

Operations and Results from the 200 Gbps TBIRD Laser Communication Mission

Kat Riesing¹, C. Schieler¹, J. Chang¹, N. Gilbert¹, A. Horvath¹, R. Reeve¹, B. Robinson¹, J. Wang¹, S. Piazzolla², A. Tarif³, B. Keer⁴

¹MIT Lincoln Laboratory, ²JPL, ³Terran Orbital, ⁴NASA GSFC

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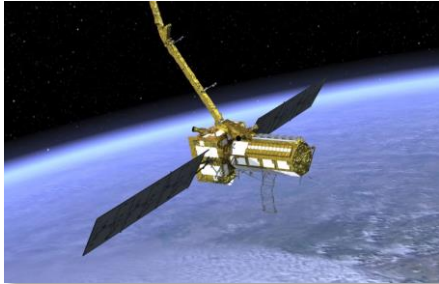
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Large Data Volumes in Low-Earth Orbit

Large and Medium Satellites

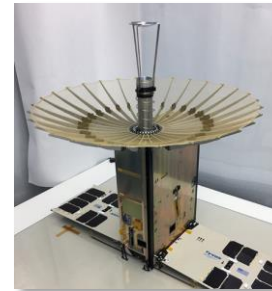


NASA-ISRO Synthetic Aperture Radar (NISAR)
(2024)

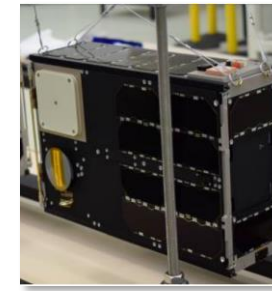


NASA Surface Water and Ocean Topography (SWOT)
In-orbit

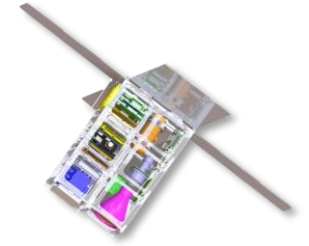
Micro/Nano Satellites



JPL RainCube
2019



GOMX-4B
Hyperspectral
Camera
In-orbit



UH Manoa
Hyperspectral Thermal
Imager (HyTI)
(2023)

Data Volume

4.8 TB/day
(downlinked)

20 TB/day (generated)
1 TB/day (downlinked)

1 TB/day
(generated)

2 TB/day*
(generated)

8 TB/day
(generated)

*Assumes 25% operational duty cycle
Image Credits, Left to Right: JPL, JPL, JPL, GomSpace, UH Manoa

State-of-the-art instruments on LEO platforms can generate raw data volumes of TBytes per day



