National Aeronautics and Space Administration

NASA

ESC Exploration & SPACE Communications

More than you ever imagined...

Sharing the NASA Experience

Dr. Obadiah Kegege

Exploration and Space Communications - Near Earth Network

Outline

- Introduction
  - About Speaker's Work Experience
  - Overview of NASA, Goddard Space Flight Center
- Space Communications and Navigation
  - Near Earth Network
  - Space Network
  - Deep Space Network
- Basics of Space Communication
- Future of Space Communication
- Student Information
  - Internship and Co-op information
- References and Acknowledgements

Engineering / R&D to Project Management

- 8 years of engineering experience in industry before NASA

2009 – 2016 at NASA

Proposals:

- Integrated LCRD LEO (Low-Earth Orbit) User Modem and Amplifier (ILLUMA)
- Pre-Aerosol, Clouds and oceans Ecosystem (PACE)

R&D Projects:

- Ka-Band Atmospheric /RF Propagation Studies
- Co-I, Integrated Solar-Panel Antenna Array
- Co-I, SmallSat Common Electronics Board
- Co-I, X-band Communication System Demonstration
- Co-I, Optimum Space-to-Ground Communication Concept for CubeSat and SmallSat Platforms

Flight/Ground System Projects :

- Compatibility Test Set (CTS) – S and Ka Band TDRS Relay Development
- SCAN Testbed - APS Development

2016-2018

Work Assignment:

1. DPM - Ocean Color Instrument – PACE mission
2. PM - Near Earth Network (NEN) Antenna Arraying

Work Experience –SCAN Testbed Project

SCaN Testbed Antenna Pointing System Development:

- Served as Radio Frequency (RF)/ Communication Systems Engineer
- Developed the Antenna Pointing System (APS) for the SCaN Testbed to track Tracking and Data Relay Satellite (TDRS) under varying conditions
  - Requirements definition
  - Hardware and software development
  - Integration and testing
  - Verification and validation.

SCAN Testbed

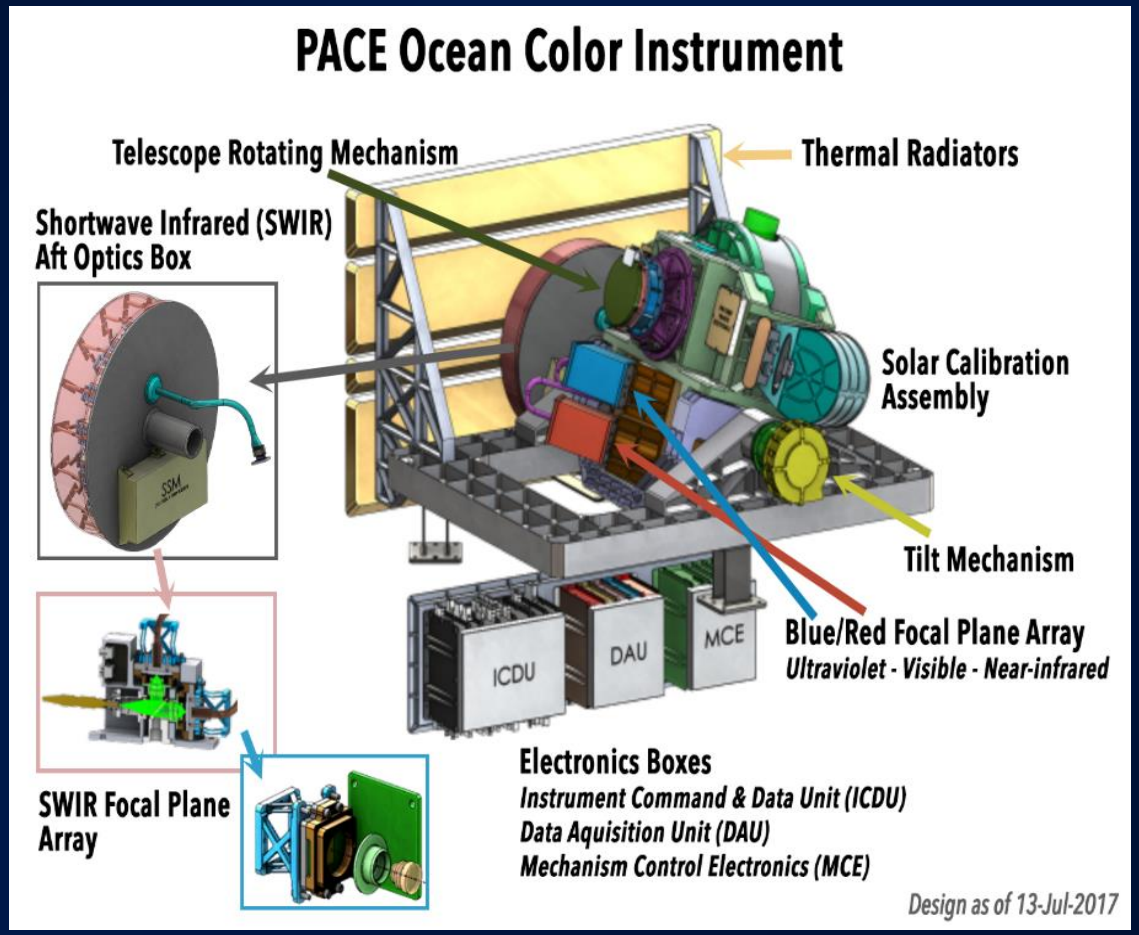
SCAN Testbed on International Space Station

https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_scantestbed.html

Work Experience - OCI Project

Technical Management Role:

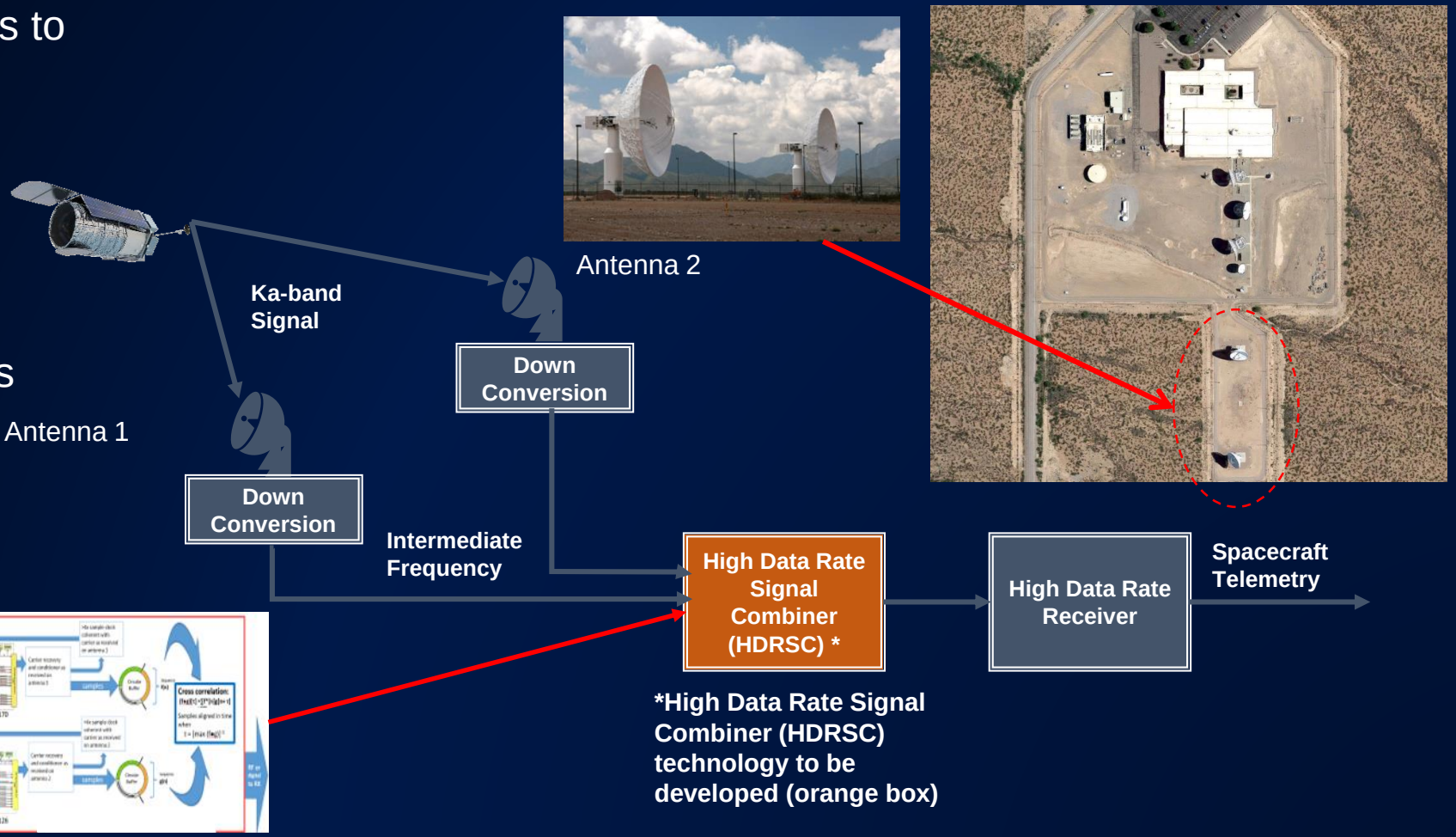
- Project planning
- Evaluating systems architecture studies, and design
- Oversight of flight instrument development activities
- Evaluating cost and schedule performance
- Technical reviews: SRR, KDP-B
- Risk management
- Export control



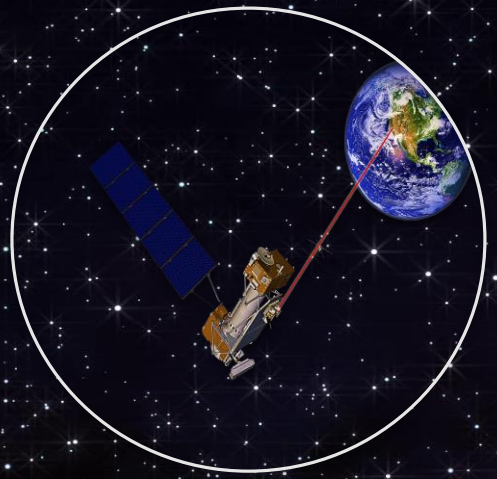
https://pace.oceansciences.org/oci.htm

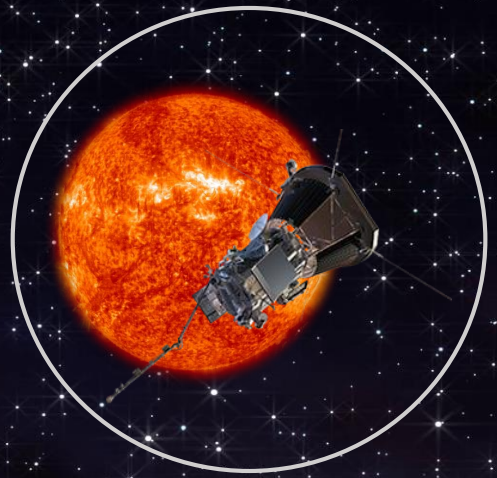
Work Experience – Near Earth Network Antenna Arraying

