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Some Aeronautical *Communications* Experiments

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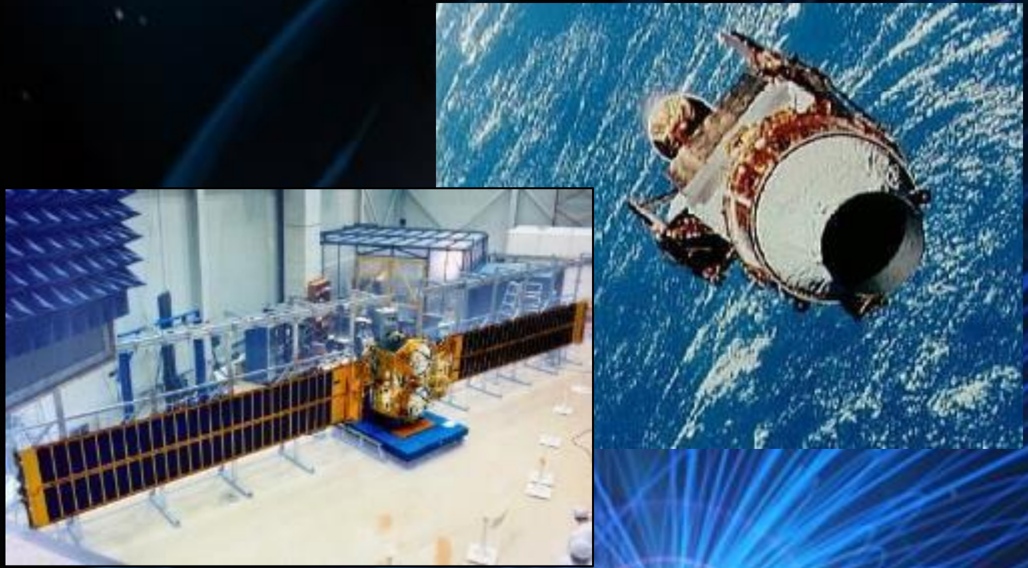
GRC Communications Highlights

https://www.nasa.gov/centers/glenn/technology



Hermes and Advanced Communication Technology Satellite (ACTS) introducing Ku and Ka-band to the world

Test ranges to characterize antennas

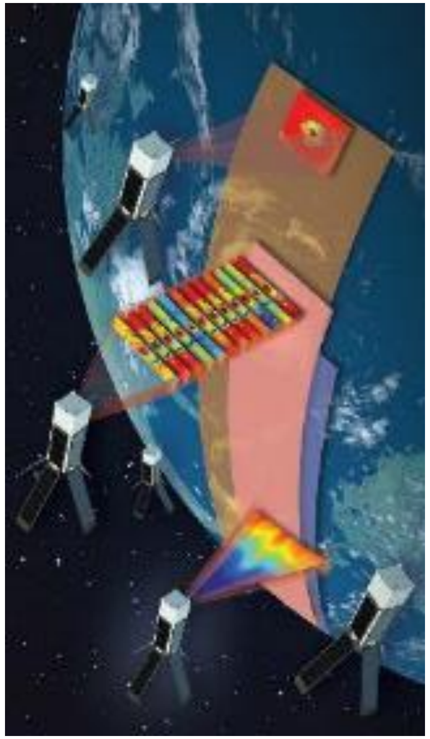
Critical component experiments onboard the International Space Station (ISS) to perform evaluations in the space environment

Laboratory facilities to develop RF & optical communication technologies and emulate network scenarios from deep space to ground

RF atmospheric propagation research

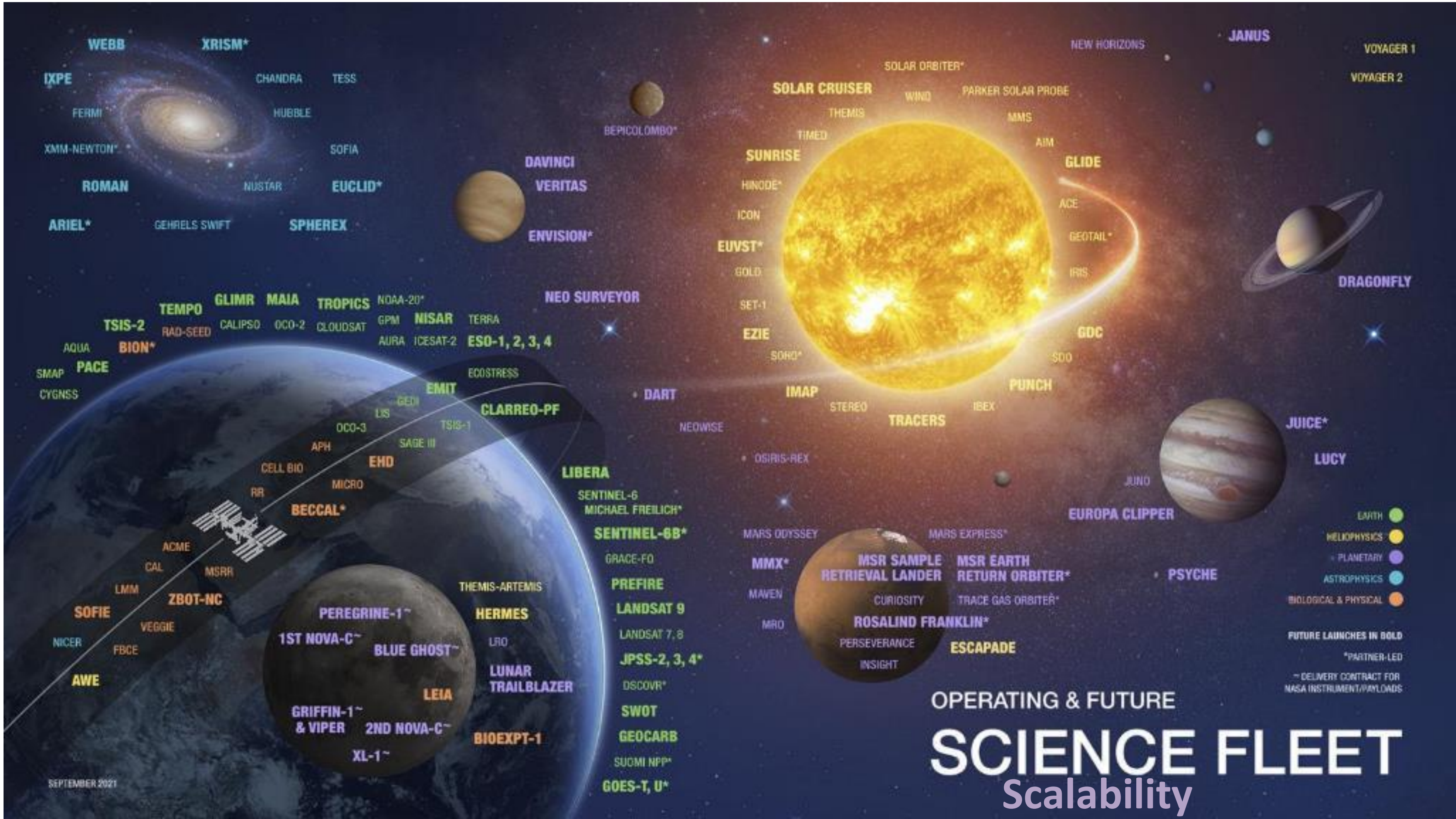
SCaN Testbed onboard the ISS to conduct software defined radio (SDR) experiments