Direct-to-Earth Lasercom

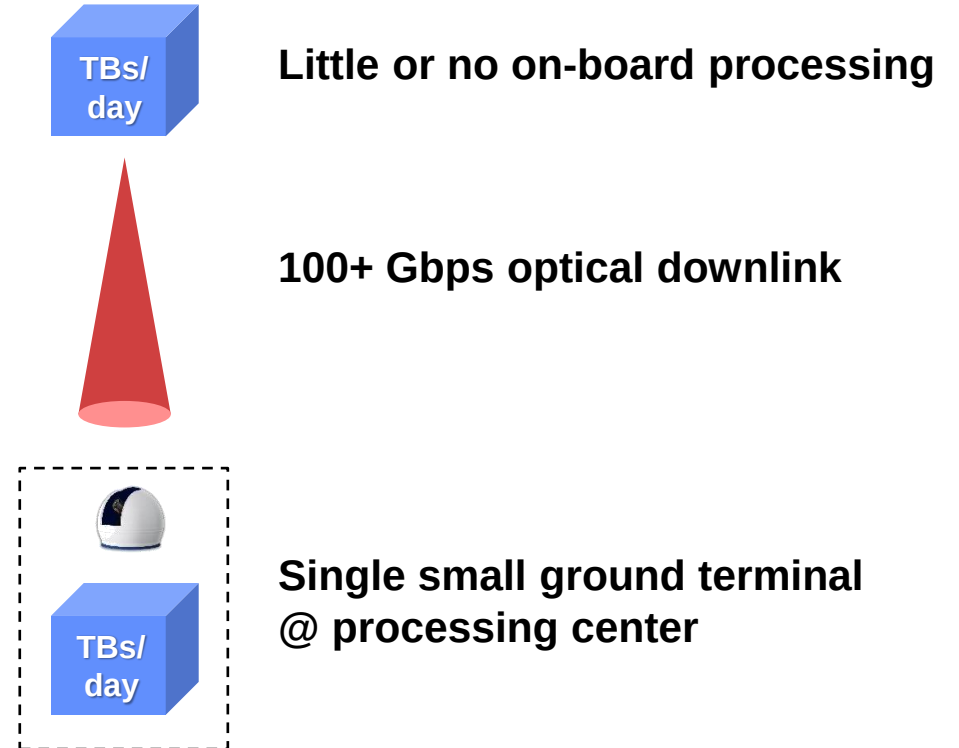
Optical Comm Comparison

- Abundant spectrum
 - THz available, unregulated
 - Enables high data rates (>100 Gbps)
- High beam directivity
 - Small, low power terminals
- Challenges: atmosphere, pointing

Data Delivery Example



Potential Architecture Enabled

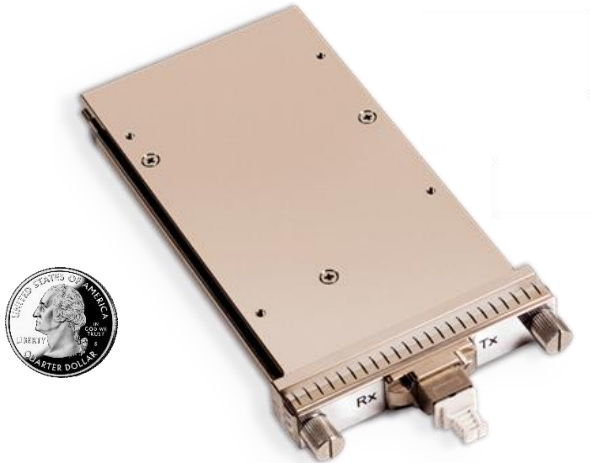


- Alternative architectures: GEO relay, direct-to-Earth RF



Enabling Commercial Technologies

High-Rate Optical Modem



**100 Gbps Fiber Telecom Transceiver
Compact Form Pluggable (CFP)**

Large, High-Speed Storage



**>500 GB, >25 Gbps Readout
Solid-State Drive (SSD)**

Optical Amplifier



**~1 W Erbium Doped Fiber Amplifier
Optical C-Band (~1550 nm)**

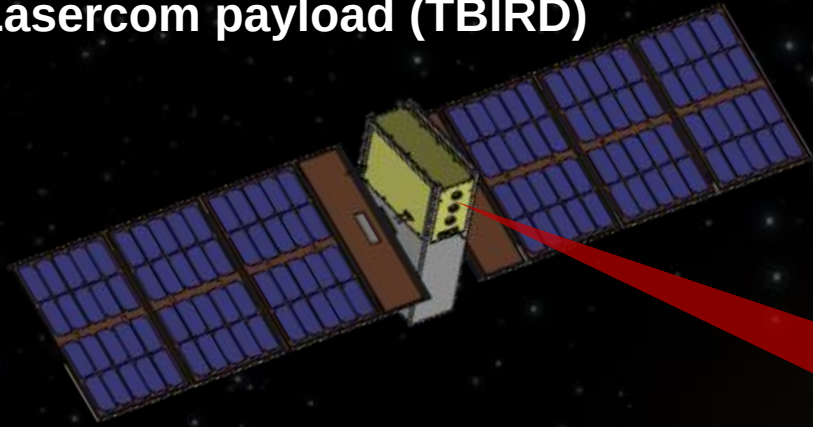
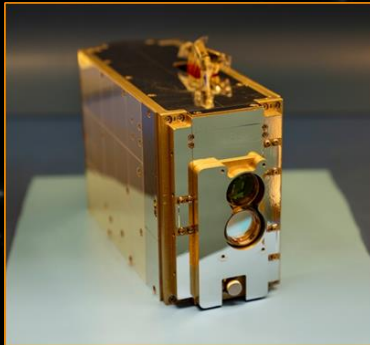
Highly integrated commercial components enable small, low-power, low-cost space terminal designs