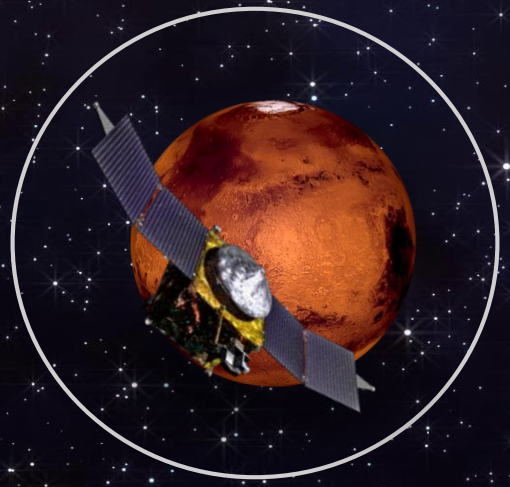
- Combine multiple signal inputs to improve gain performance at data rates up to, and beyond, 600 Mbps
  - Provide the NEN with a **critical capability** for supporting high data volume cis-lunar missions

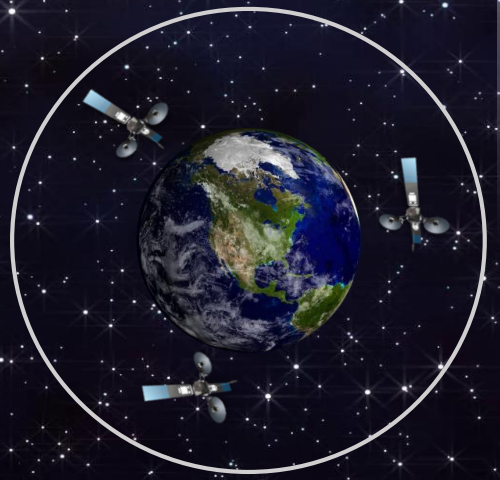


NASA Missons







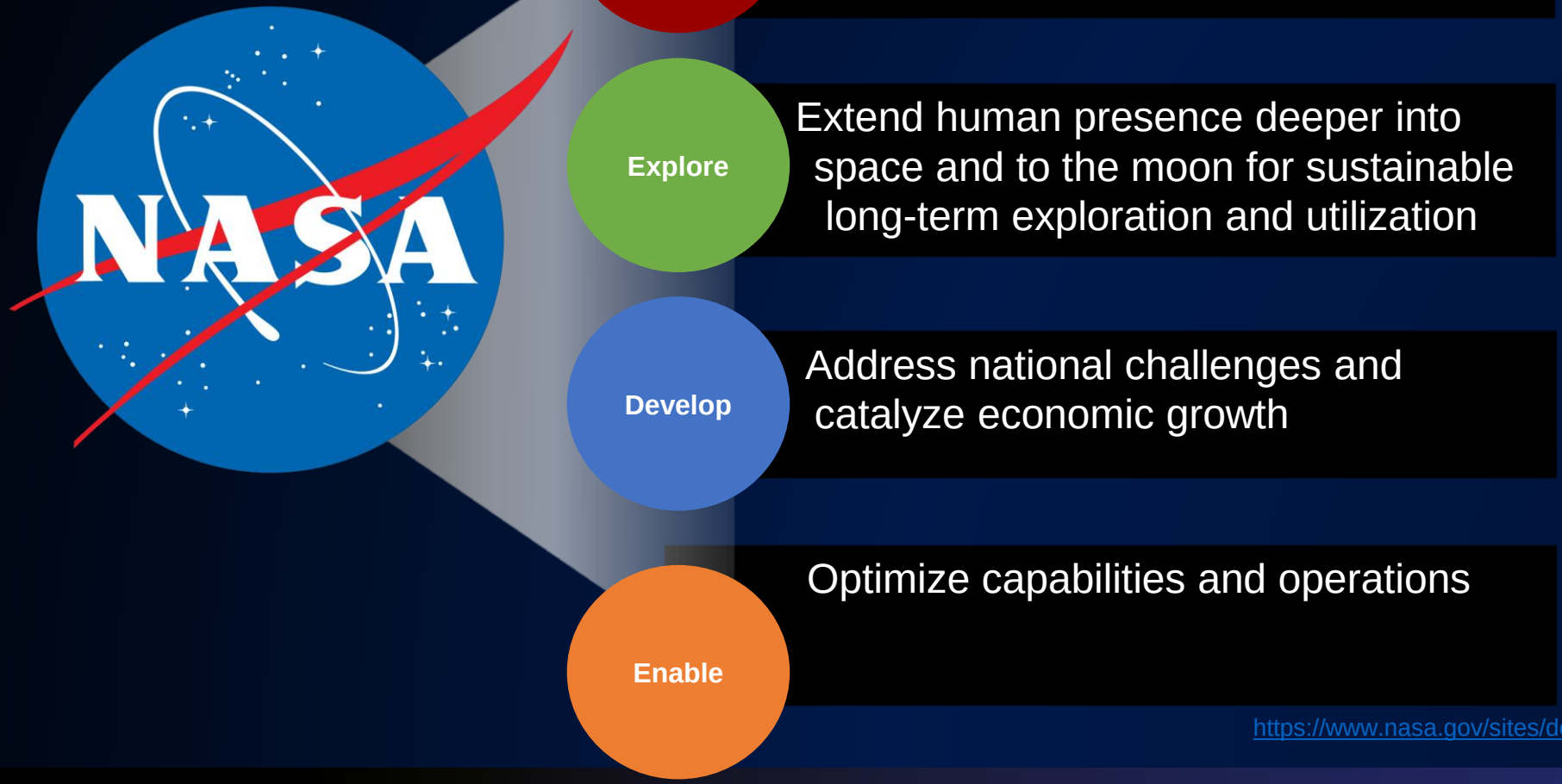


Helpful Links

- http://www.nasa.gov/about/
- http://www.nasa.gov/missions/

NASA 2018 Strategic Plan

Vision: To Discover and Expand Knowledge for the Benefit of Humanity



https://www.nasa.gov/sites/default/files/atoms/files/nasa_2018_strategic_plan.pdf

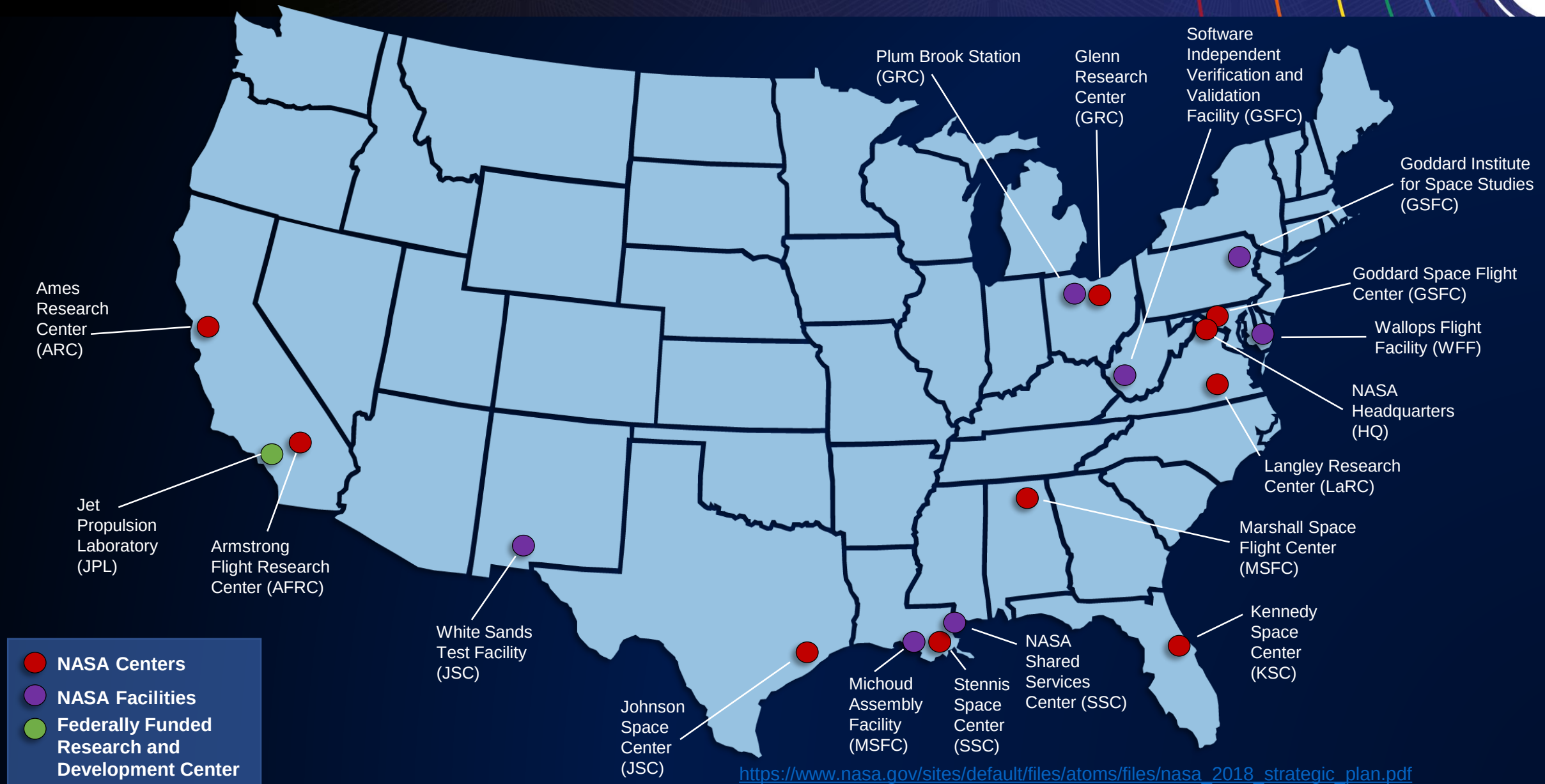
NASA's 2018 Strategic Plan

STRATEGIC GOAL 3: ADDRESS NATIONAL CHALLENGES AND CATALYZE ECONOMIC GROWTH

- **Strategic Objective 3.3:**
  Inspire and Engage the Public in Aeronautics, Space, and Science.
  - Inspire, engage, educate, and employ the next generation of explorers through NASA-unique Science, Technology, Engineering and Mathematics learning opportunities.
- **Performance Goal 3.3.3:**
  Provide opportunities for learners to engage with NASA's aeronautics, space, and science people, content, and facilities in support of a diverse future NASA and aerospace industry workforce.
- **Performance Goal 3.3.5:**
  Provide opportunities for learners to contribute to NASA's aeronautics, space, and science missions and work in exploration and discovery.

https://www.nasa.gov/sites/default/files/atoms/files/nasa_2018_strategic_plan.pdf

NASA Centers and Facilities



https://www.nasa.gov/sites/default/files/atoms/files/nasa_2018_strategic_plan.pdf

NASA Goddard Space Flight Center (GSFC)

http://www.nasa.gov/centers/goddard/home/installations.html

Independent Verification and Validation Facility, located in Fairmont, W.Va.