Current NASA Science Missions



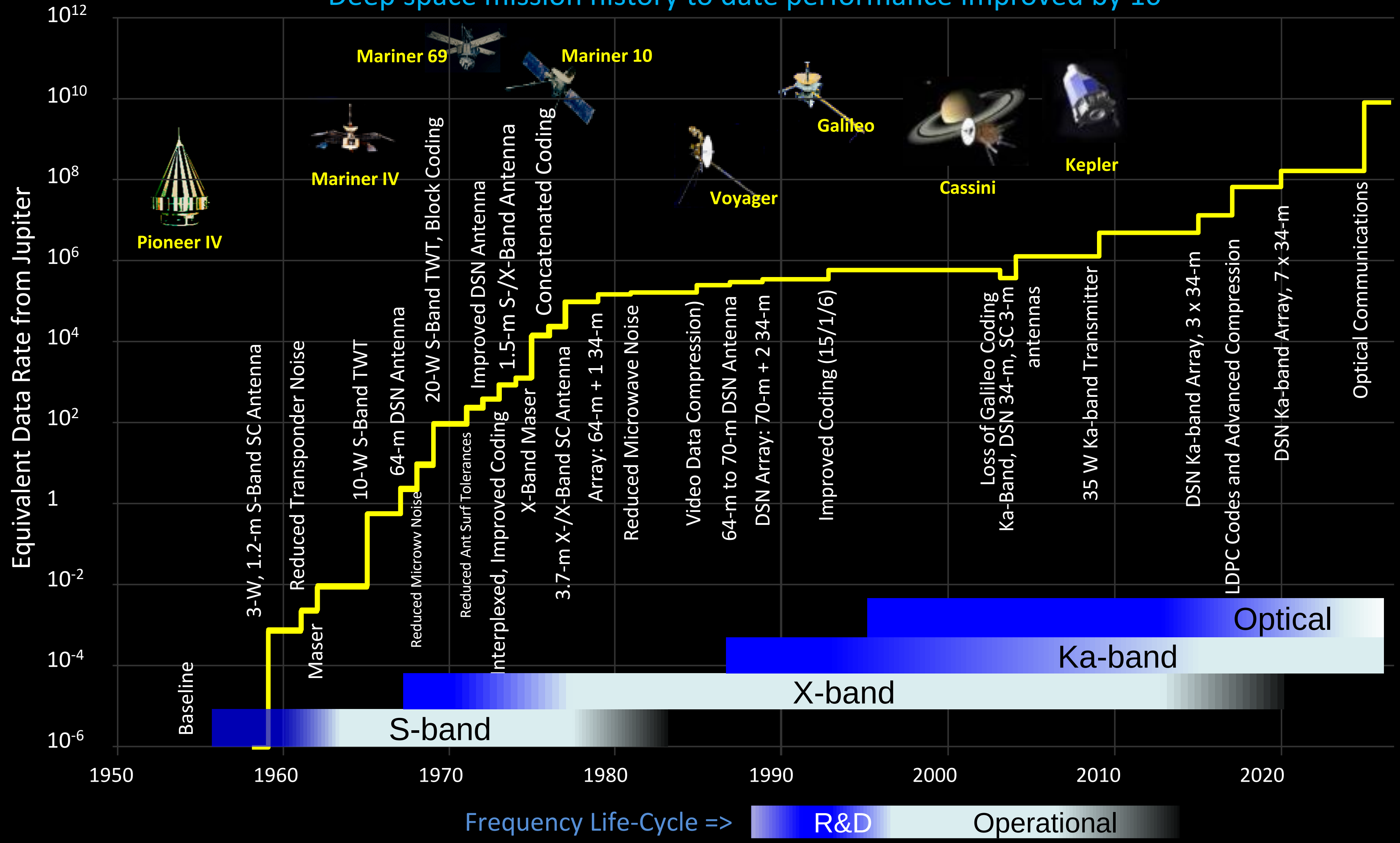
Downpour of Data

Imaging and remote sensing data generation is outpacing our capability to transmit to Earth



Aerospace Communications Evolution

Deep space mission history to date performance improved by 10^{13}



Aerospace telemetry market growth forecast

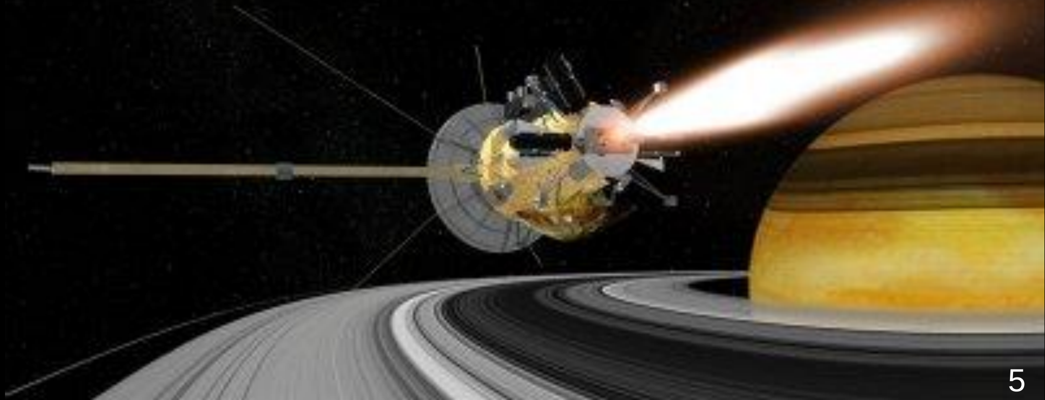
Data to Serve the Missions Spans Many Purposes, Rates and Quality of Services (QoS)

Different types of data, with different requirements (BER, bandwidth, latency, security, custody, etc.)

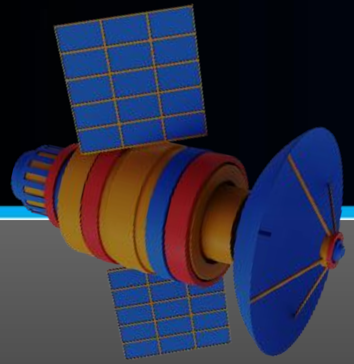
- Tracking, telemetry and control (TT&C)
- Scientific data from instrumentation
- Pictures (high-resolution, stereoscopic, hyper-spectral)
- Video (composite of images)
- Biometric, voice, text messages to/from astronauts
- Asymmetric versus balanced forward & return links
- Networks versus PTP links of spacecraft, relays, surface assets

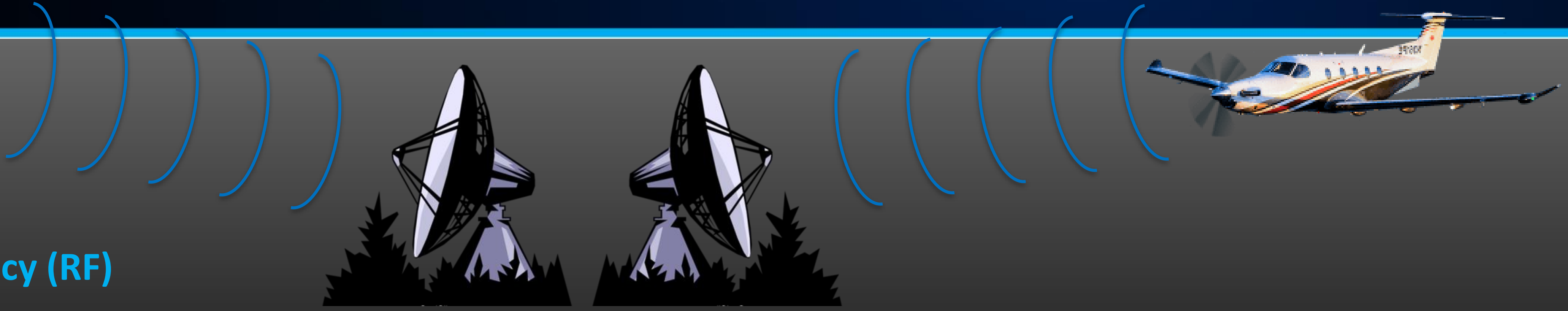
What do missions want?