Terabyte Infrared Delivery (TBIRD) Mission



6U CubeSat in LEO (PTD-3)
3U Lasercom payload (TBIRD)



- TBIRD is payload of NASA Pathfinder Technology Demonstrator 3 (PTD-3) mission
- Leverage fiber telecom equipment for 200 Gbps burst delivery (TBs per pass)
- Achieve robust data transfer through atmospheric channel
- Demonstrate body pointing architecture with payload pointing feedback

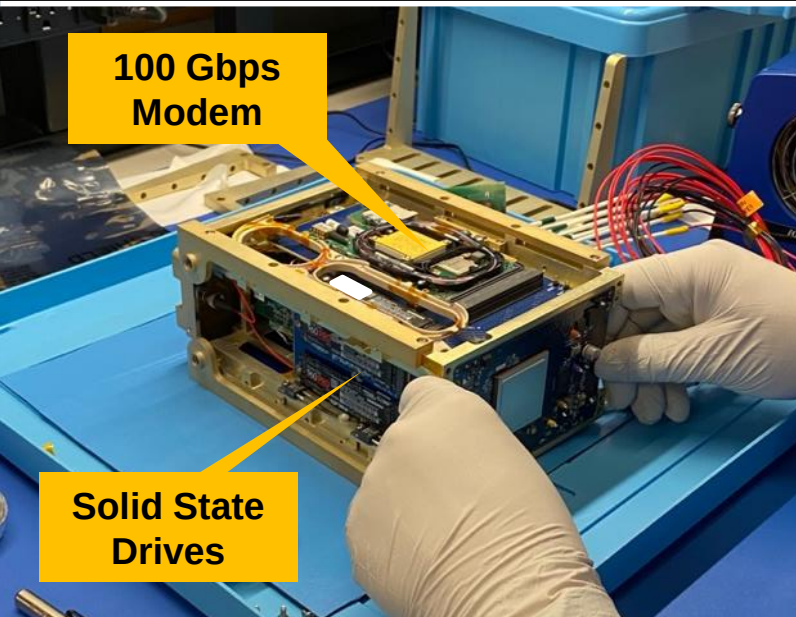
200 Gbps downlink



Ground terminal at JPL's
Optical Communication
Telescope Laboratory (OCTL)
in Southern California