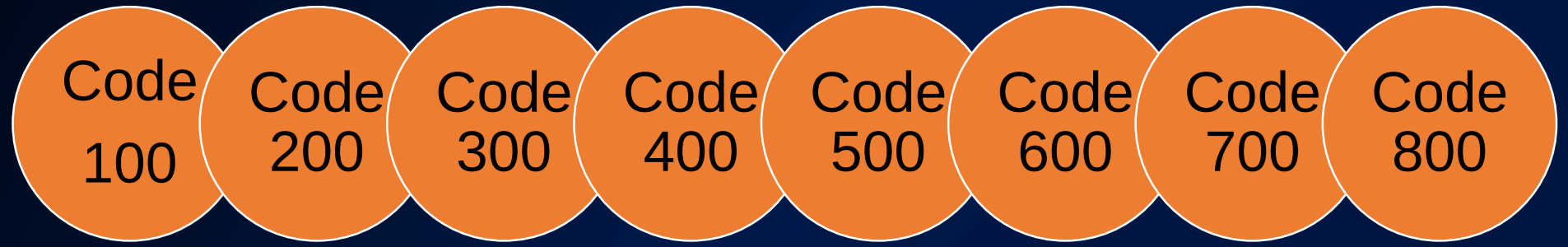
Goddard Institute for Space Studies, in New York City

White Sands Test Facility, located in San Andres Mountains outside Las Cruces, N.M.

Goddard Space Flight Center, main campus, located within Greenbelt, Md

Wallops Flight Facility, located on Virginia's Eastern Shore

NASA Goddard Space Flight Center (GSFC) Organizations and Projects



Office of the Director

Management Operations

Safety & Mission Assurance

Flight Projects

Engineering & Technology

Sciences & Exploration

IT & Communications

Suborbital & Special Orbital Projects

Open the link to view GSFC Organizations and Projects

- http://www.nasa.gov/centers/goddard/about/organizations/org2.html

Goddard Space Flight Center
Exploration and Space Communications

23

launches supported per year on average. Expected to double with increased HSF and CubeSat missions

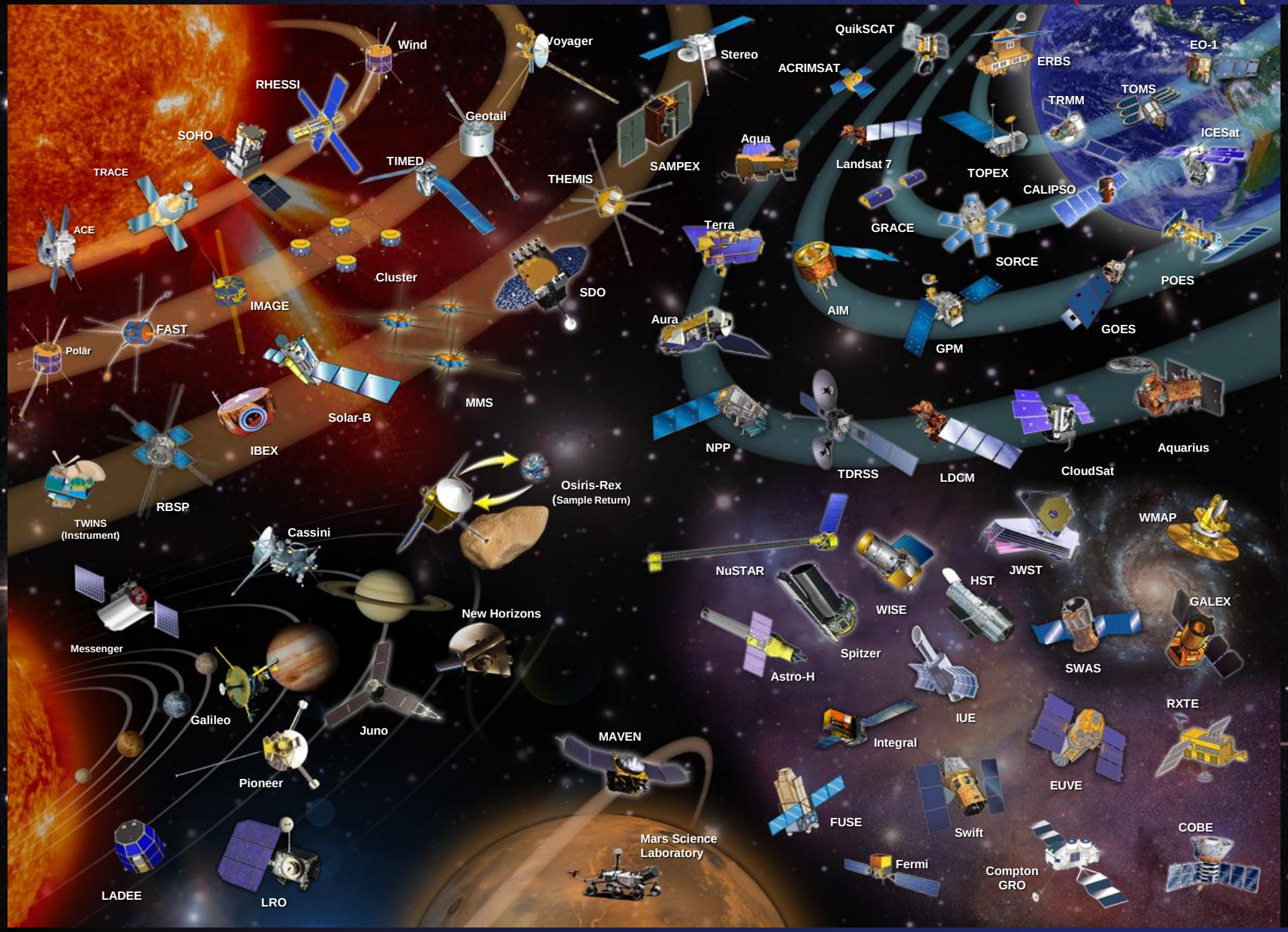
98%

of NASA data transmitted goes through Goddard each day as of July 2016.

1,200

Blu-ray disks worth of data $_{est.}$ equates to the volume that SN and NEN handle every day.

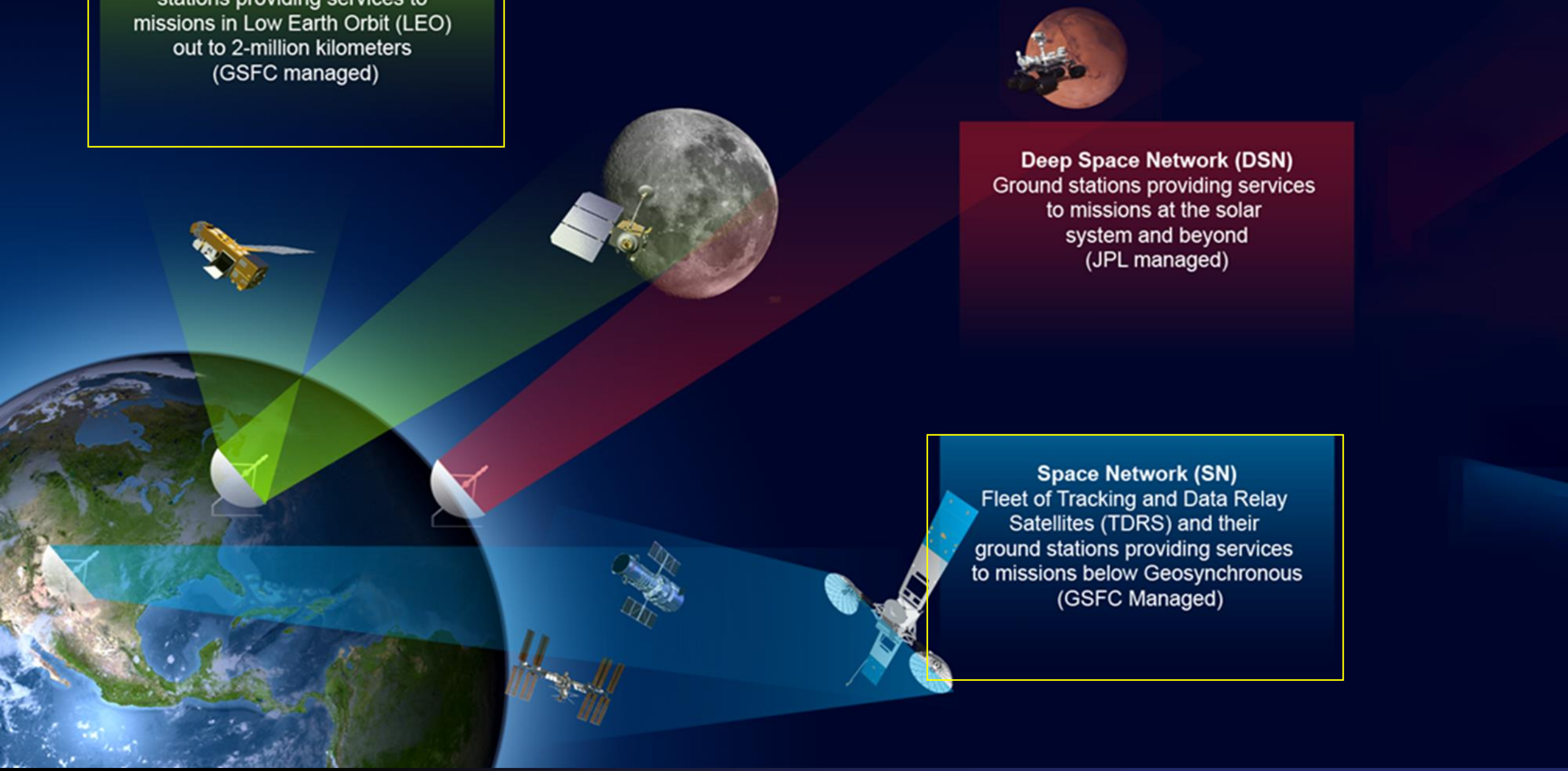
MISSIONS SUPPORT



NASA's COMMUNICATIONS NETWORKS

National Aeronautics and Space Administration

Near Earth Network (NEN)
NASA and commercial ground stations providing services to missions in Low Earth Orbit (LEO) out to 2-million kilometers (GSFC managed)

