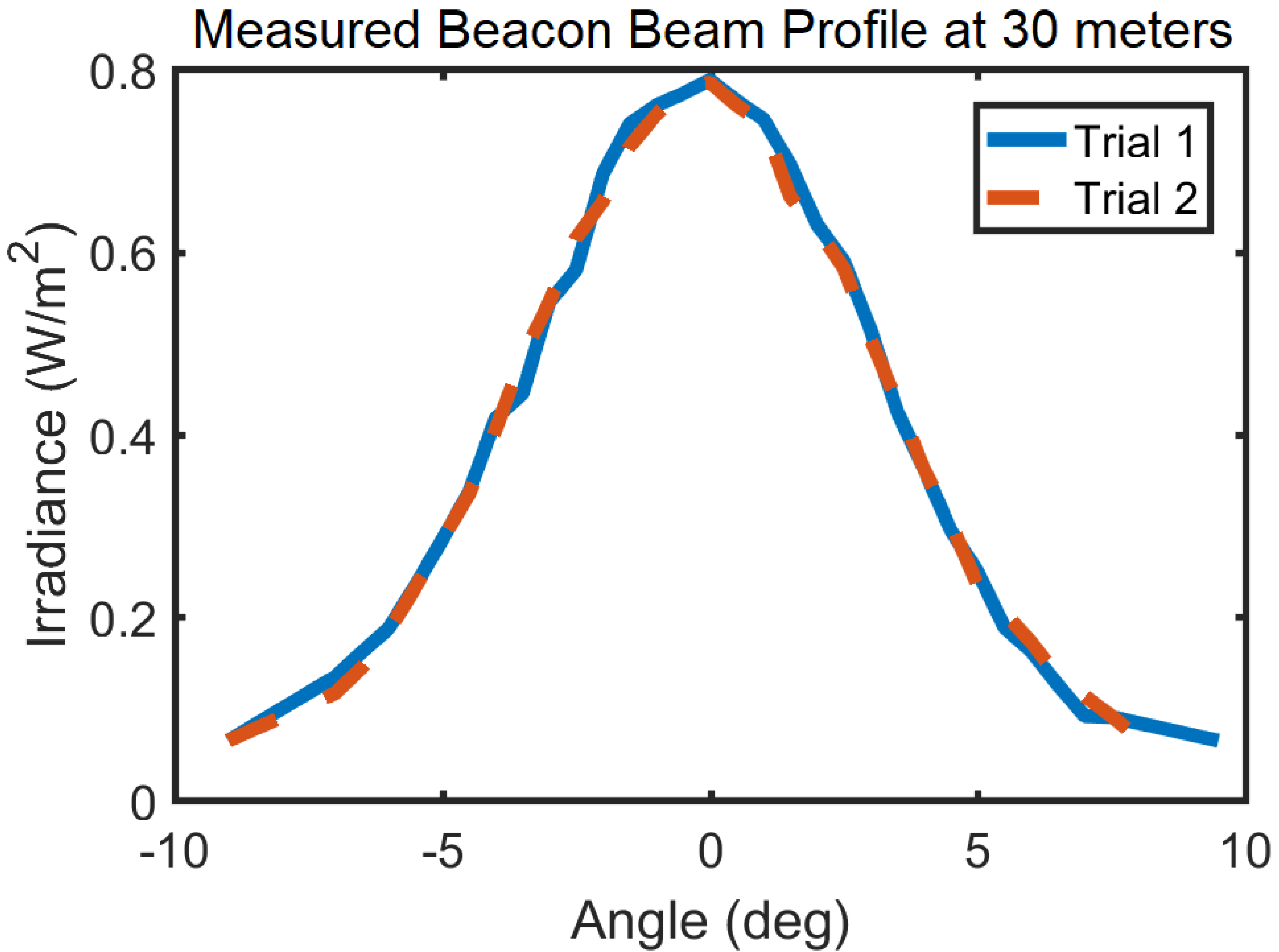

400 km - 2000 km, depending on altitude and elevation of target satellite
Uplink LED Beacon
8.16° Beam at 528 nm
Downlink Laser
0.12° Beam at 1550 nm

LED Beacon Link Budget

Parameter	Value	Units	Notes/Source
Peak Wavelength	528	nm	For Cree XP-E2 green LED
Optical Transmit Power	12.01	dBW	Measured as 15.9 W
Transmit Gain	29.01	dB	Measured as 9.12 deg FWHM
Free Space Path Loss	-263.37	dB	620 km path length
Atmospheric Loss	-4.5	dB	Assuming 20 deg elevation
Pointing Loss	-3	dB	Assumed
RX Gain	93.44	dB	7.9 mm aperture
RX Loss	-3	dB	Assumed
Received Power	-133.41	dBW	Sum of gains and losses
Detector QE	0.215		For MT9D131 sensor
Exposure Time	0.2	s	Assumed (similar to other AeroCube-5 images)
BPFF	0.147		For Edmund optics lens
Background Radiance	0.0015	W/m^2/sr/nm	
Dark current	60	e-/s/pix	For MT9D131 sensor
Read Noise (RMS)	22	e-/s/pix	For MT9D131 sensor
Signal	690	e-	Signal on brightest pixel
Noise	35	e-	Sum of shot noise, dark noise, and read noise
SNR	12.88	dB	