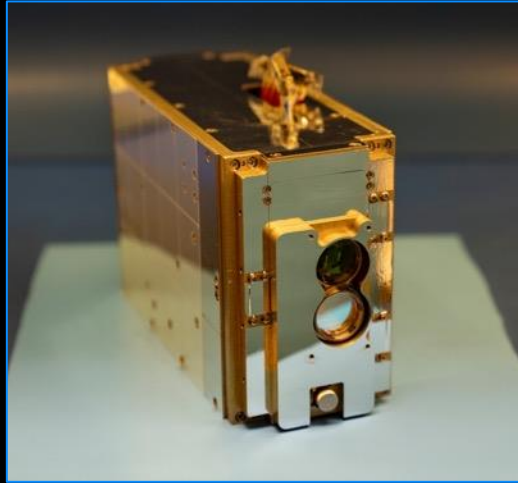
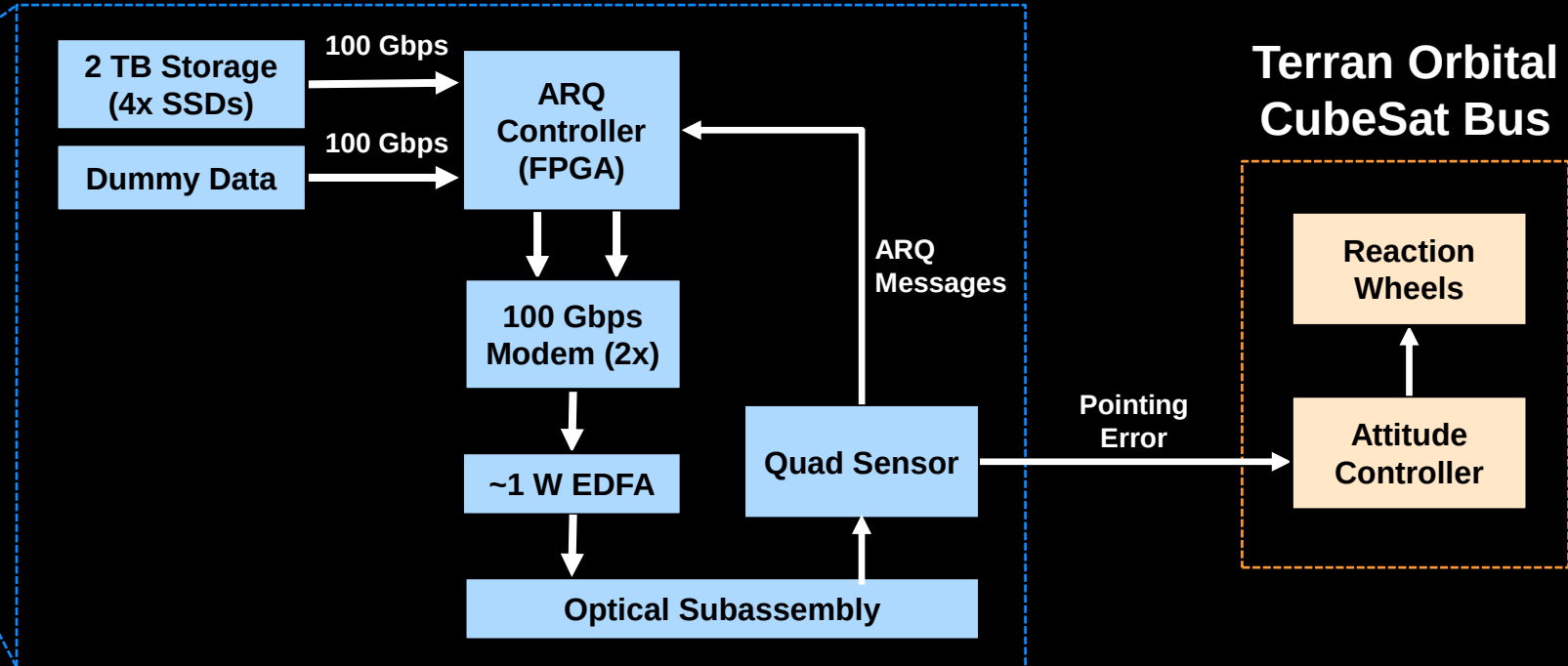
TBIRD Demonstration





Communication and Body-Pointing Architecture

MIT LL Lasercom Payload



ARQ: Automatic Repeat reQuest
SSD: Solid State Drive
EDFA: Erbium Doped Fiber Amplifier