- Uninterrupted data from anywhere in the solar system, more pictures, faster video, 3D, IMAX, telepresence, etc.
- High peak data rates to support human exploration
- QoS provisions for priority, latency, error rate, security



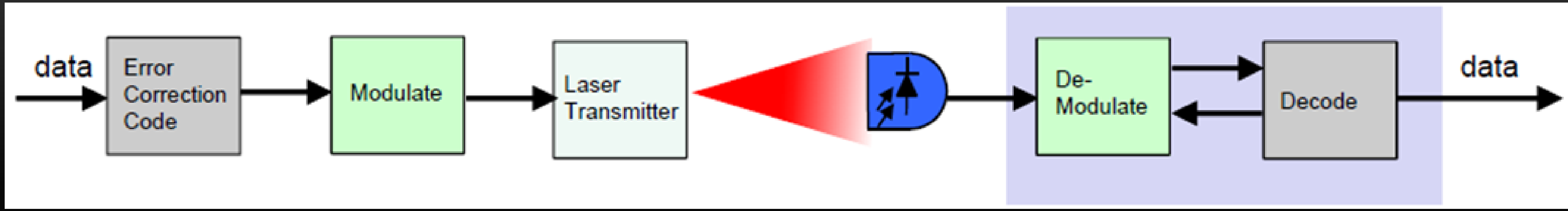
Improving Point-to-Point Links





Radio Frequency (RF)

Optical (laser)

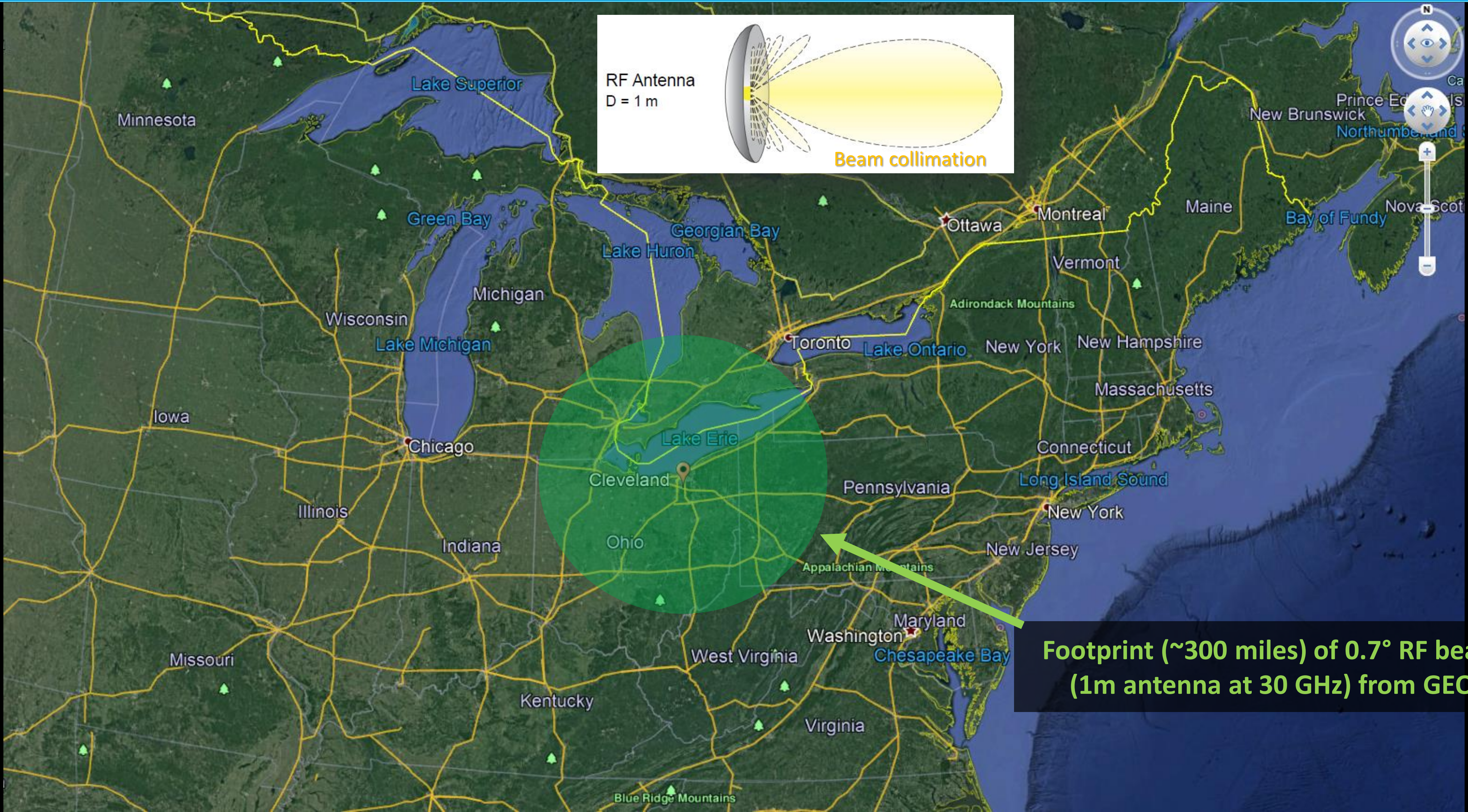


Type	Direction	Volume	Quality requirements	Applications
Telemetry	Return link	Moderate	High	• Vehicle data • Subsystem status
Commands	Forward link	Low	Very high	• Controlling vehicle • Controlling payloads
Tracking/navigation	Either or both	Very low	Very high accuracy	Position and navigation
Science data	Return link	High	Moderate	• Sensor data • Imaging
Comm services	Bidirectional	Very high	Moderate	Relays

RF Beam from a Satellite in Geosynchronous Equatorial Orbit (GEO)