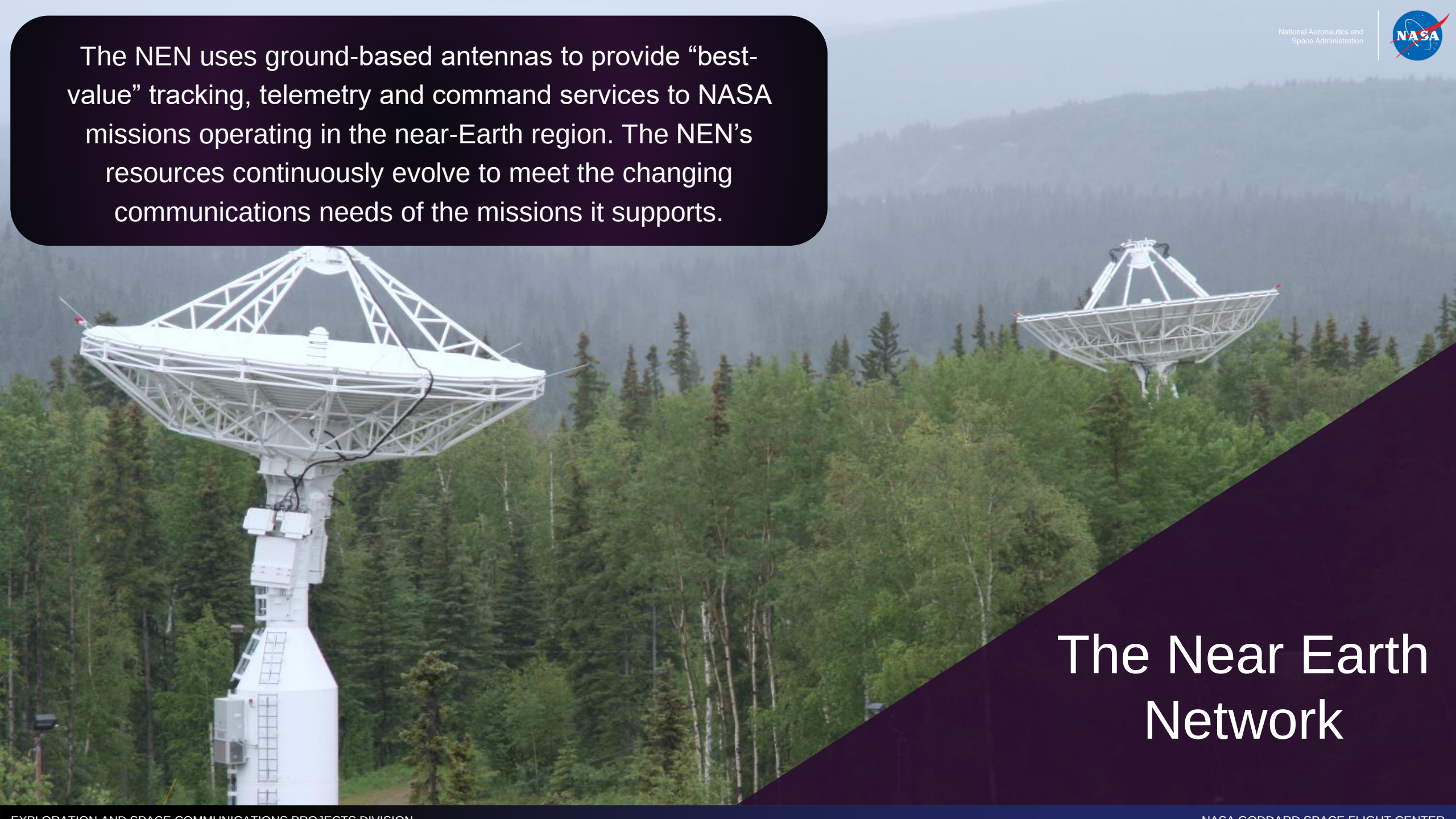


Deep Space Network (DSN)
Ground stations providing services to missions at the solar system and beyond (JPL managed)

Space Network (SN)
Fleet of Tracking and Data Relay Satellites (TDRS) and their ground stations providing services to missions below Geosynchronous (GSFC Managed)

National Aeronautics and Space Administration

The NEN uses ground-based antennas to provide “best-value” tracking, telemetry and command services to NASA missions operating in the near-Earth region. The NEN’s resources continuously evolve to meet the changing communications needs of the missions it supports.



The Near Earth Network

NEN Capabilities

- Polar-orbiting missions
- High data rates
- Data transmission to missions beyond LEO out to libation point

NASA owns a number of ground stations, such as those in Wallops Island, Virginia, and the Alaska Satellite Facility, but the network also contracts out coverage from commercial stations. Together, they comprise more than 20 sites covering more than 40 spacecraft.

National Aeronautics and Space Administration

NASA

Map of Near Earth Network Stations

Alaska Satellite Facility
Faribanks, Alaska

NOAA FCDAS Ground Station
Gilmore Creek, Alaska

SSC/USN Alaska
North Pole, Alaska

KSAT Svalbard Satellite Station
Svalbard, Norway

KSAT Singapore Satellite Station
Singapore

Swedish Space Corporation
Kiruna, Sweden

Wallops Ground Station
Wallops, Virginia

White Sands 1 Antenna
White Sands, New Mexico

Launch Communications Segment
Florida and Bermuda

SSC/USN Australia
Dongara, Australia

SSC/USN Hawaii
South Point, Hawaii

Swedish Space Corporation
Santiago, Chile

KSAT Troll Satellite Station
Troll, Antarctica

SANSA Ground Station
Hartebeesthoek, South Africa

McMurdo Ground Station
McMurdo Base, Antarctica

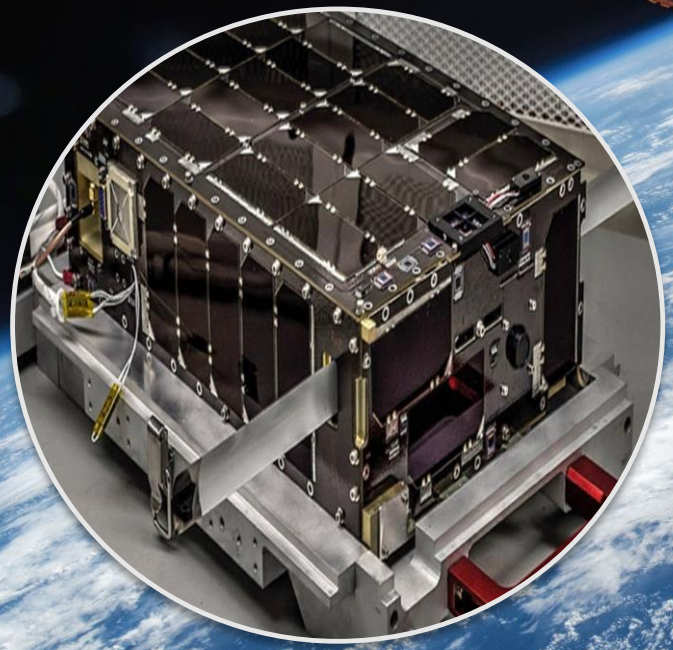
Near Earth Network: NASA

Near Earth Network: Partner

Near Earth Network: Commercial

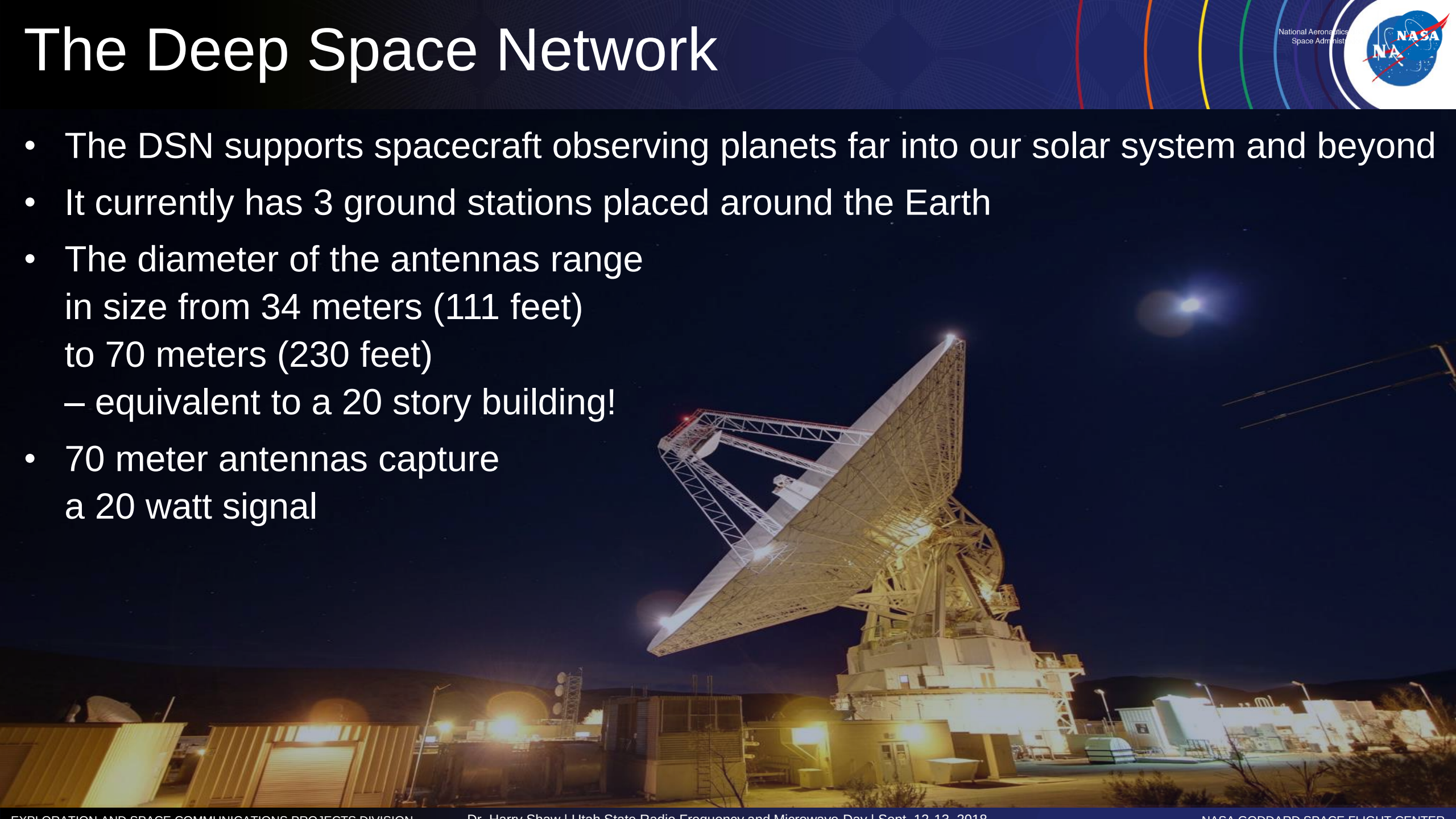
NASA’s CubeSats

CubeSats, also known as nanosatellites, offer a low-cost way to get science data from space. These missions typically last 90 days and are intended for small-scale research projects. NASA often partners with universities and schools to create some of these short-term research projects.