MIT LL
JPL
Terran

Ground Terminal

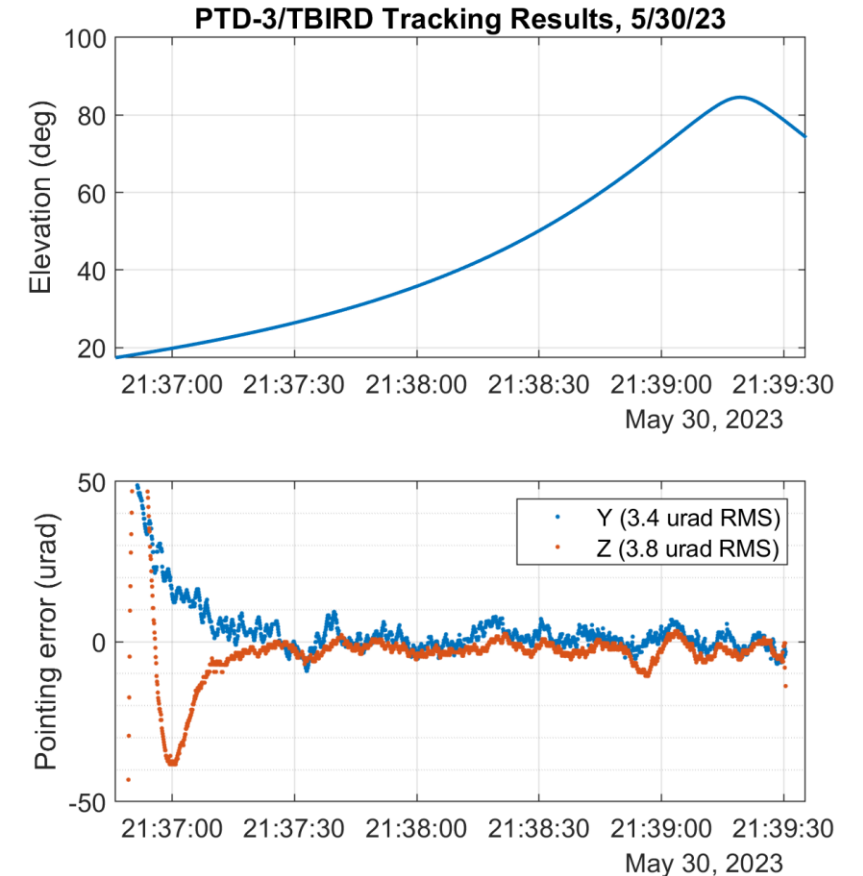
JPL/MIT LL
Ground Terminal



State-of-the-Art in Nanosatellite Pointing

- **JPL's ASTERIA mission has demonstrated the best nanosatellite inertial pointing to date**
 - Two-stage: 0.5 arcsec RMS, 1-axis
 - Body pointing only: 1.6 arcsec RMS*, 1-axis
- **Aerospace Corporation's OCSD demonstrated open-loop ground pointing for CubeSat lasercom**
- **PTD-3/TBIRD has demonstrated the best nanosatellite ground tracking to date**
 - **Body pointing w/ payload feedback: 1 arcsec (5 urad) RMS, 1-axis**
 - Demonstrated with up to 1 deg/s slew

