Science Mission Directorate

2018 Technology Demonstration Industry Day

Technology Demonstration MO

Technology Title:	A LEO-Based Hybrid RF-Optical Data Relay Network
Affiliation:	Analytical Space, Inc.

Technology Description, Current Performance Metrics, and Performance Goals

A LEO Nanosatellite network capable of high-speed satellite crosslinks in RF and high-speed downlinks with RF and Optical systems. Each relay satellite will have a high-gain dual-band antenna, a high speed laser downlink.
Performance metrics include high speed satellite RF crosslink, and high speed optical downlink.
Goals include high satellite crosslink data capacity, successful data relay through multiple satellite nodes, and low latency data relay through the network.

Current TRL

7

TRL By May 2021

9

Industry State of the Art Technology

Immediate:
-First to deploy very high-gain antenna on a nanosatellite platform to enable duplex LEO operations
-First to demonstrate high-speed commercial laser downlink, surmounting many technical barriers
-First to establish high-data rate commercial nanosatellite relay communication
Long Term:
-First relay network to allow widely economically feasible satellite downlink capacity and latency services

Technology Development Challenges to Meet TRL

Identification and access to ideal orbits allowing access to satellites in need of increased downlink capacity and lower downlink latency.
Relay satellite crosslinks capable of data-rates that meet remote sensing satellite needs.
Sufficient access to space to deploy a capable relay network.

Potential HPD Science Application (Optional)

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Contact Information

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Additional Comments

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Assumption: Technology required to be at TRL 5 by May 2021

analytical space

A LEO-Based Hybrid RF-Optical Data Relay Network

May 31, 2018

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Demand

Industry is demanding images with greater detail more frequently.

Capability

Modern apertures are capable of increasingly high spatial and spectral resolution.

Deficiency

RF downlink rates are much lower than imager data acquisition rates.

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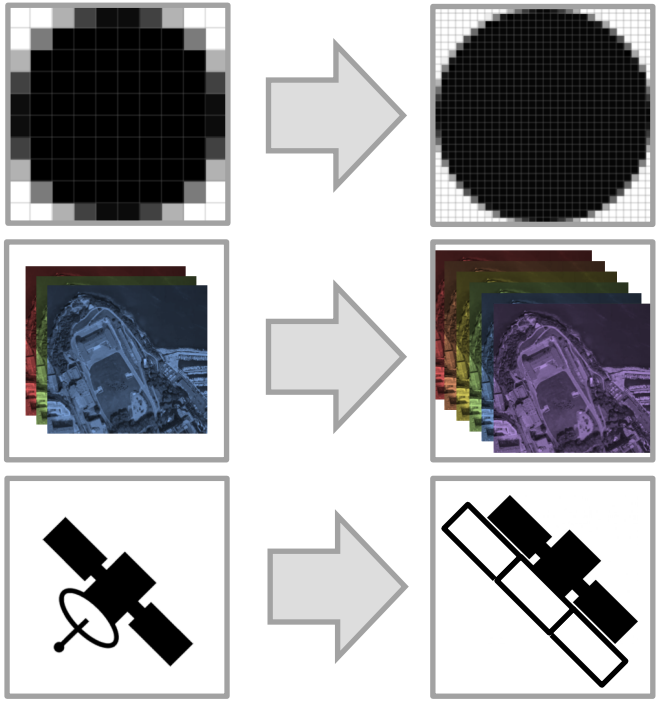
IMAGE DATA DENSITY

Remote sensing technologies acquire images that take up increasingly more data.



Higher Resolution

Hyperspectral Imaging

Large Deployable Radar Arrays

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INDUSTRY REQUIREMENTS

Modern image acquisitions are *massive*.