- Eighty 528 nm high-power LEDs with lenses on 20 metal core PCBs
- PCBs mounted on a ⅛ inch aluminum sheet
- LED array mounted on Celestron Advanced VX telescope mount
- Telescope mount implements two line element (TLE) tracking using John Eccles' Satellite Tracker
- Dubbed the "Beaver Signal" after MIT's mascot



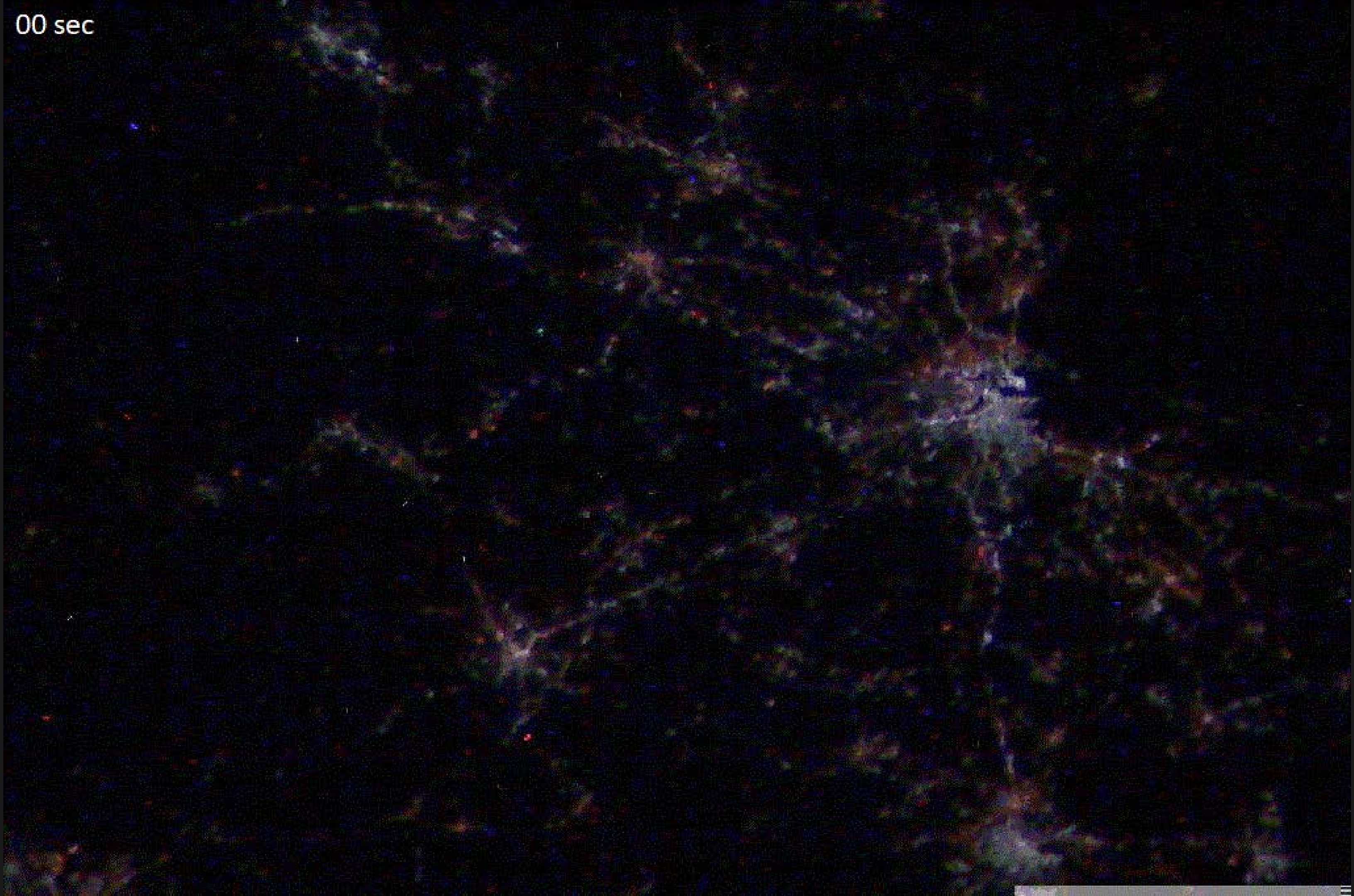

Measured Beacon Beam Profile at 30 meters
0.8
0.6
0.4
0.2
0
-10
-5
0
5
10
Angle (deg)
Irradiance (W/m2)
Trial 1
Trial 2