*low-frequency bias removed

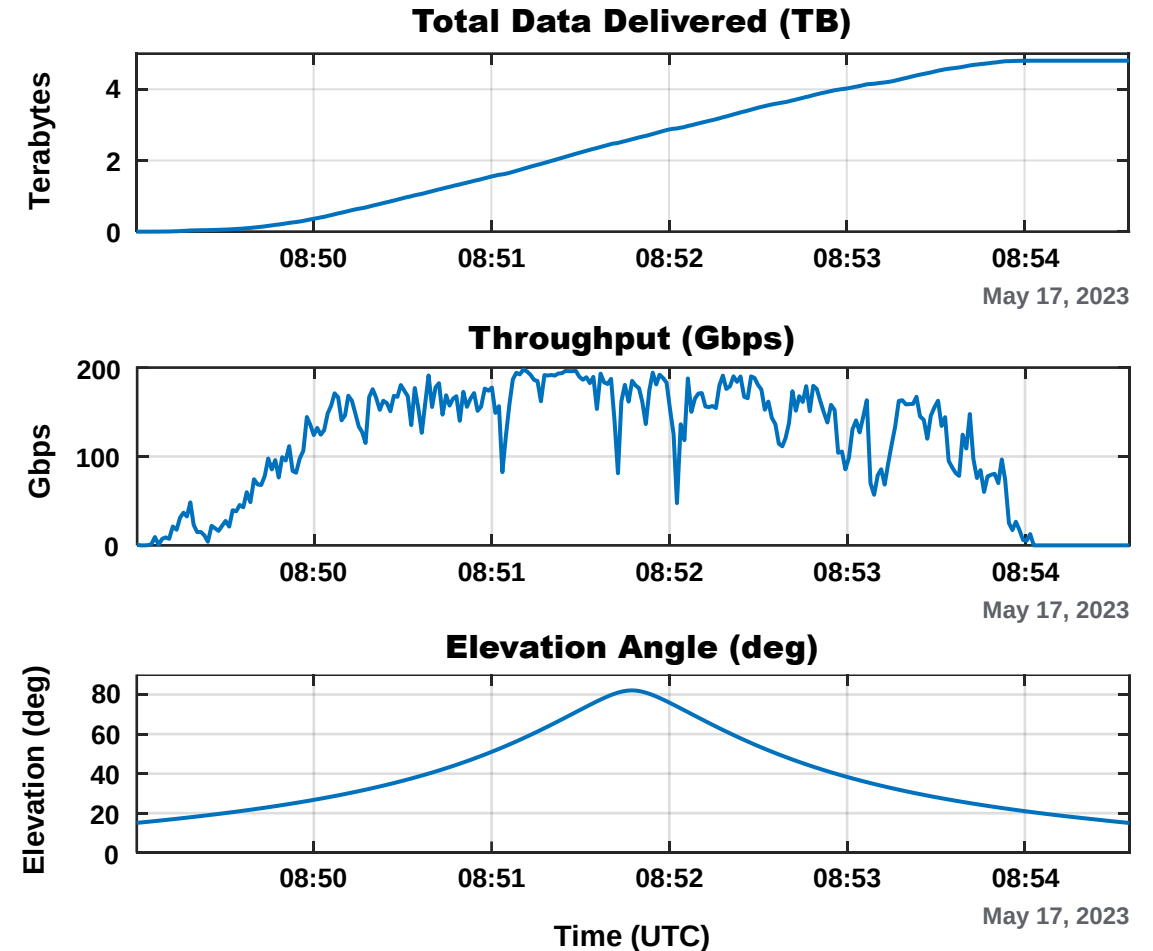


PTD-3/TBIRD has demonstrated the best nanosatellite ground tracking to date



Data Delivery Example (5/17/23)

- Operated in 200 Gbps mode (100 Gbps on two wavelength channels)
- Downlinked 4.8 TB error-free in 5 minutes
- Reached 200 Gbps throughput (end-to-end error free data rate with 1-second averaging)