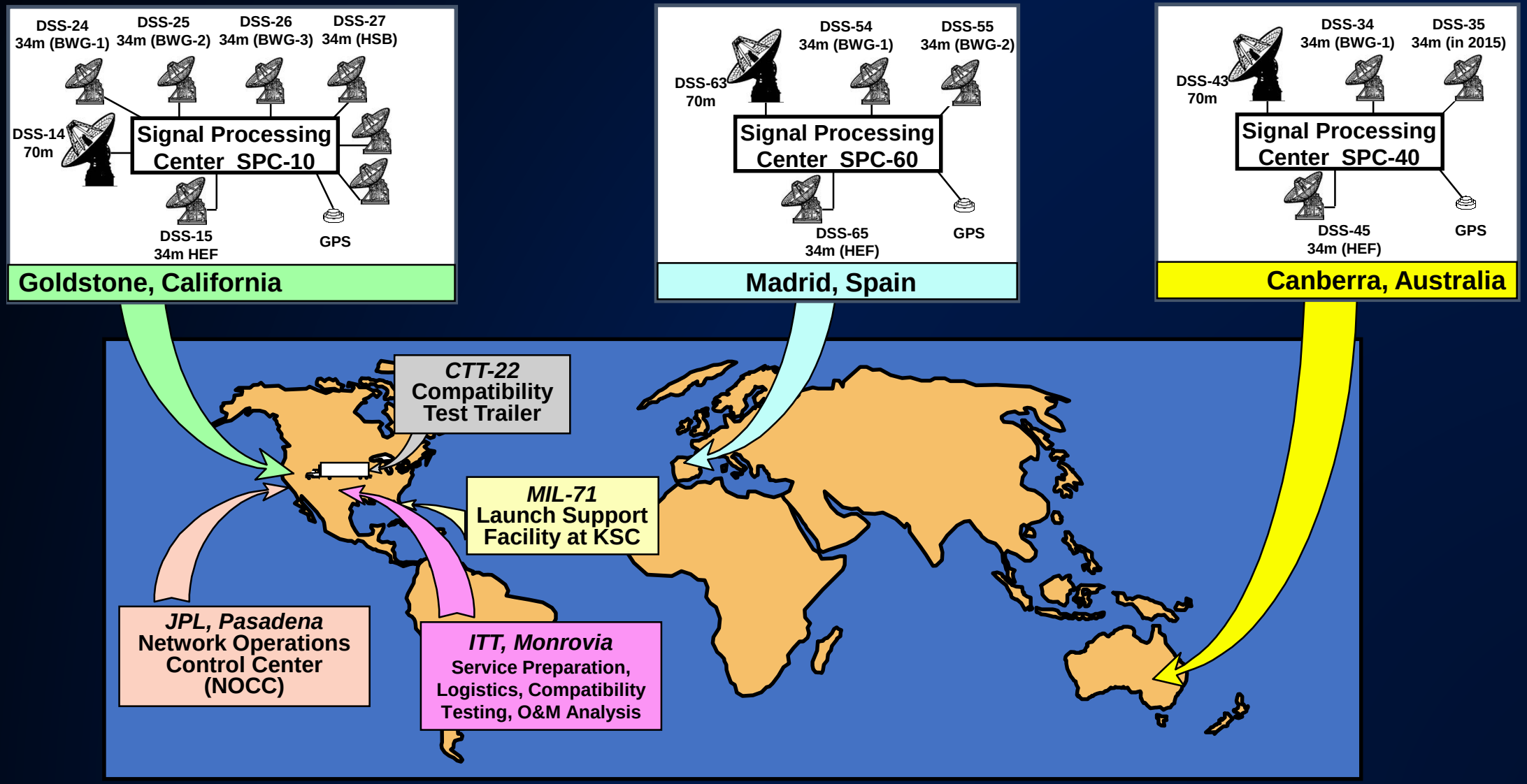


The Deep Space Network

- The DSN supports spacecraft observing planets far into our solar system and beyond
- It currently has 3 ground stations placed around the Earth
- The diameter of the antennas range in size from 34 meters (111 feet) to 70 meters (230 feet) – equivalent to a 20 story building!
- 70 meter antennas capture a 20 watt signal

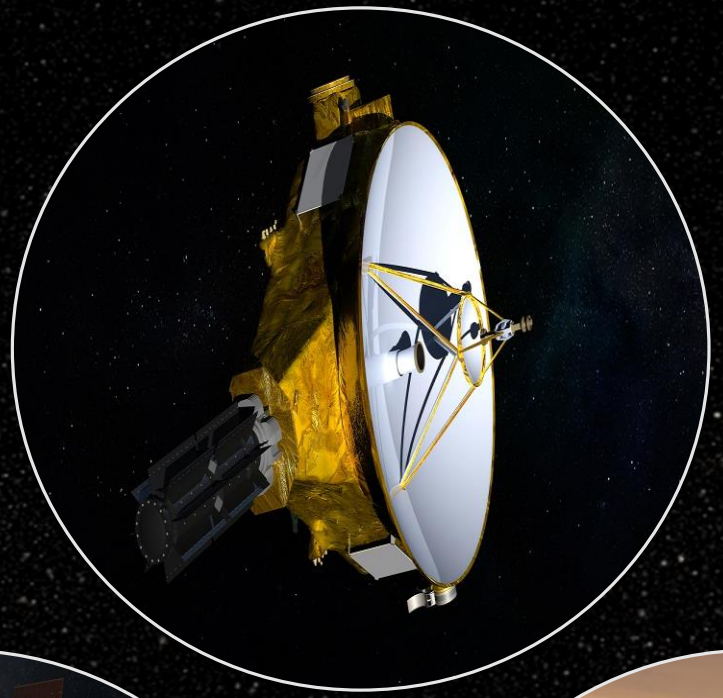


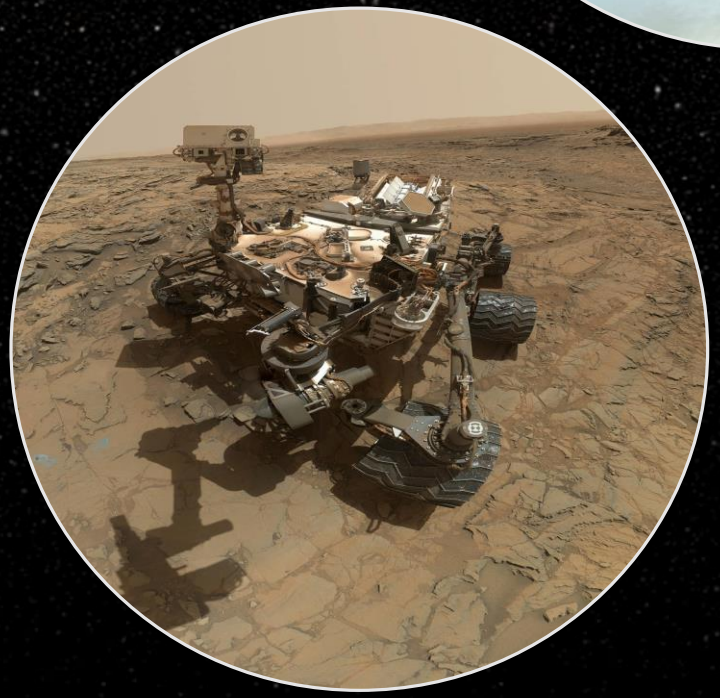
Deep Space Network Facilities

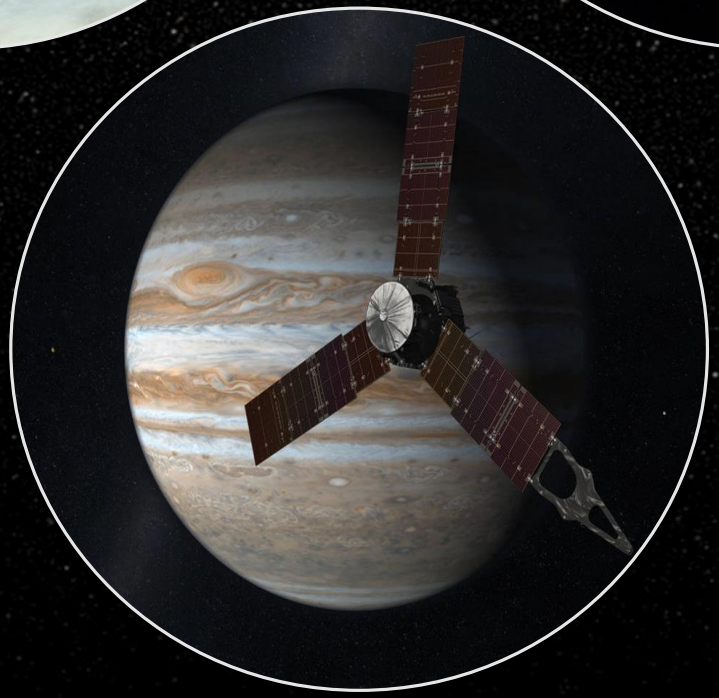


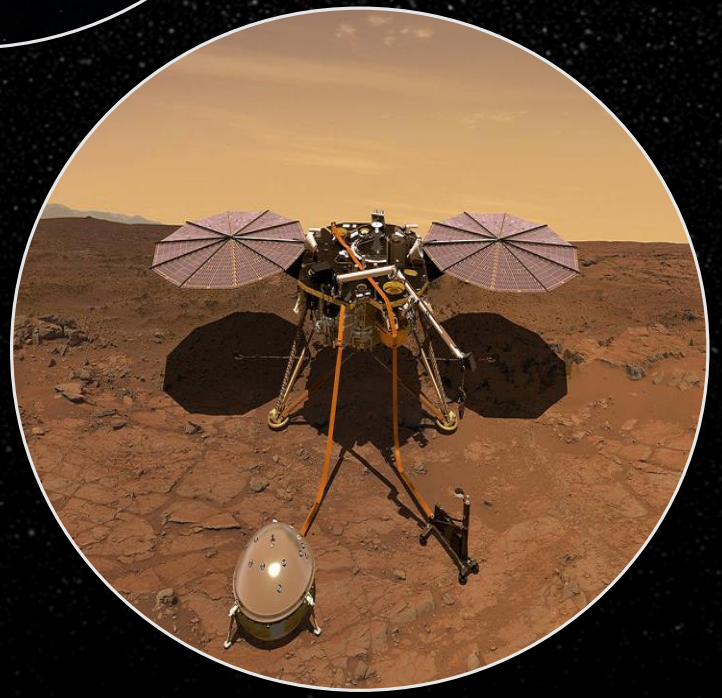
http://www.nasa.gov/sites/default/files/694635main_Pres_Public_University_Navarra_Astronaut_Robotic.pdf