Image created with Google Maps

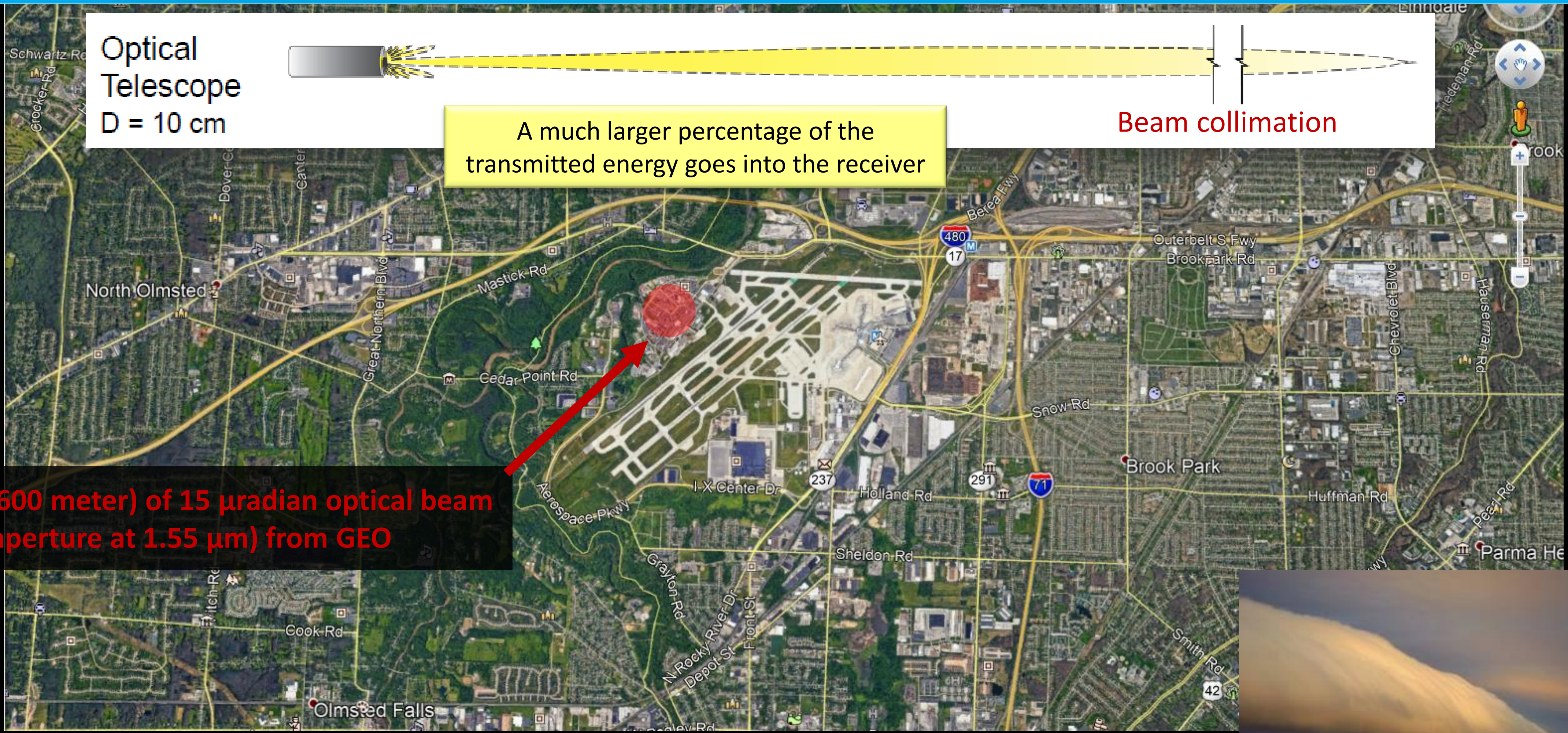
Electromagnetic beamwidth is ruled by the diffraction limit



Optical Beam from Geosynchronous Equatorial Orbit (GEO)

Benefits and Challenges

Image created with Google Maps



Footprint (~600 meter) of 15 μradian optical beam (4" aperture at 1.55 μm) from GEO

- \+ Great for privacy (physical security), can add QKD for additional layer
- \+ Higher received energy density = higher data rates (increased SNR)
- -- …but comes at the cost of very challenging pointing control

Clouds and mist can interrupt a laser

Technology
Readiness
Level

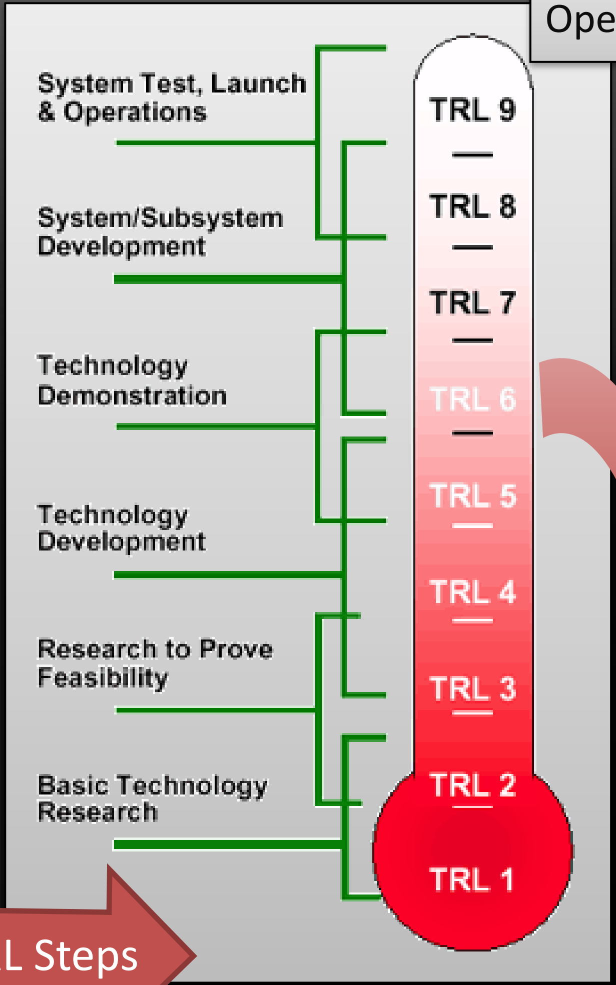
Transition From Ground-Based TRL 6 to Space Ops TRL 7 is a Major Step

Plus, technology is more than hardware

***D**efine,*
***D**esign,*
***D**eploy…*

Introducing new technology from the lab into the operable network…

TRL Steps



Operations

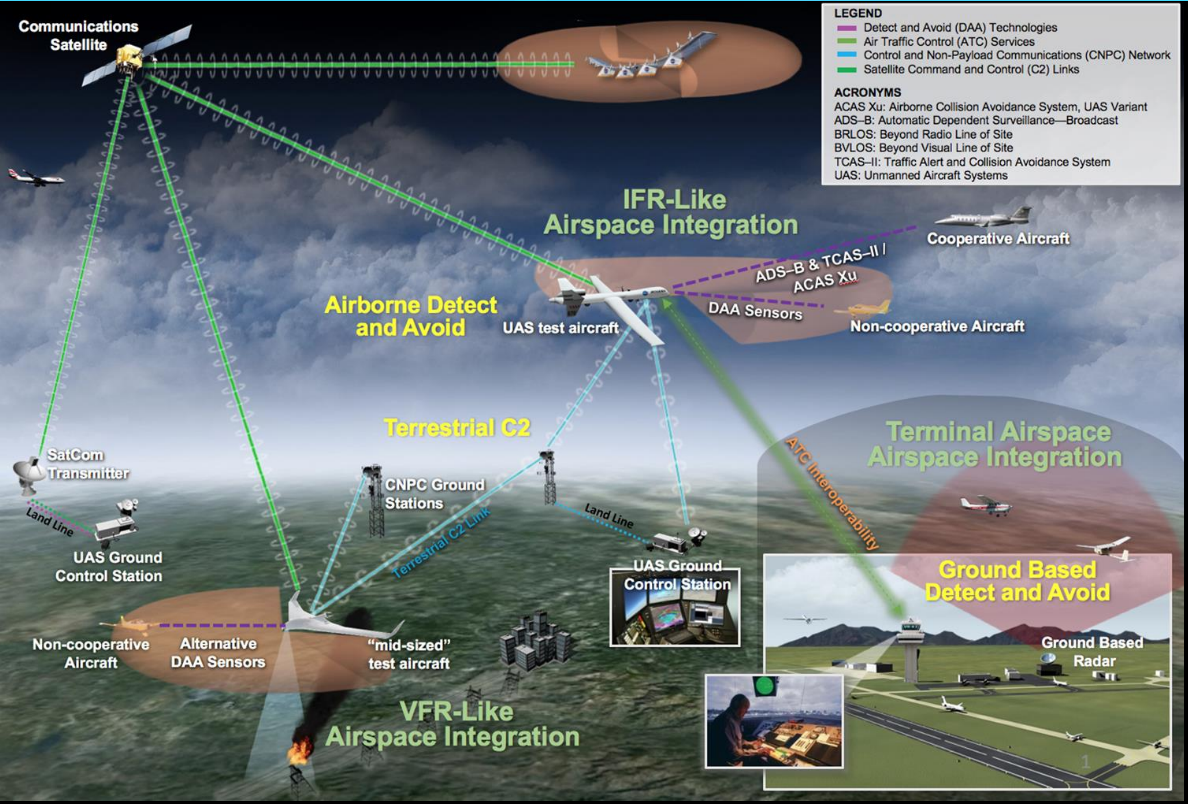
Beware of the Never Use Scrap Heap!