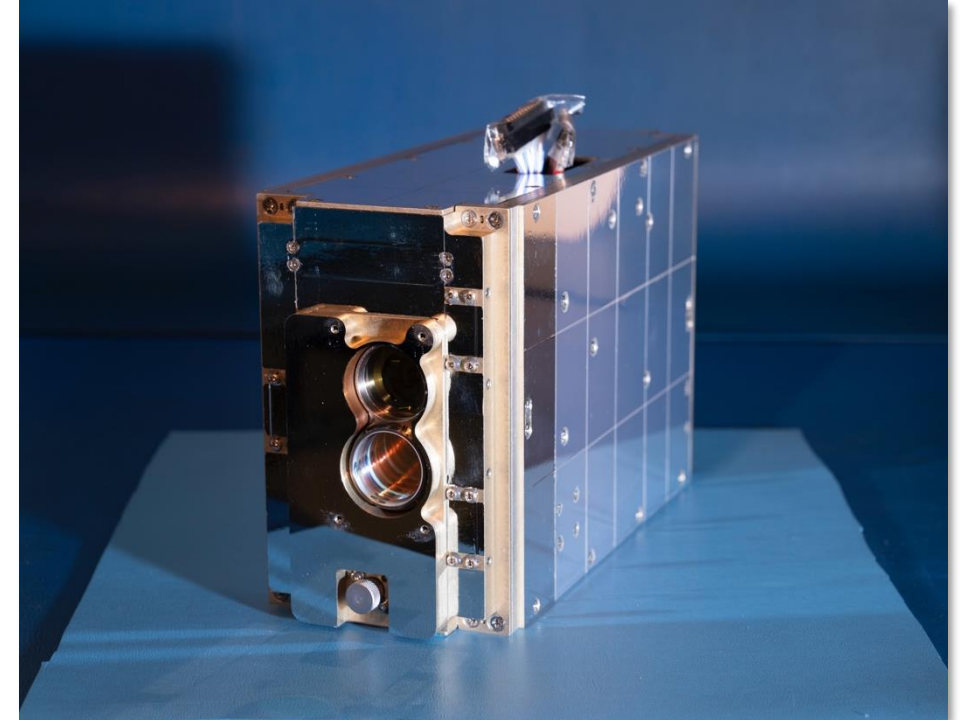


TBIRD has achieved the fastest downlink from space



Summary

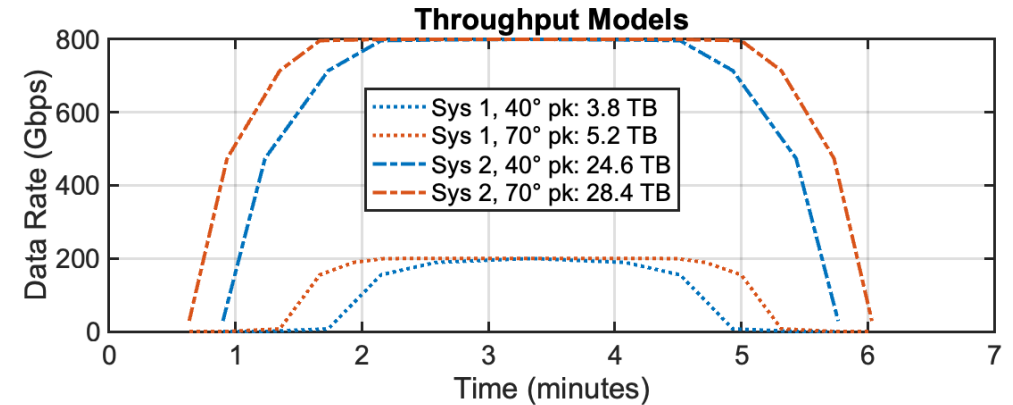
- **TBIRD has operated successfully since launch in May 2022**
- **Key achievements**
 - ~5- μ rad Cubesat closed-loop body pointing
 - 100 & 200 Gbps downlinks from LEO
 - Downlinked >1 Terabyte error-free in a variety of atmospheric conditions
 - Validated use of terrestrial COTS components in space
 - Performed end-to-end transfer from space buffer to ground buffer at 100 Gbps
- **Mission is ongoing with more experiments planned**





Implications for Future High Rate Lasercom Systems

- Pointing accuracy demonstrated with TBIRD/PTD-3 (5 urad RMS) could support much narrower lasercom beams
- Narrower beams enable more data delivery with smaller ground terminals