	Pixels Captured per Second	Spectral Bands	Dynamic Range	Uncompressed Data Generation Rate*
<30cm Optical Imager	8.0×10^7	8x	11 bits	**7,040 Mbps**
Small Satellite Imager	1.2×10^7	9x	11 bits	**1,200 Mbps**
iPhone 8	1.2×10^7	R,G,B	10 bits	**360 Mbps**

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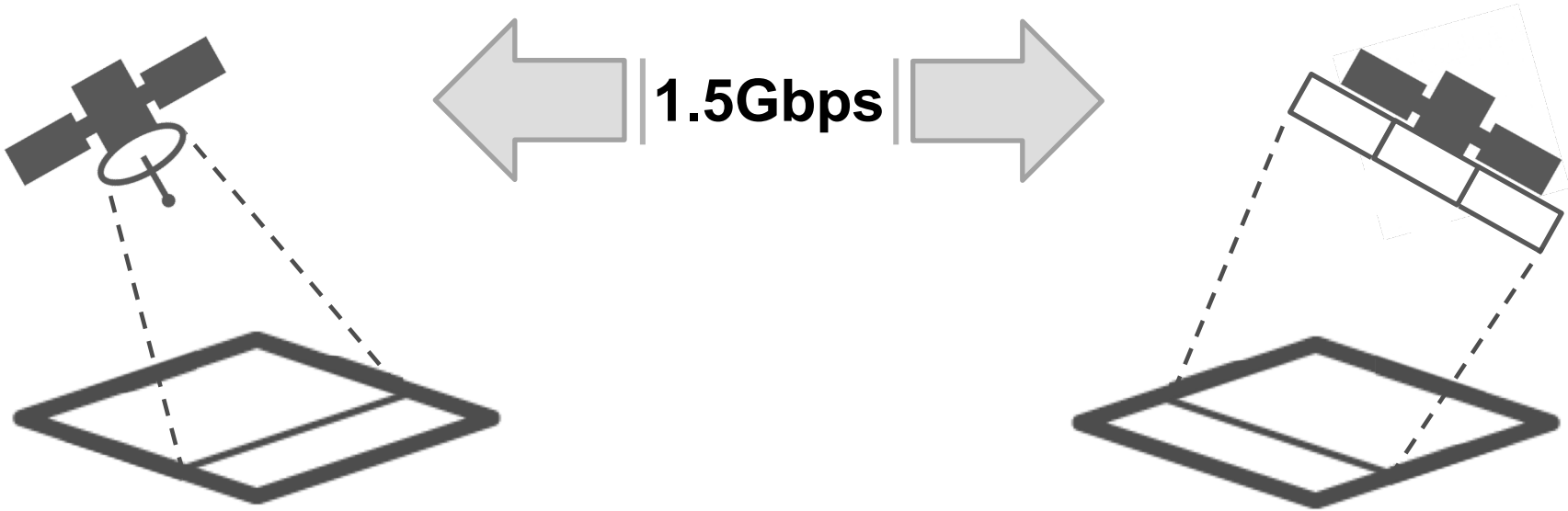
SAR DATA GENERATION

Both parabolic and planar array SAR satellites generate large amounts of data.



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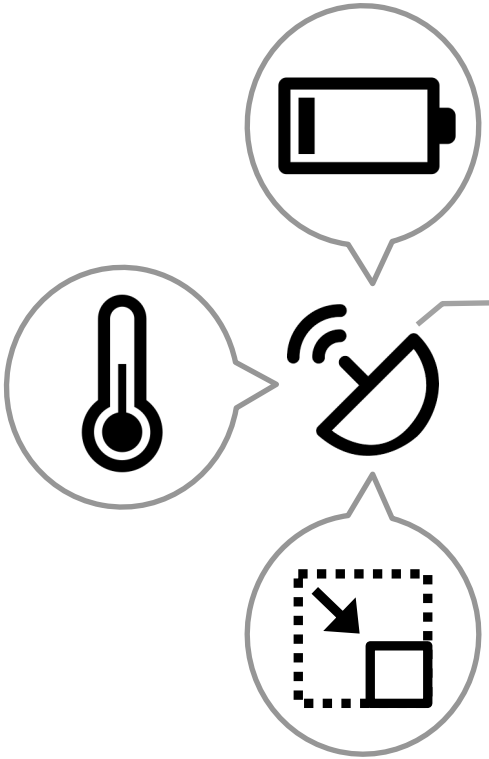
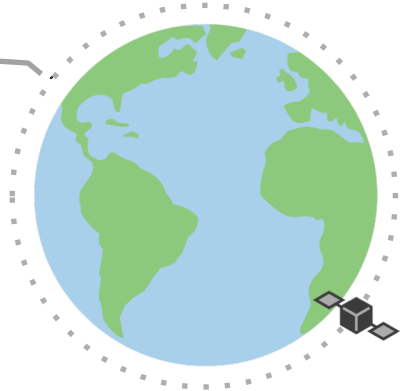
DOWNLINK LIMITATIONS