Deep Space Customers



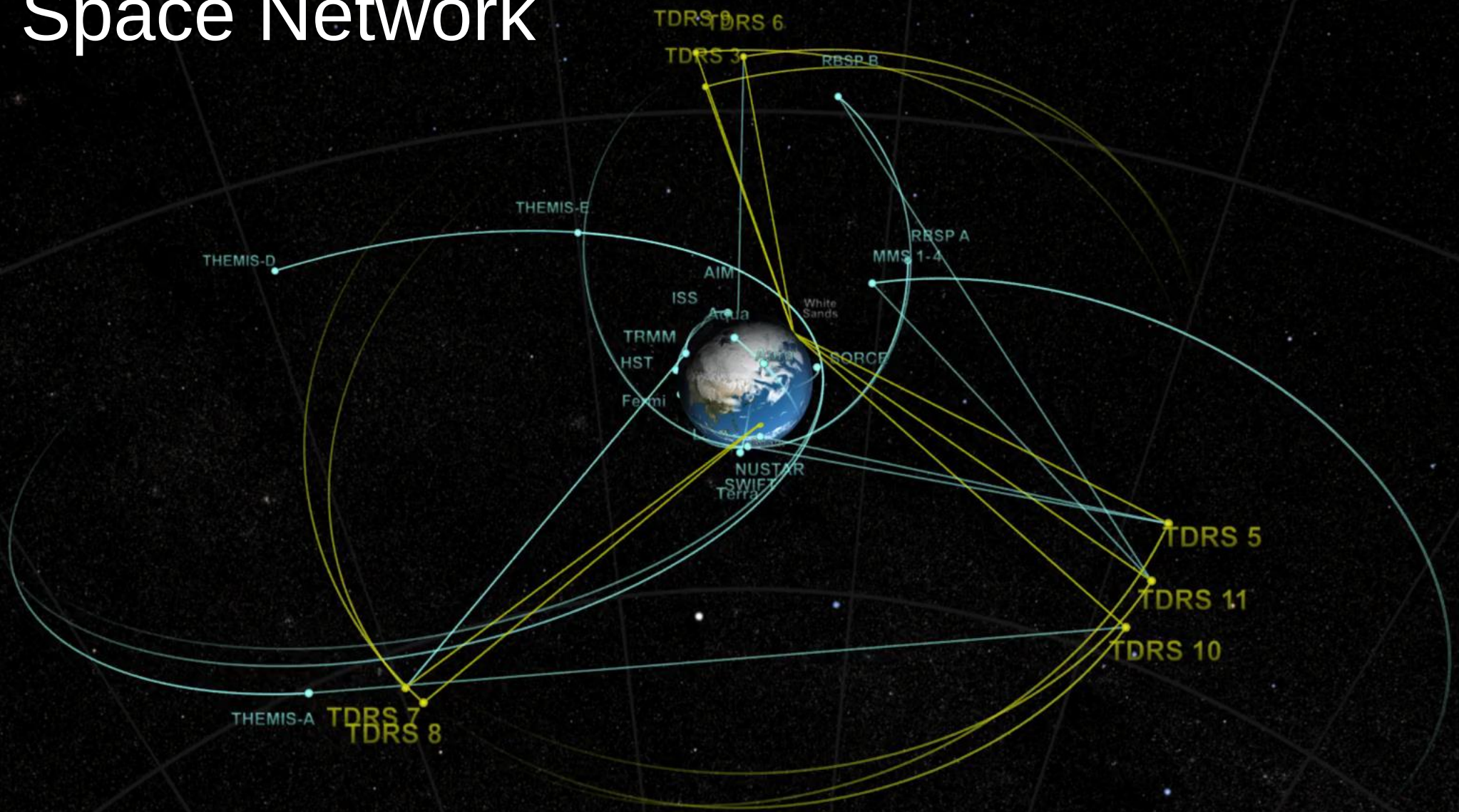






The Space Network

National Aeronautics and Space Administration



The TDRS Constellation

The Space Network

- The Space Network (SN) is a combination of national and international ground stations paired with NASA's Tracking and Data Relay Satellite (TDRS) fleet
- Currently, there are 10 TDRSs geosynchronously orbiting the Earth at 22,000 miles

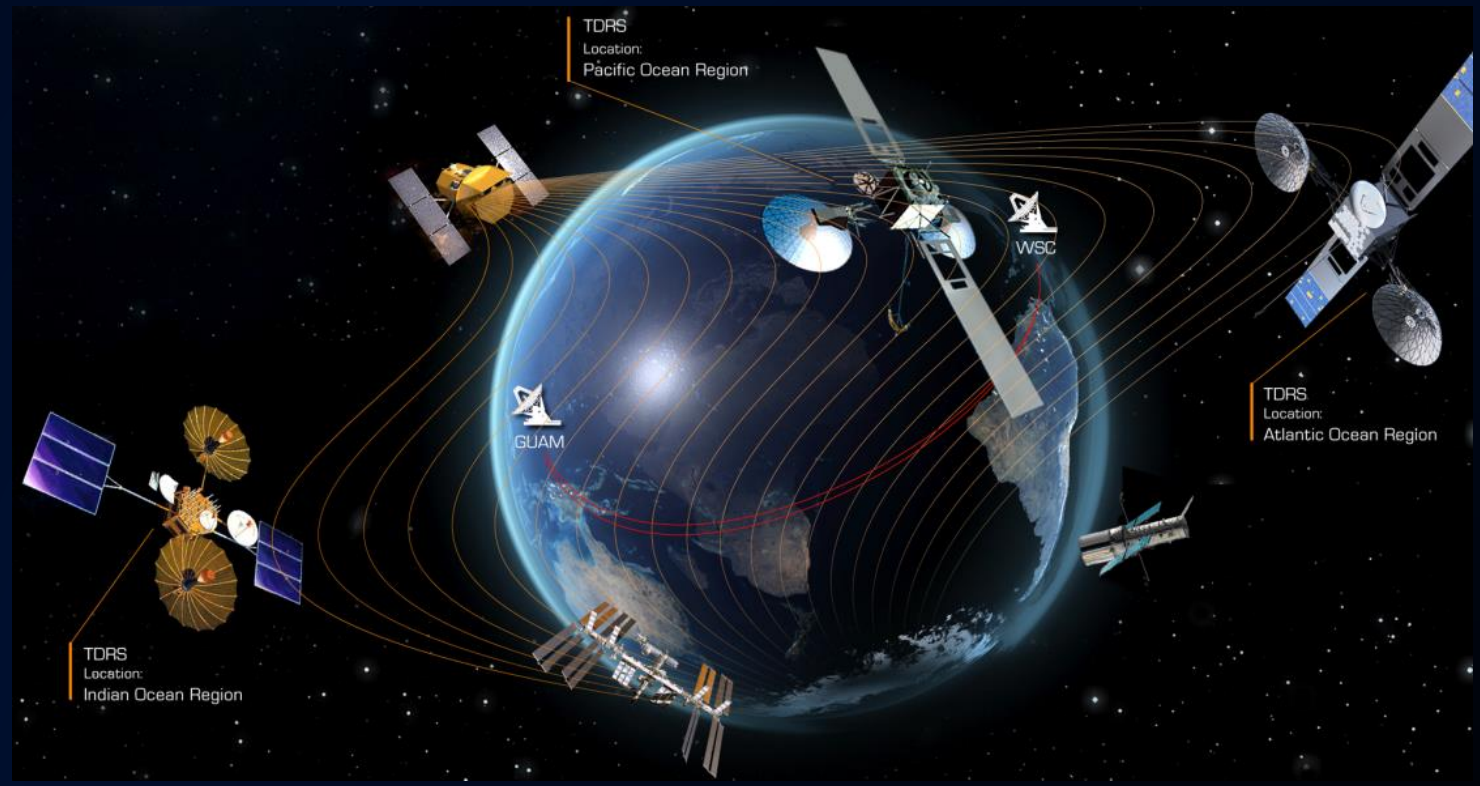
WSGT

GRGT

- Using radio frequency (RF) the SN is capable of transmitting to and receiving data from spacecraft with 100% coverage of the satellites orbit
- Data collected on user spacecraft is sent to a TDRS, which then downlinks the data to the White Sands Ground Terminal (WSGT) or the Guam Remote Ground Terminal (GRGT). This data is then sent to the customer.

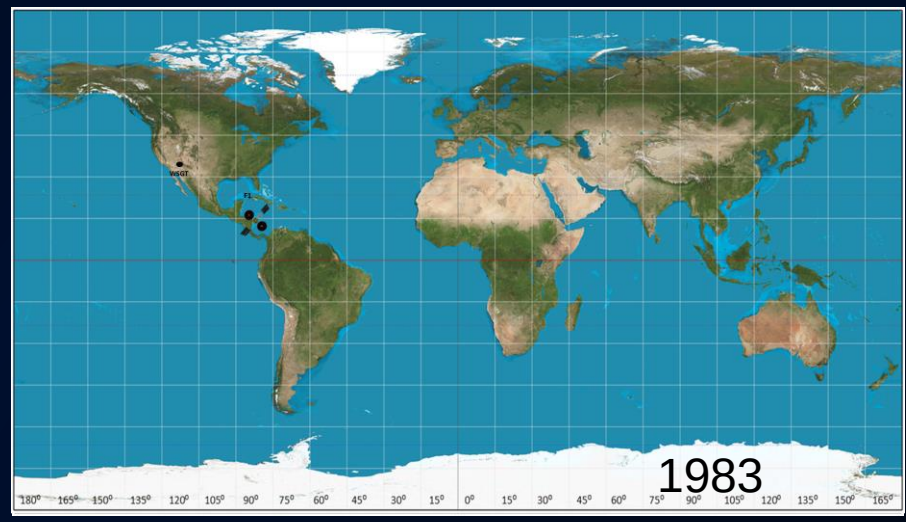
Space Network Capabilities

- S-band RF capabilities
- Increased transmission rates
- Coverage of 3 major oceanic regions
- The SN provides tracking and data acquisition services between low Earth orbiting (LEO) spacecraft and data processing facilities.
- The position, time and frequency data provided by the SN enables users to maintain precise spacecraft orbit prediction, orbit determination and attitude determination and control.