- Field testing performed with the help of Aerospace Corp's AeroCube-5
- 1.5 U LEO cubesat with 7.9 mm aperture and 2M RGB Bayer CMOS sensor
- Provided validation of link budget and system design
- Images during an overpass of Wallace Astrophysical Observatory on the morning of May 16, 2017
- Modulated on and off with a 20 second period

Image Credit: The Aerospace Corporation

LED beacon testing at Wallace Astrophysical Observatory on the morning of May 16, 2017


N
Test Site
Boston
Worcester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Summary:

- LED beacons are viable replacements for beacon lasers in many applications

- Knowledge of receiver location can be conveyed by non-coherent LED arrays
  - Wider beam width
  - Less regulatory hassle
  - More portable

- Additional work is necessary prior to deployment of an operational system
  - Switch to IR LEDs (~980 nm) and test with Aerospace's CUMULOS
  - More rapid modulation of the beacon to distinguish it from light pollution in real time

- LED beacons will enable the rapid deployment of a large number of optical ground stations

A Special Thanks To...

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- MIT Lincoln Laboratory
- Northrop Grumman
- SmallSat Organizers and Judges

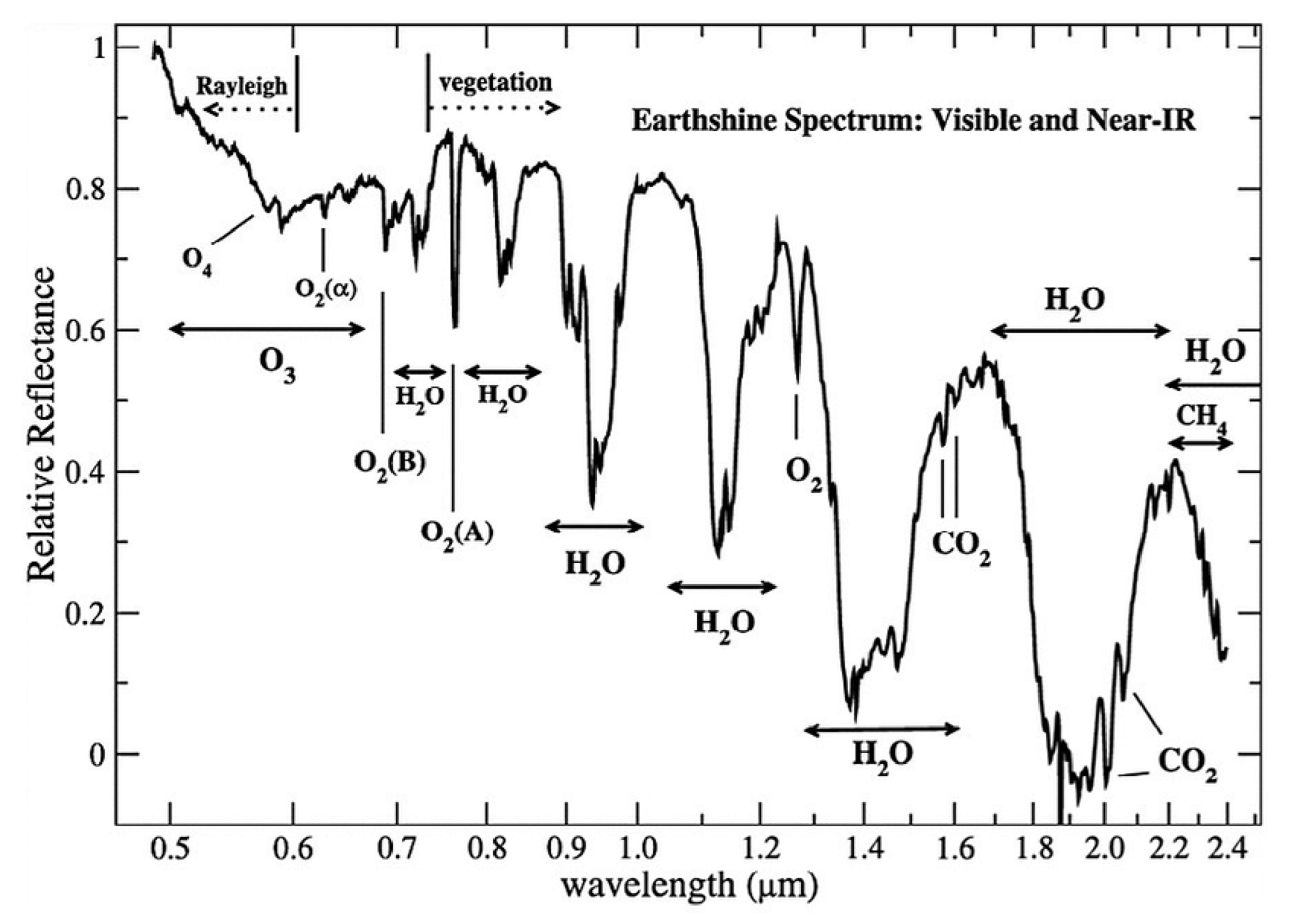

Image Credit: Turnbull et al 2006

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