Orbital geometry and downlink radio technology hamper satellite offload capacity.



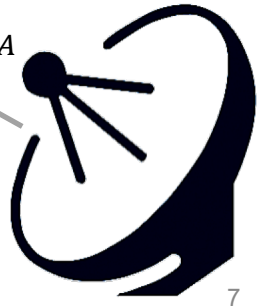
Limited ground station placement



Volume, power and thermal satellite constraints

$$G = \frac{4\pi \mathbf{A}}{\lambda^2} e_A$$

Limited satellite antenna dimensions caps gain



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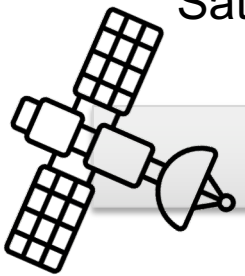
SATELLITE IMAGER THROTTLING

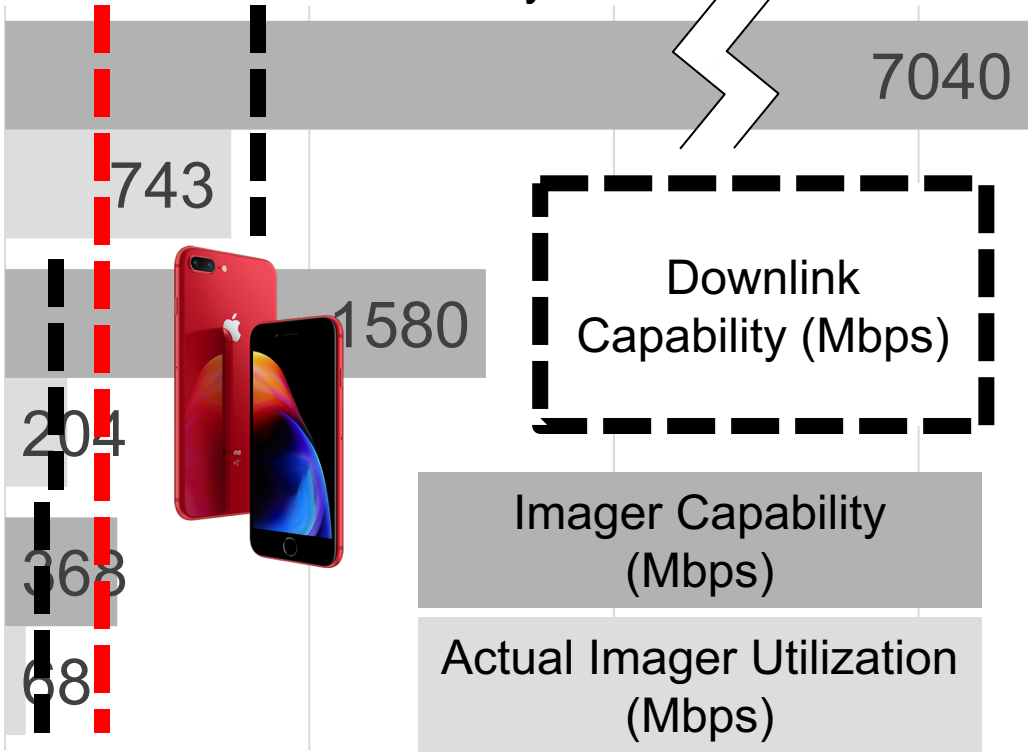
Satellites restrict their imagers to match their downlink systems.



>2000kg EO Satellite (2016)

<10kg EO Satellite (2017)

<200kg EO Satellite (2008)



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How do we address this problem?