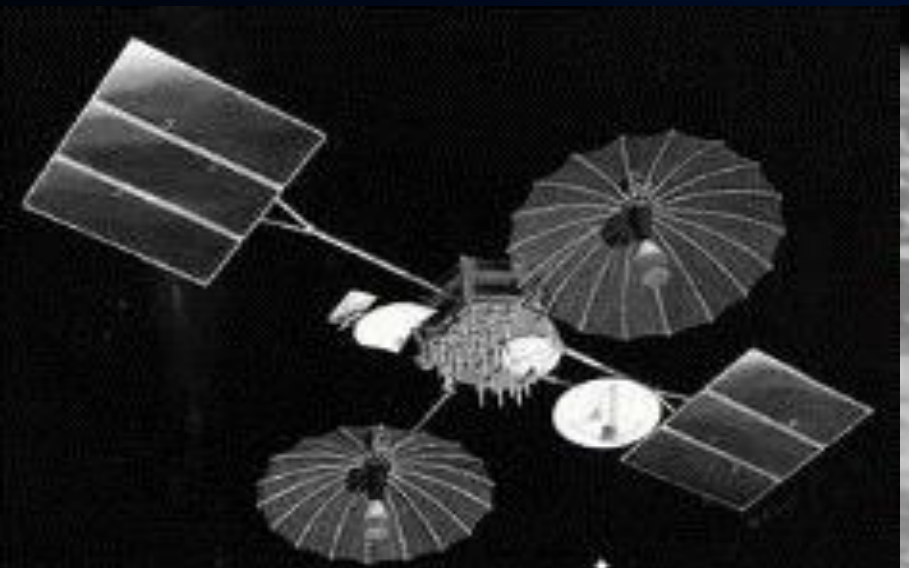


TDRS Replenishment

- The TDRS fleet is comprised of three generations
- There are 10 TDRSs currently in orbit
- New TDRSs are launched to:
  - Replenish outdated TDRSs in GEO
  - Support higher data rates
  - Enhance communications security