Recent emphasis on COTS hardware and crowd-sourced software tries to bridge the gap

Aerospace Architectures

Migrating to Flexibility, Scalability and Affordability

Customer Needs



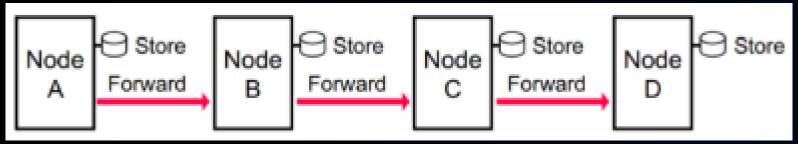
Network Topology Transformations

Goals for communication networks

- Reduced mission burden with short mesh links for increased connectivity, enables proximity telerobotics
- Common architecture reduces development costs
- Reuse of hardware and software: family of product variations for different environments
- Efficient use of spectrum

Several networking challenges present

- Disconnection (*interruptions in service, can be unscheduled*)
- Buffering (*levies storage requirements on vehicles*)
- Latency (*negates ACK - based protocols*)
- Security (*imparts requirements on transceivers*)



The Bundle Protocol (BP)

Delay/Disruption/Disconnection Tolerant Networking (DTN)

Store, Carry, Forward…

DTN approach organizes systems

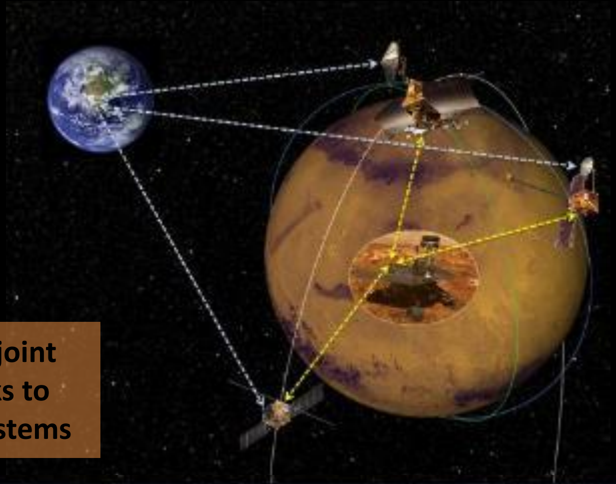
- Licklider Transmission Protocol (LTP) provides reliability over long link delays and/or frequent interruptions in connectivity
- Contact Graph Routing (CGR) enables dynamic route computation to optimize performance and reduce mission operations costs
- Bundle Security Protocol (BSP) provides a mechanism for source authentication and data integrity and confidentiality
- Ameliorates forward/return link & bus asymmetry
- Reactive fragmentation and storage

Development Goals

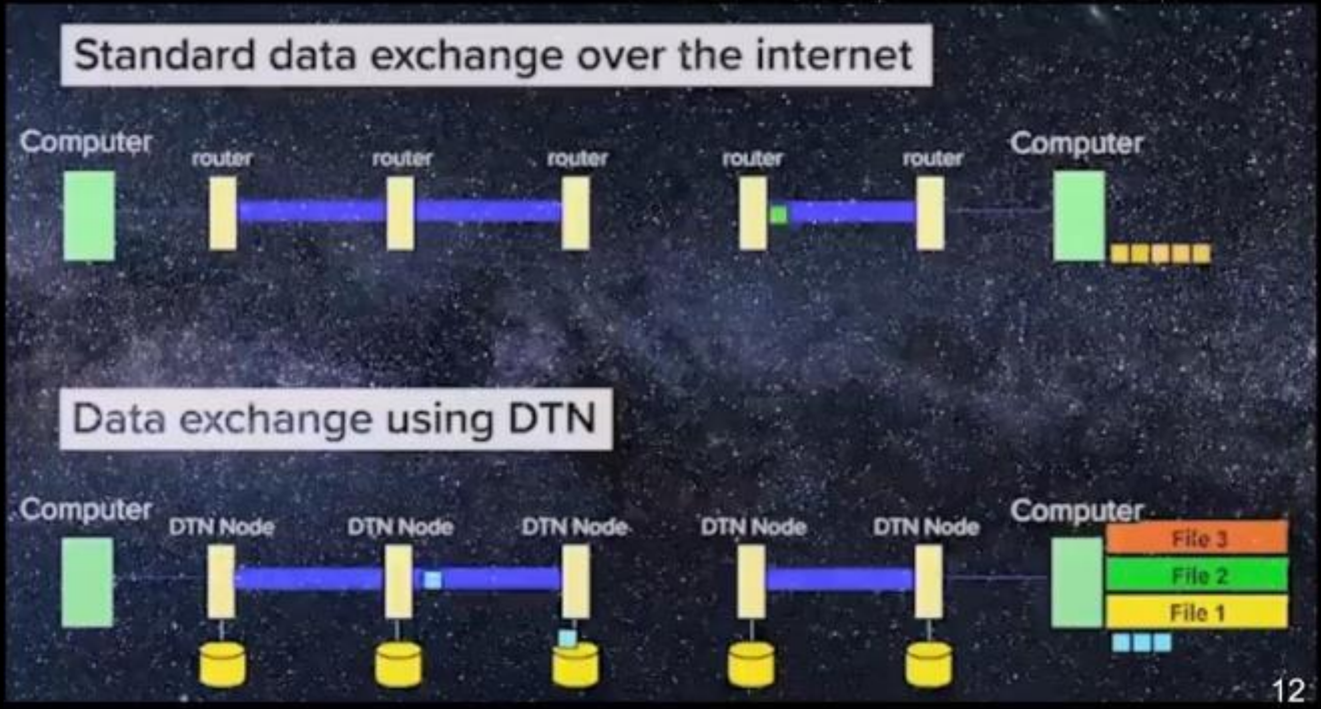
- Ensure DTN is not the communications bottleneck
  - 1-10 Gb/s now, 100 Gb/s later
- Commercialization through open-sourcing
- Interoperability and ease-of-use