A LEO Relay Network!

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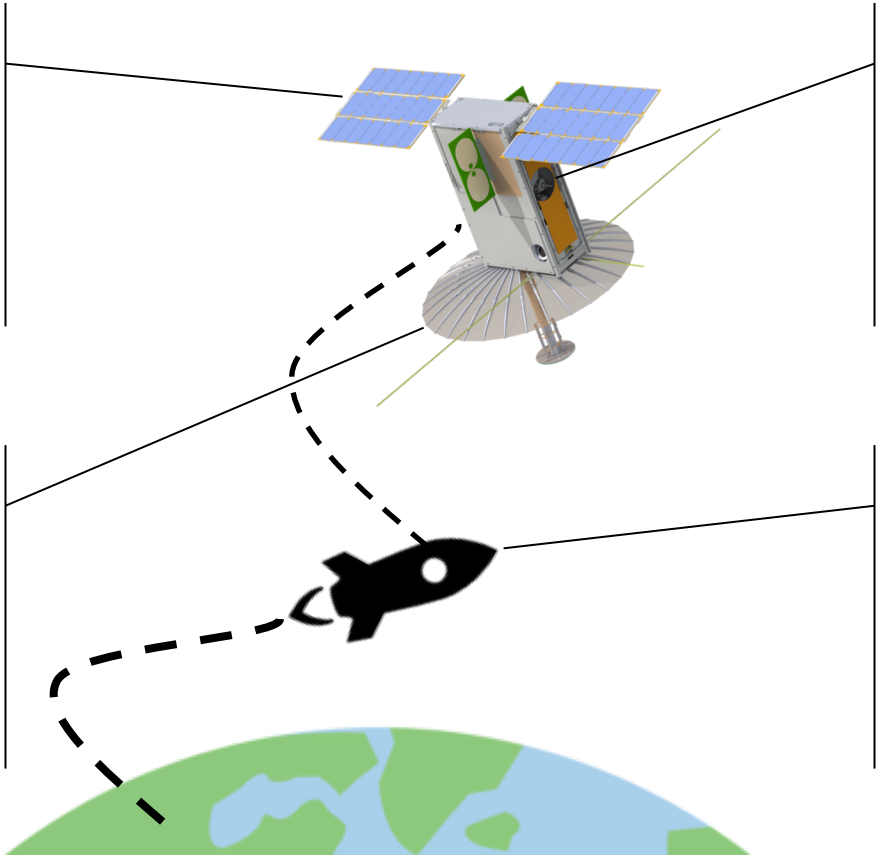
LEO RELAY ENABLING TECHNOLOGIES

Low-cost nanosatellite subsystems



Laser downlink system

High-gain dual-band antenna

Affordable access to space

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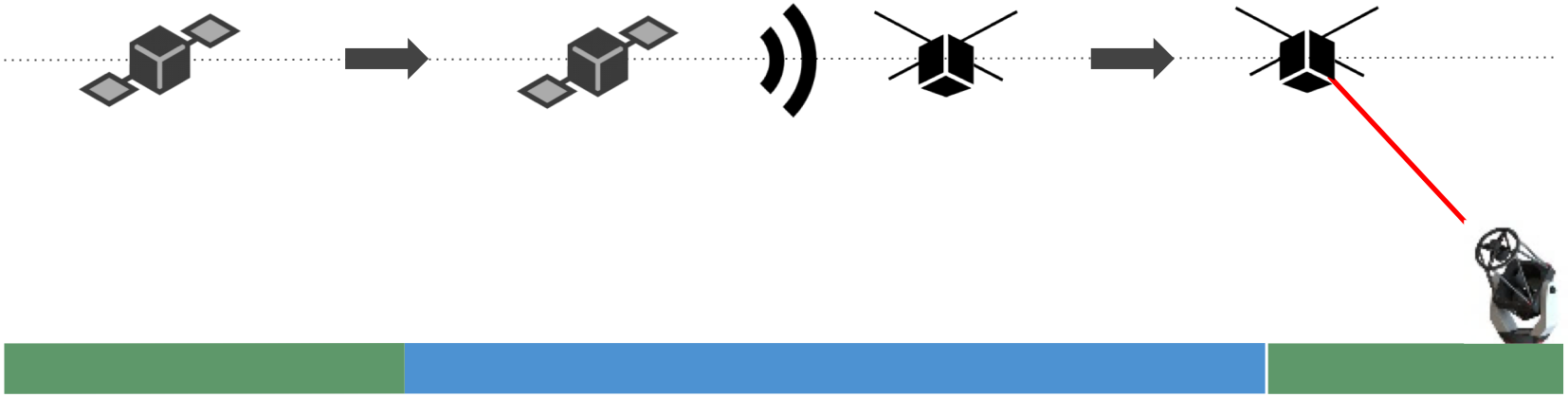
THE SOLUTION – OPTICAL SMALLSAT DATA RELAY