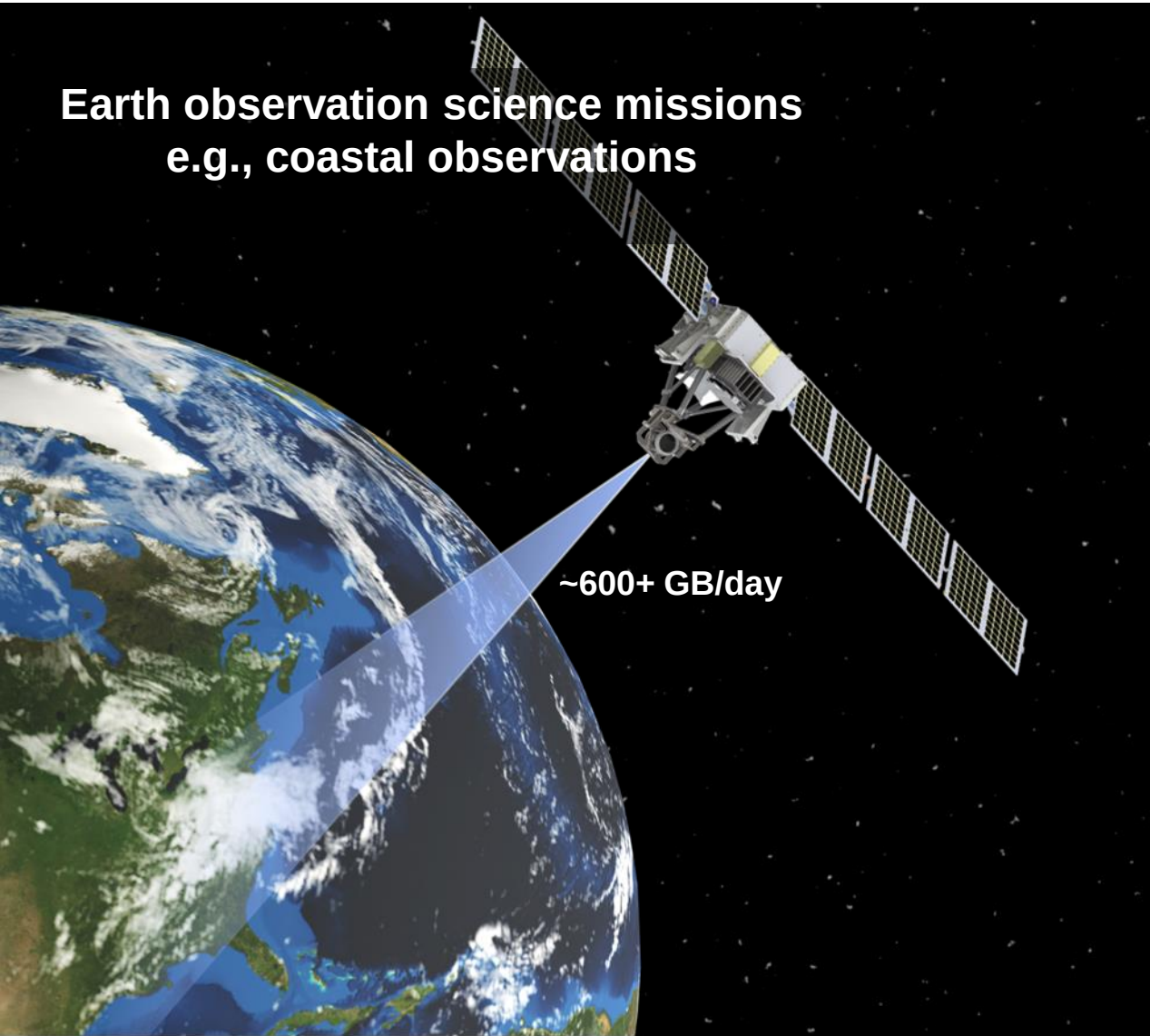


	TBIRD (Demonstrated)	System 1: Very small ground terminal	System 2: Higher data rate
Beamwidth (FWHM)	380 urad	100 urad	100 urad
Ground terminal aperture	100 cm	25 cm	60 cm
Max data rate	200 Gbps	200 Gbps	800 Gbps
Data delivery	Several terabytes per pass	Several terabytes per pass	Tens of terabytes per pass



Meeting Future Mission Needs

Earth observation science missions
e.g., coastal observations



Astrophysics missions, such
as Event Horizon Explorer