Other use cases

- Off grid communications
- Disaster response
- Environmental monitoring



DTN unites the formerly disjoint collection of assets and links to form a cohesive system of systems

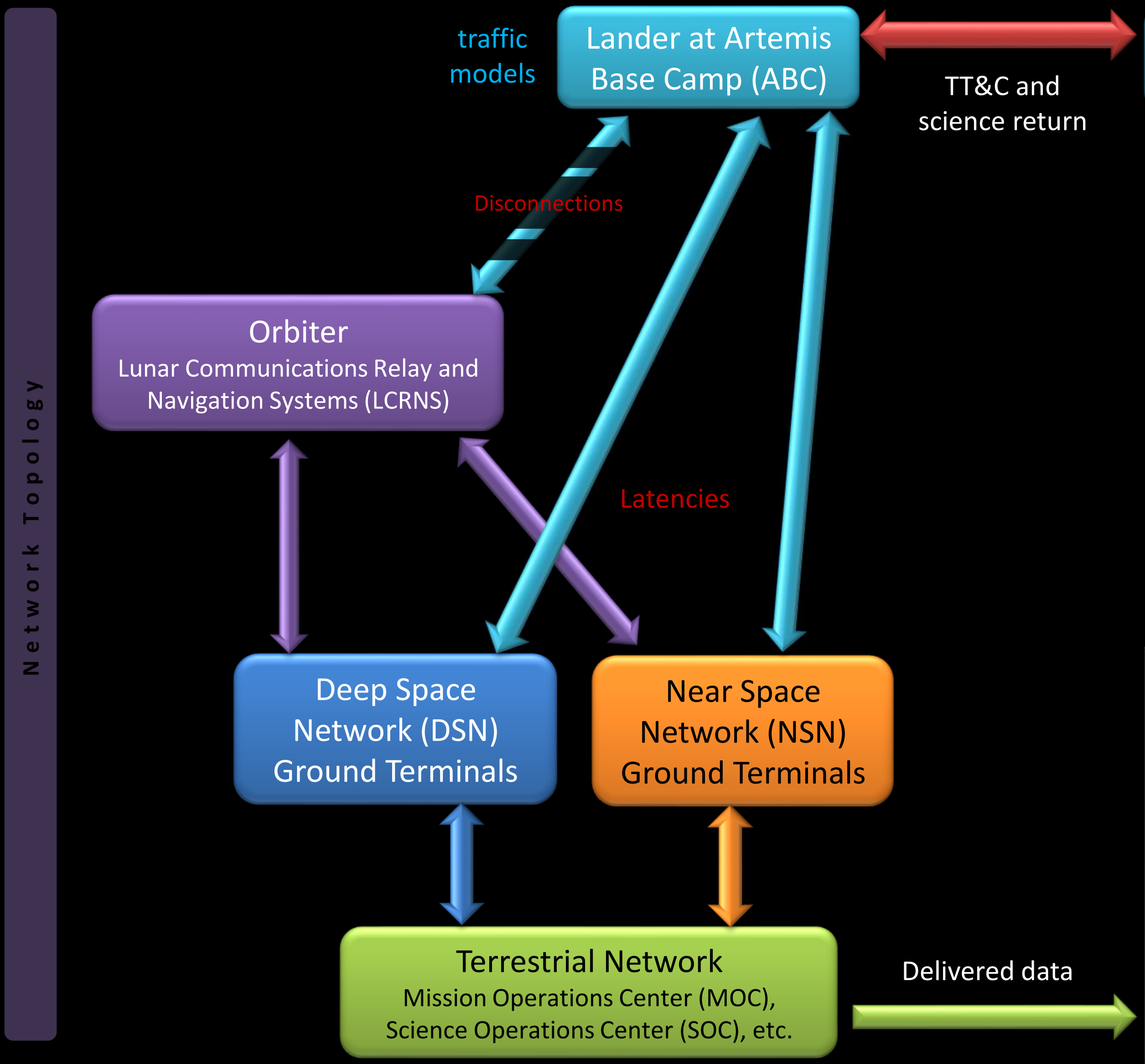


Emulating LunaNet Internetworked Operations

Buffering data until a transmit opportunity arises, where an end-to-end path may not be available

***S**tore,*
***C**arry,*
***F**orward…*

Laboratory emulation testbed



Science gathering mission

Received data

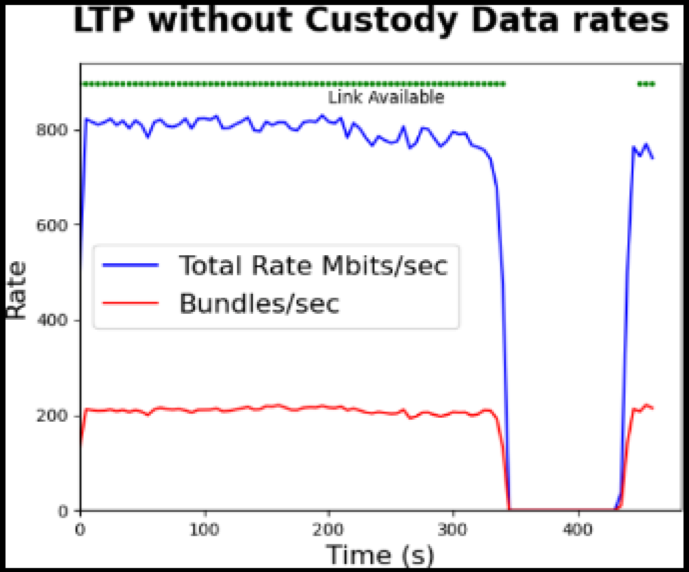
Aircraft Flight Experiments

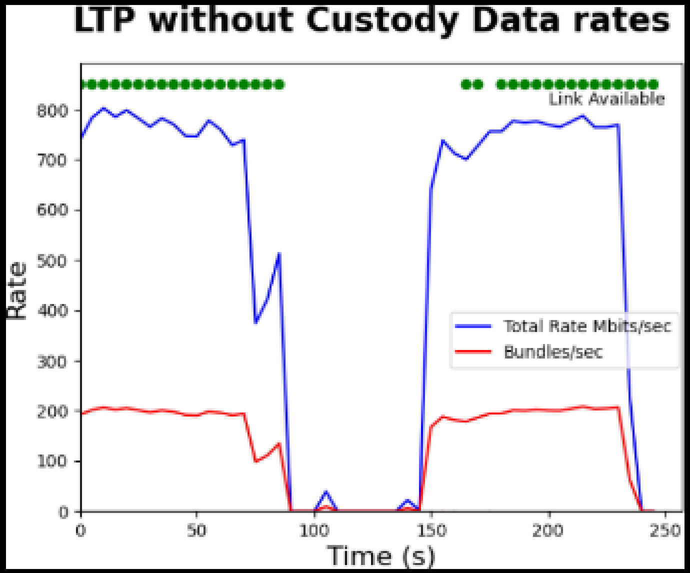
NASA Twin Otter Aircraft
with Laser Terminal