1 EO satellite **images** while over land

2 EO satellite **crosslinks** to co-orbital relay satellite over the ocean

3 Relay satellite **downlinks optically** over land



Land
30% of Earth's Surface

Ocean
70% of Earth's Surface

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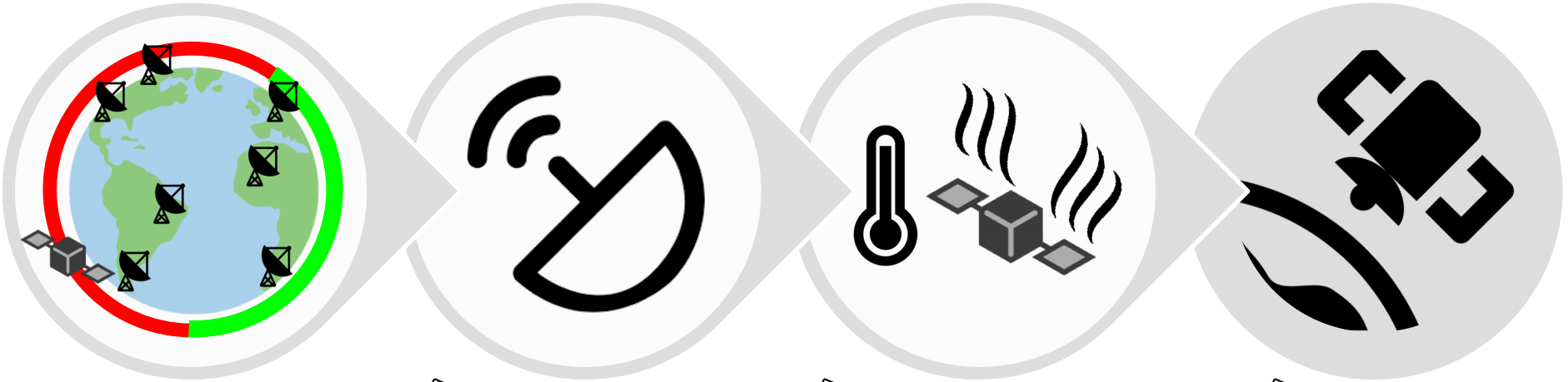
CURRENT SATELLITE DOWNLINK CAPACITY



30%
Ground Station Access per Orbit

×

800Mbps

200Mbps

×

100% Downlink*

56% Image
44% Downlink*

=

1.4Tb/orbit

150Gb/orbit

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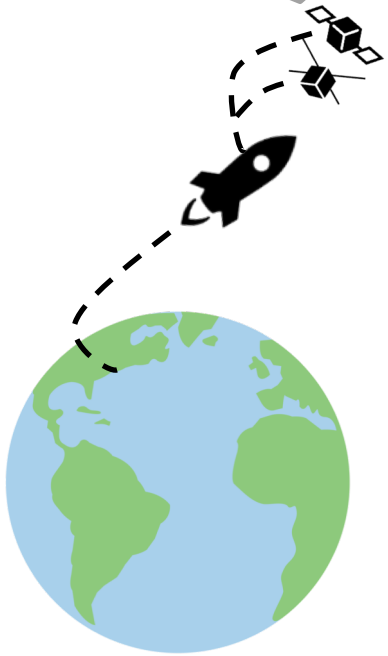
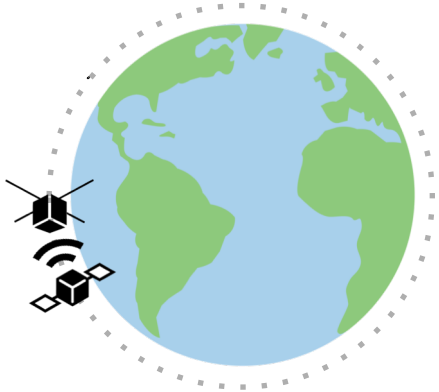
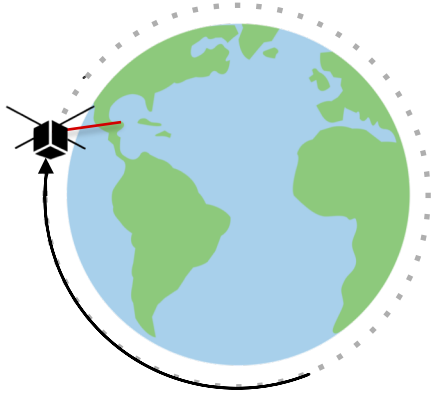
DATA RELAY IMPACT – IDEAL CO-DEPLOYMENT

EO satellite deploys with relay satellite into the same orbit



Satellites crosslink over oceans – time previously spent idle





Relay satellite stores data then quickly and economically downlinks over land

810Gb/orbit*
***58%* Additional Capacity**

650Gb/orbit*
***435%* Additional Capacity**

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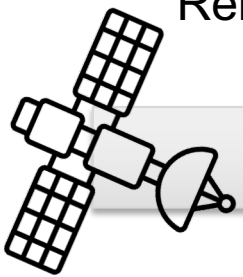
RELAY NETWORK IMPACT

Relay networks can massively increase downlink capacity.



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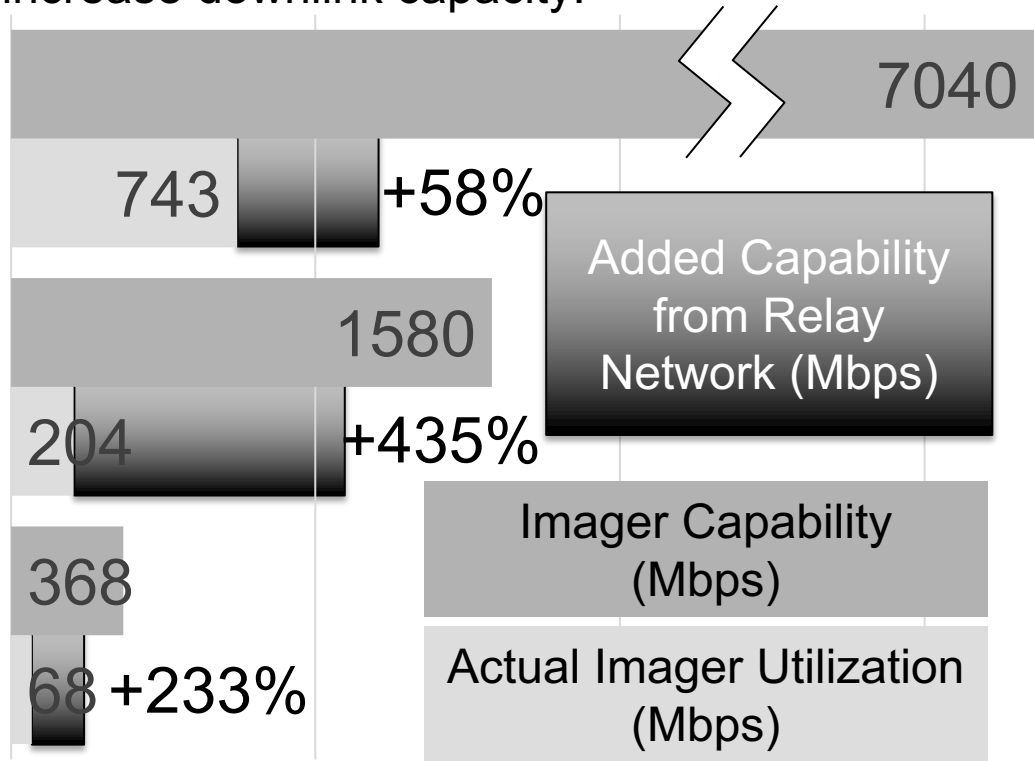