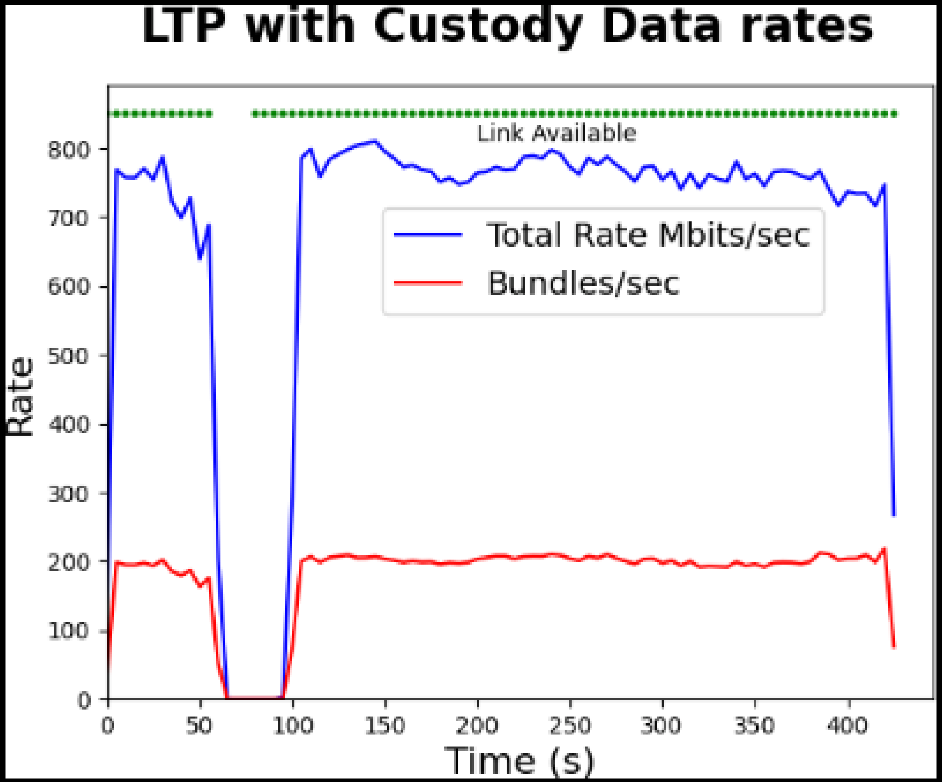
Laser Ground Terminal near GRC hangar

- Successfully conducting laser communications flight testing on GRC aircraft
- Achieved near-Gbps rates to/from ground terminal
- Exchanged TB of hyperspectral data over multiple days
- Communicated across obscuration interruptions such as landing gear, trees, etc.

Flight Results



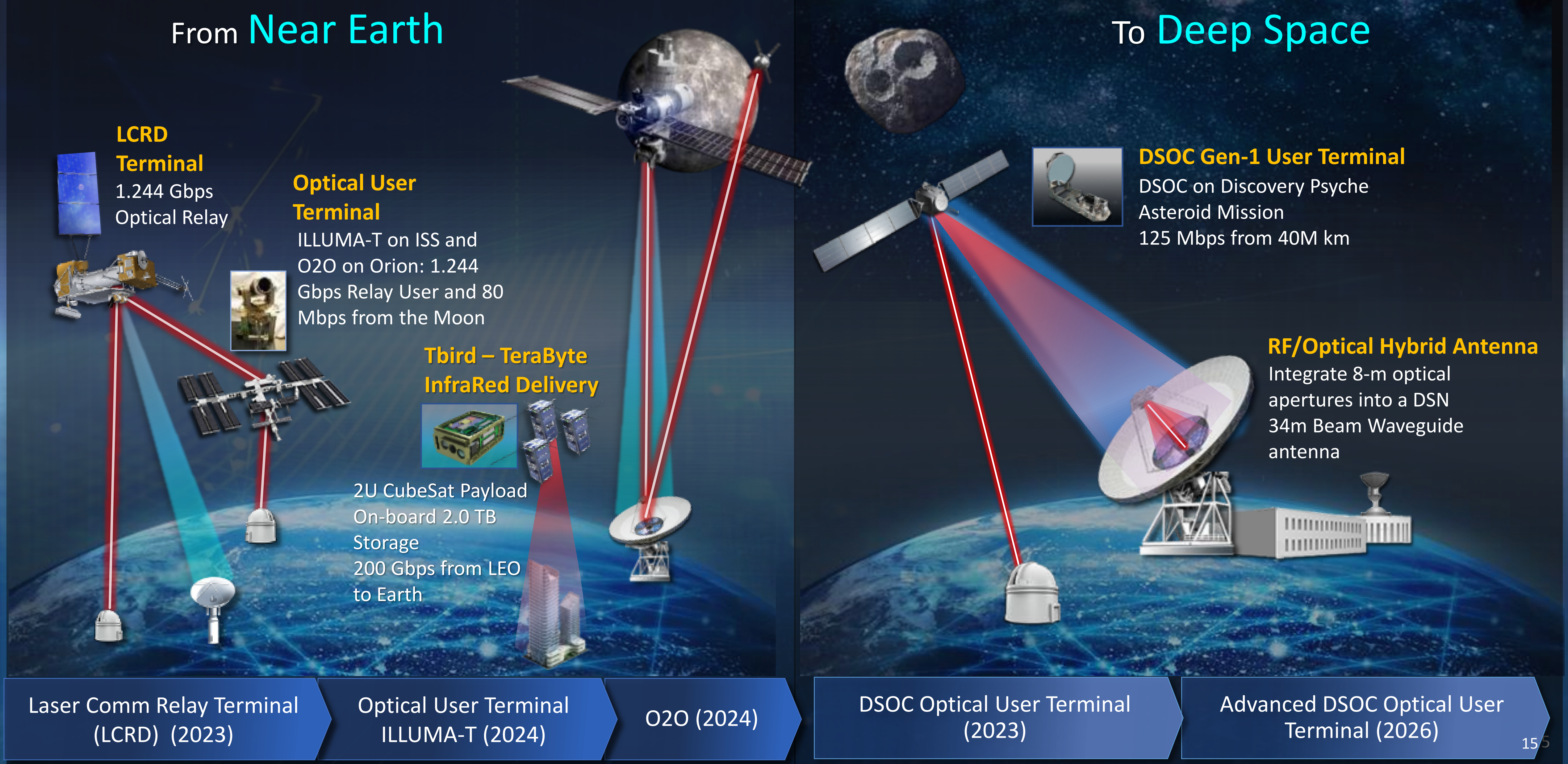




- Took place at 35-50km
- All tests recovered from a signal interruption
- Custody tests successfully sent and received 100% of bundles