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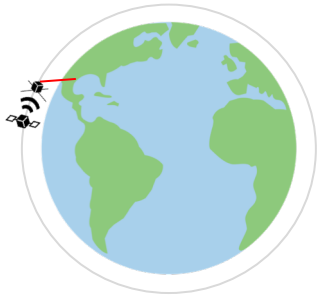
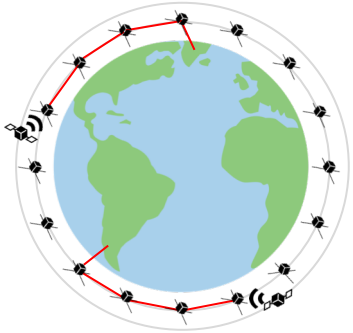
DATA RELAY IMPACT – EXTENDED NETWORK

	Single Satellite Co-Deployment	Single Satellite Lower Altitude | Matched LTAN	Partial Orbital Plane Lower Altitude | Matched LTAN	Full Orbital Plane Lower Altitude | Matched LTAN
				
Additional Downlink Capacity per Orbit	**810Gb/orbit** ***58% Additional Capacity***	**10Gb/orbit** ***1% Additional Capacity***	**51Gb/orbit** ***4% Additional Capacity***	**230Gb/orbit** ***11% Additional Capacity***
	650Gb/orbit ***435% Additional Capacity***	**1.4Gb/orbit** ***1% Additional Capacity***	**7.8Gb/orbit** ***5% Additional Capacity***	**23Gb/orbit** ***15% Additional Capacity***

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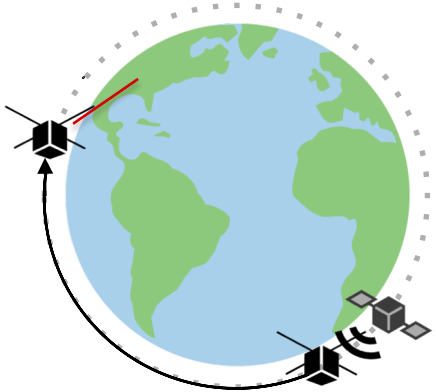
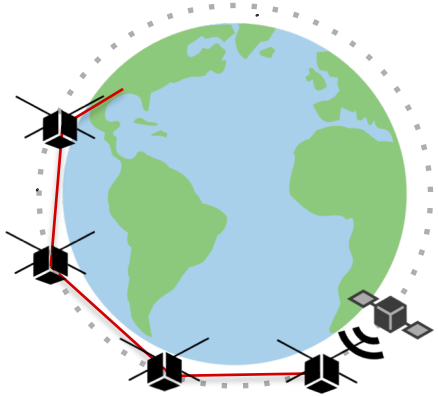
SCALED NETWORK BENEFITS

Phase 1: Store & Forward



- Dedicated, co-orbital
- Dual S/X-Band cross-link
- Optical data downlink

Phase 2: Low-latency Routing



- RF or Optical cross-link
- Networked cross-links
- Optical data downlink

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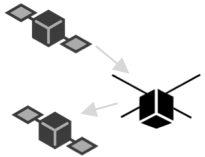
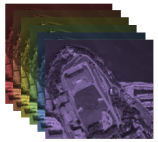
SCALED NETWORK CAPABILITIES

	Co-Orbital Satellites	Full Network
Greater Efficiencies	 Higher asset utilization	 Dynamic tasking
	 Smaller asset base	
New Capabilities	 More pixels, more spectral bands	Image ↓ Analysis Near-real-time data delivery

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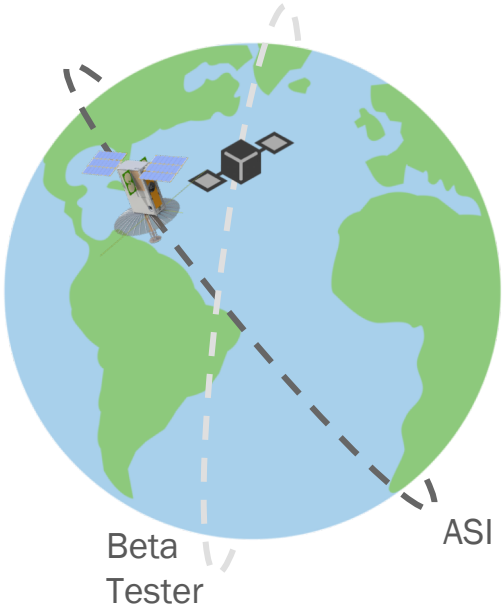
CURRENT BETA MISSION – MAY 2018

Single Satellite in ISS Orbit



Demonstrated Capabilities

Deployable Antenna
First to deploy very high-gain antenna on a nanosatellite platform to enable duplex LEO operations

Laser Downlink System
First to demonstrate high-speed commercial laser downlink, surmounting many technical barriers

Satellite Crosslink
First to establish high-data rate commercial nanosatellite relay communication

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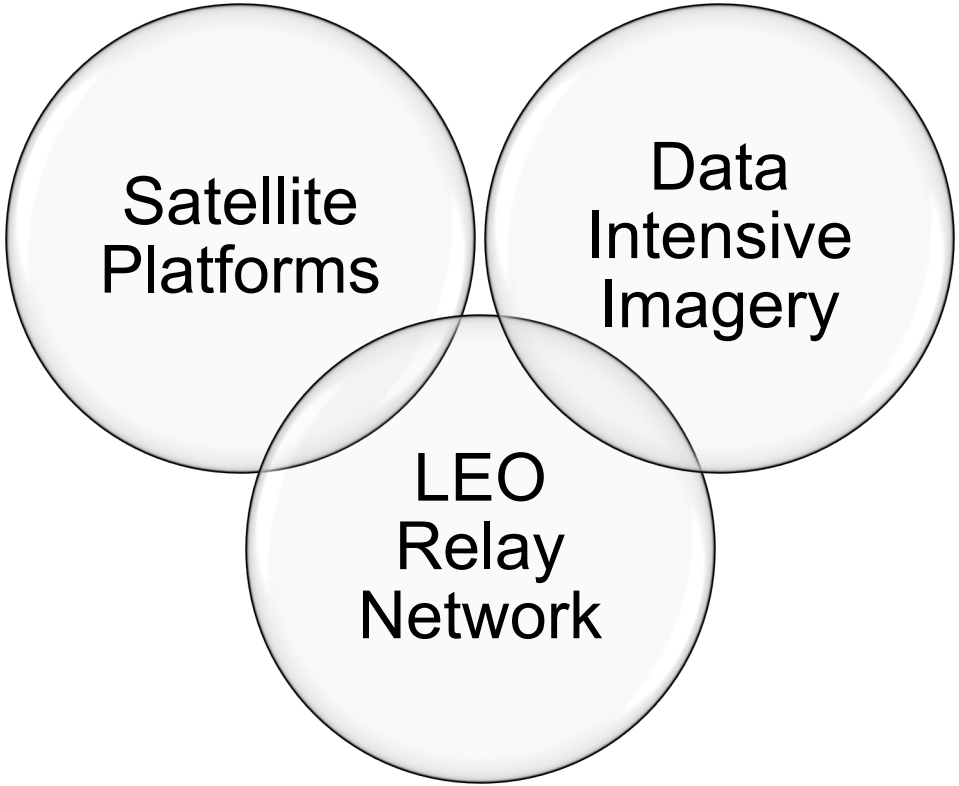

Earth Observation is on the cusp of reaching new heights – relay networks will allow us to realize this potential.

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