Optical Communications Technology Demonstrations

High Data Rates



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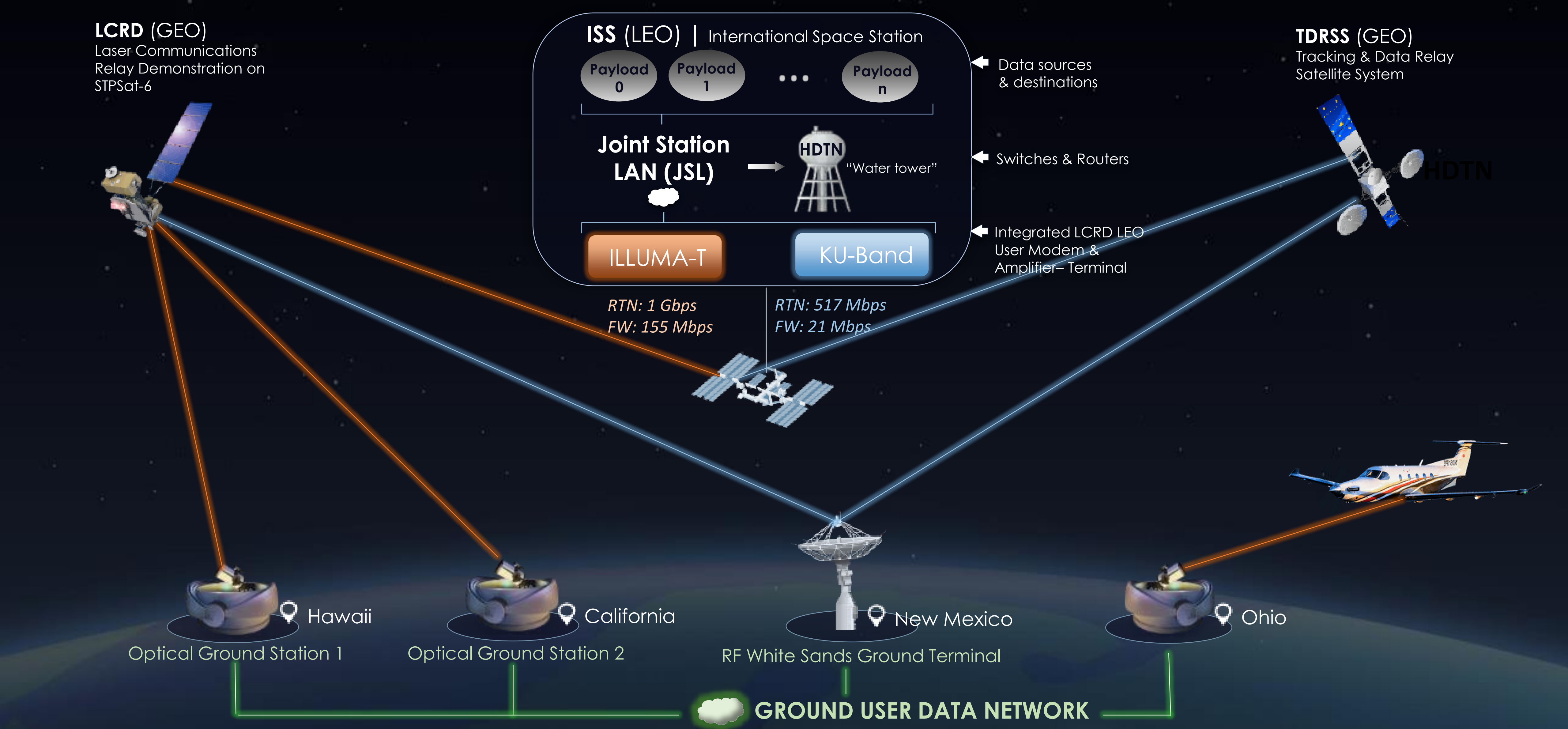
Internetworked ISS Concept of Operations

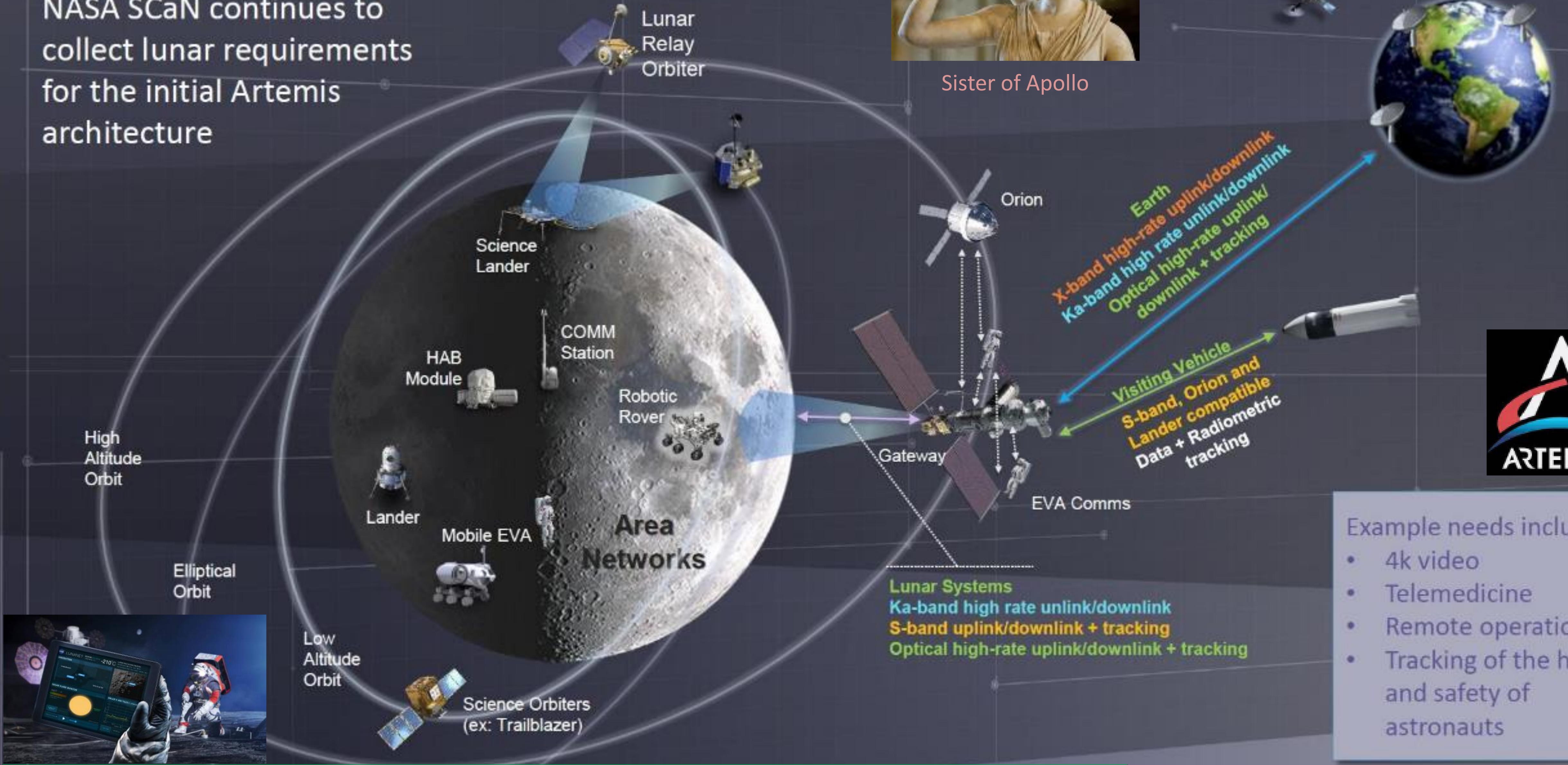
Delivering a high rate (Gbps) networking system to the ISS to support an upcoming laser communications demo (collaborating with GSFC, MSFC & JSC)



Enabling Requirements for Artemis

NASA SCaN continues to collect lunar requirements for the initial Artemis architecture

Sister of Apollo



Example needs include:

- 4k video
- Telemedicine
- Remote operations
- Tracking of the health and safety of astronauts

Q: How will a mixture of RF, optical, gov, commercial, academic & international assets interoperate and protect from each other?

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Thank you for your kind attention!