First Generation
TDRS-A to TDRS-G



Second Generation
TDRS-H to TDRS-J

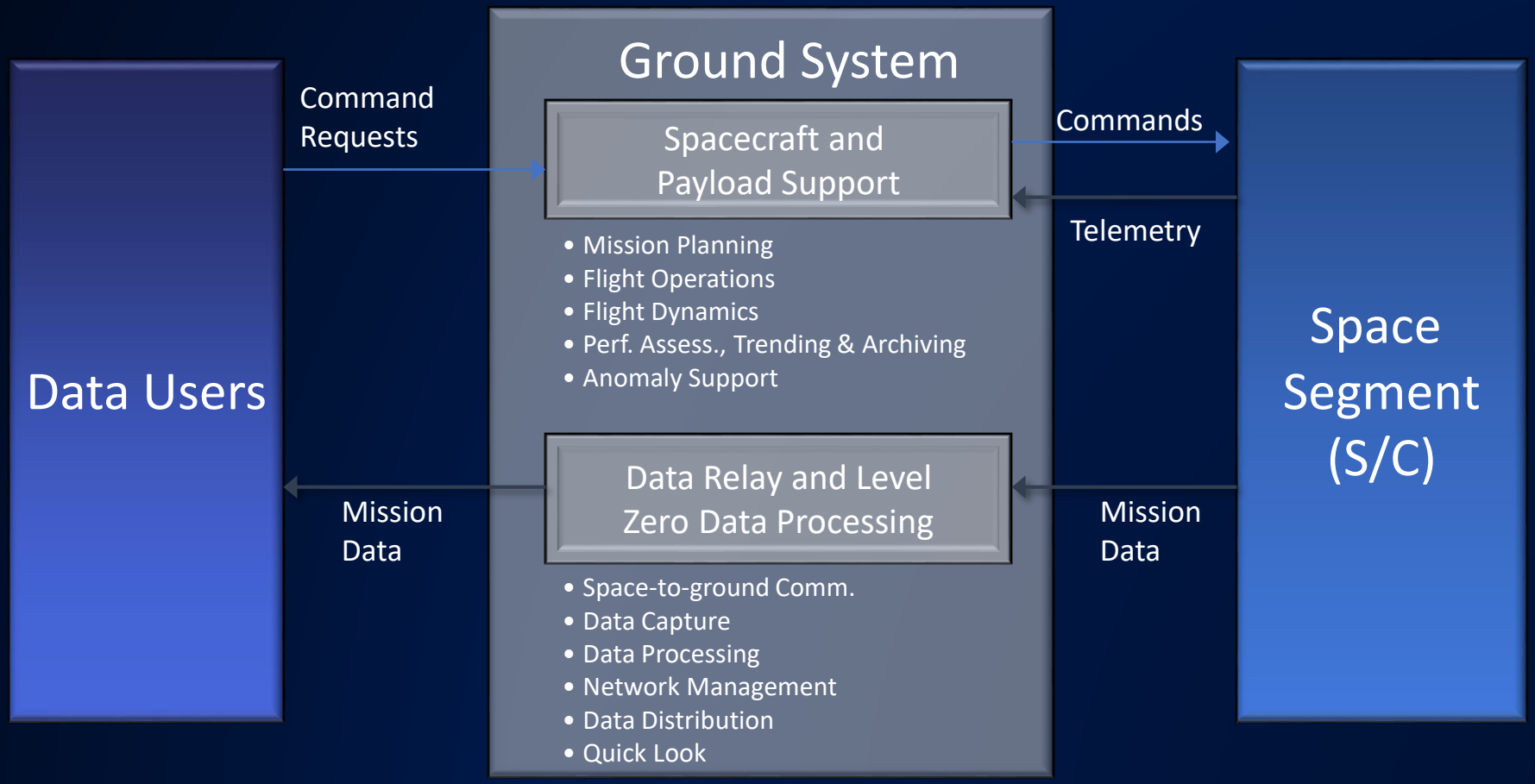
Third Generation
TDRS-K to TDRS-M

NASA Networks Span the Globe

Space Communication Basics

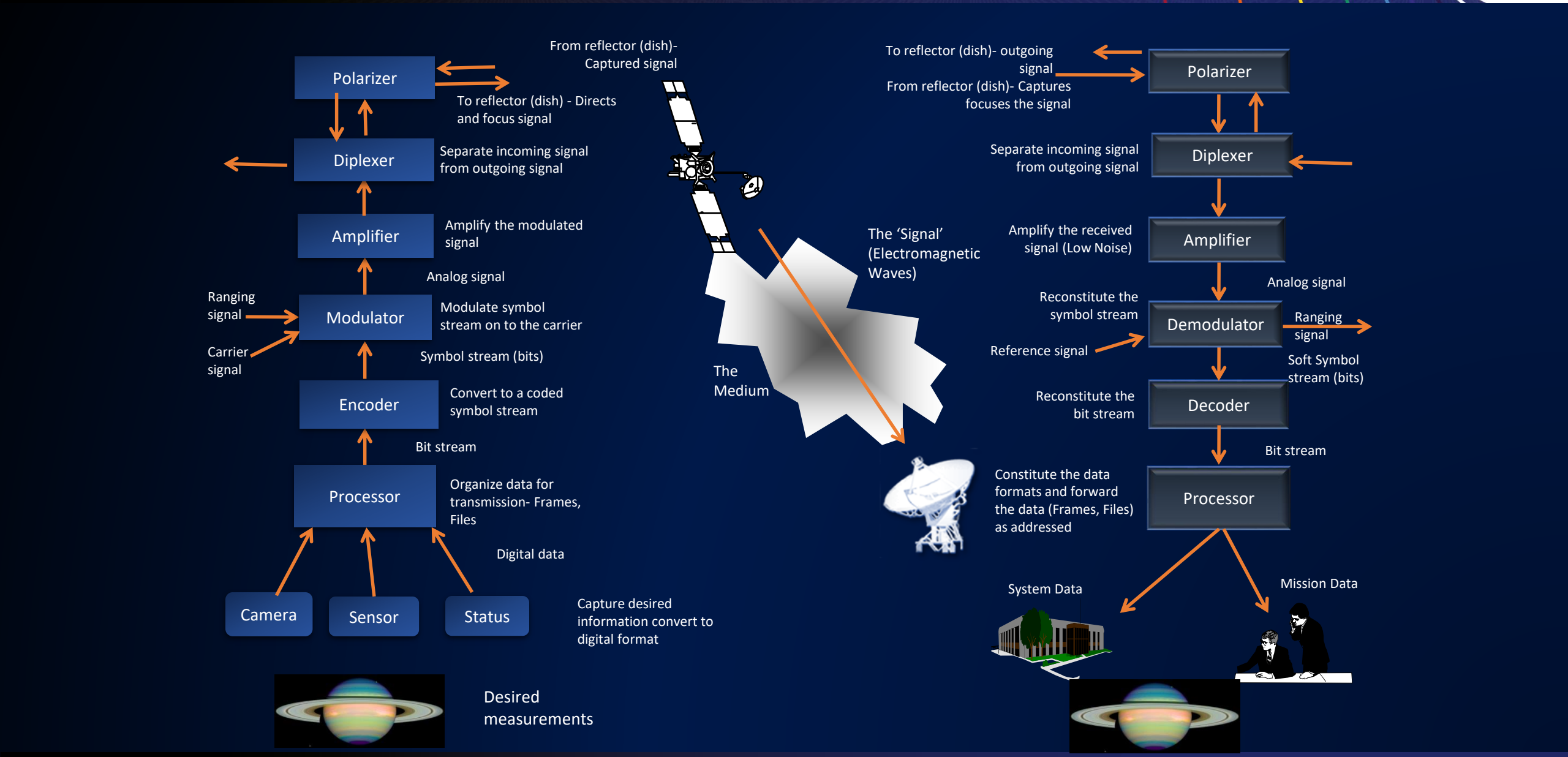
Space Operations 101

Relation Between Space Segment, Ground System, and Data Users*

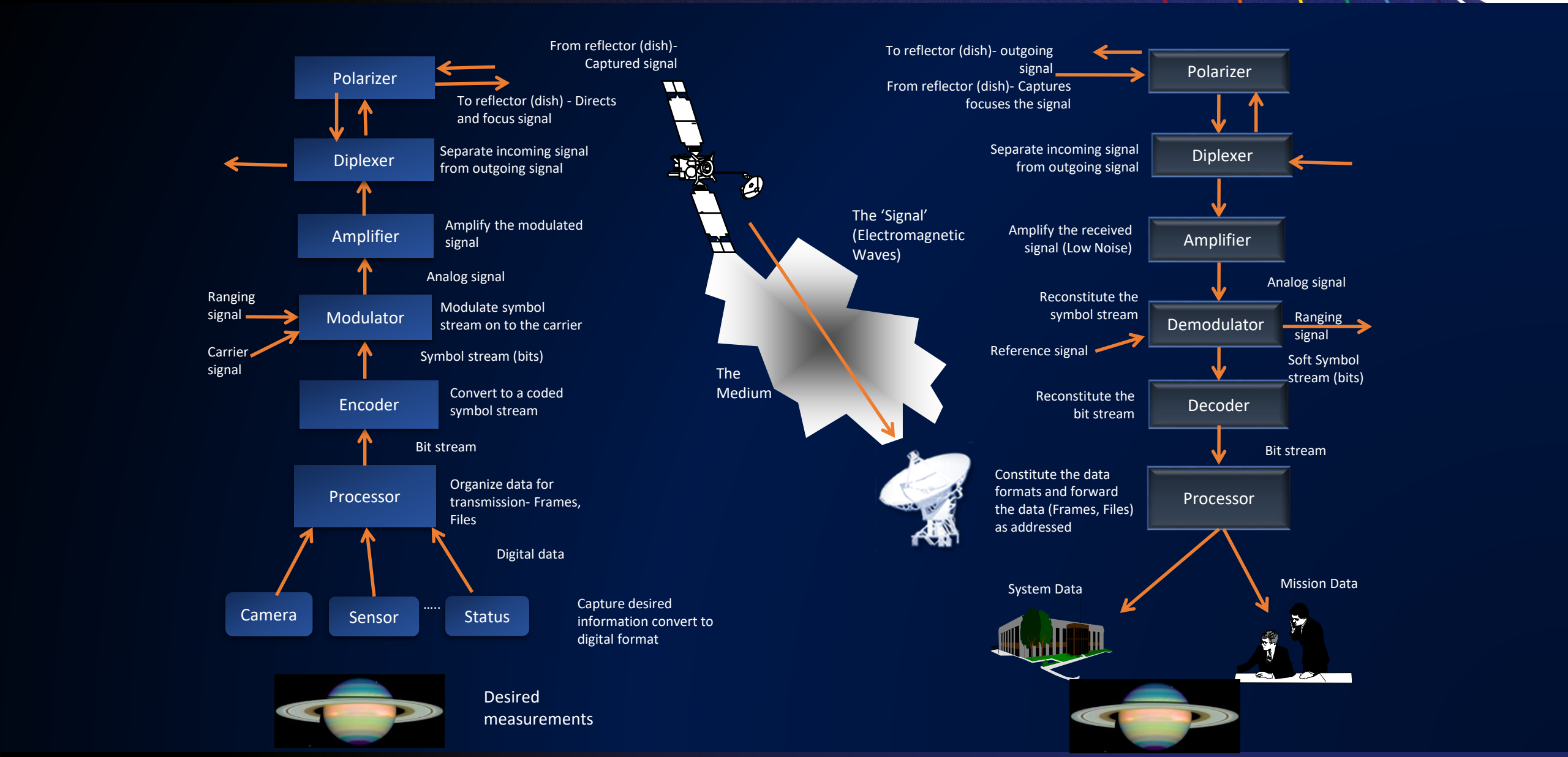


* Based on Wertz and Wiley; Space Mission Analysis and Design

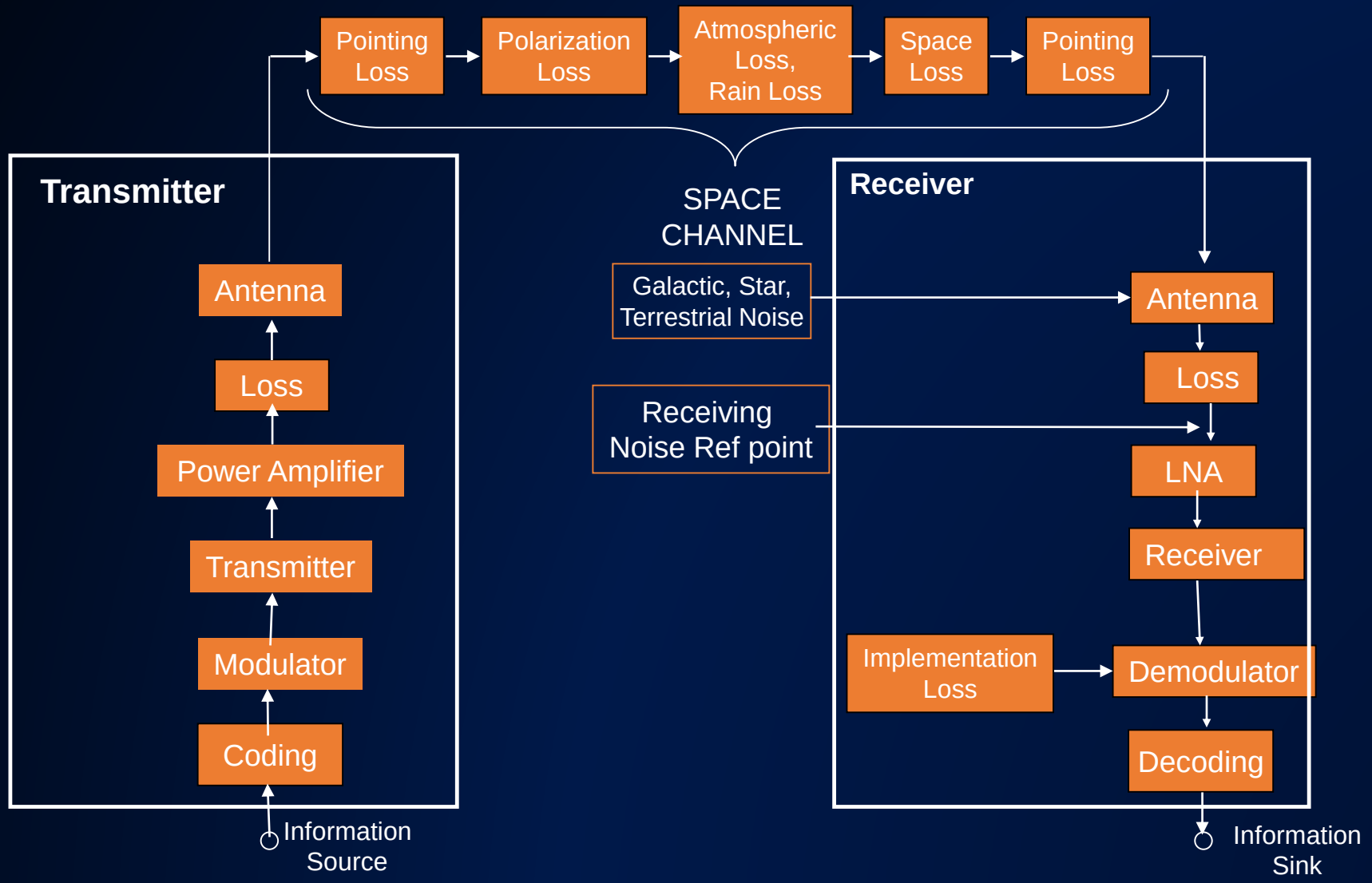
Space Communications - End to End Process



Space Communications - The Medium



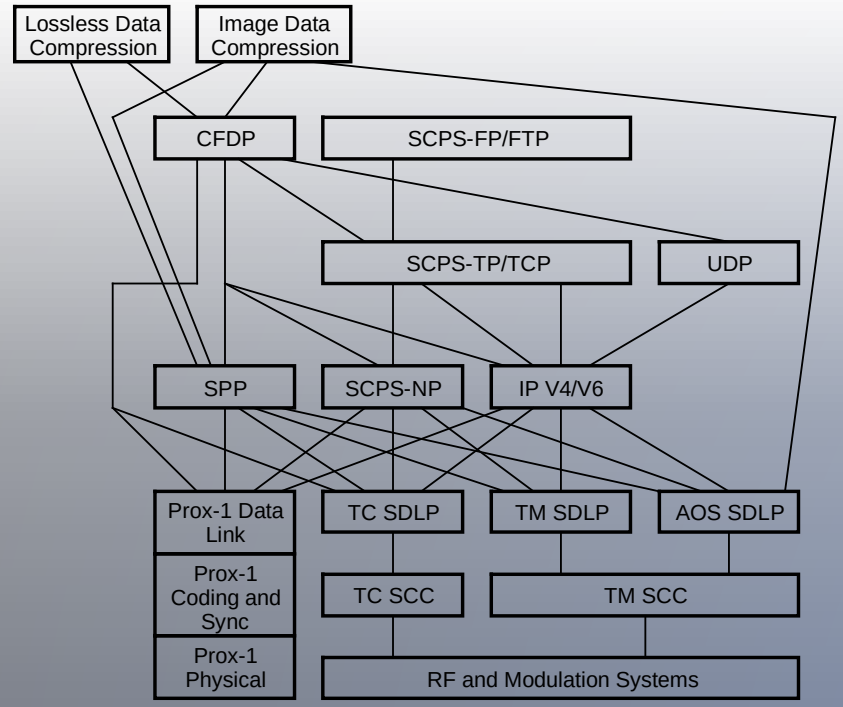
The Problem



Satellite transmitter-to-receiver link with typical loss and noise sources

Standardization of Communications Protocols and Space Internetworking

Example of CCSDS Protocol Stack - Consistency and Interoperability



SCPS-SP and IPSec can be used between the Transport and Network layers in any combination of protocols.

SPP = Space Packet Protocol
SDLP = Space Data Link Protocol
SCC = Synchronization and Channel Coding

Figure 2-2: Some Possible Combinations of Space Communications Protocols

(Reference: CCSDS. 130.0-G-2. Overview of Space Communications)

- Application Layer Protocols
  - SCPS File Protocol (SCPS-FP)
  - Lossless Data Compression
  - Image Data Compression
  - CFDP provides the functionality of the both the Application Layer (i.e., functions for file management), as well as the Transport Layer.
- Transport Layer Protocols
  - SCPS Transport Protocol (SCPS-TP) Version 6
  - The CCSDS File Delivery Protocol (CFDP)
  - TCP and UDP can be used on top of SCPS-NP, IP Version 4 and IP Version 6
- Network Layer Protocols:
  - Space Packet Protocol
  - SCPS Network Protocol (SCPS-NP)
  - Internet Protocol (IP), Version 4
  - Internet Protocol (IP), Version 6
- Data Link Layer
  - Data Link Protocol Sublayer of the Data Link Layer:
    - TM Space Data Link Protocol
    - TC Space Data Link Protocol
    - AOS Space Data Link Protocol
    - Proximity-1 Space Link Protocol - Data Link Layer
  - Synchronization and Channel Coding Sublayer of the Data Link Layer:
    - TM Synchronization and Channel Coding
    - TC Synchronization and Channel Coding
    - Proximity-1 Space Link Protocol - Coding and Synchronization Layer
- Physical Layer
  - Recommends the characteristics of the RF/Optical and modulation systems used for Communications over space links between spacecraft and ground stations.

The Future of Space Communications

New communications systems will continue enabling NASA to support tremendous volumes of data at higher rates with quicker response times.

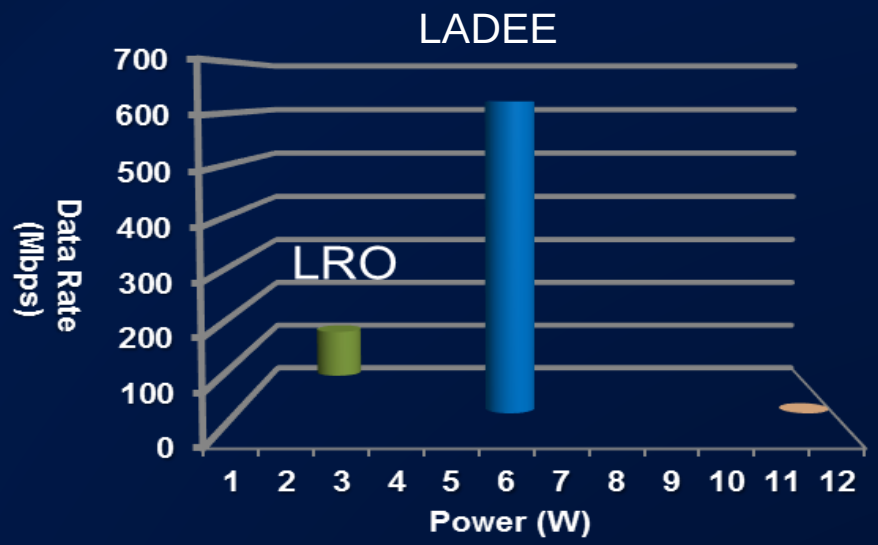
Goddard Space Flight Center is developing and testing optical communications technology to enhance communications and navigation activities and services for the user.

Optical Communications

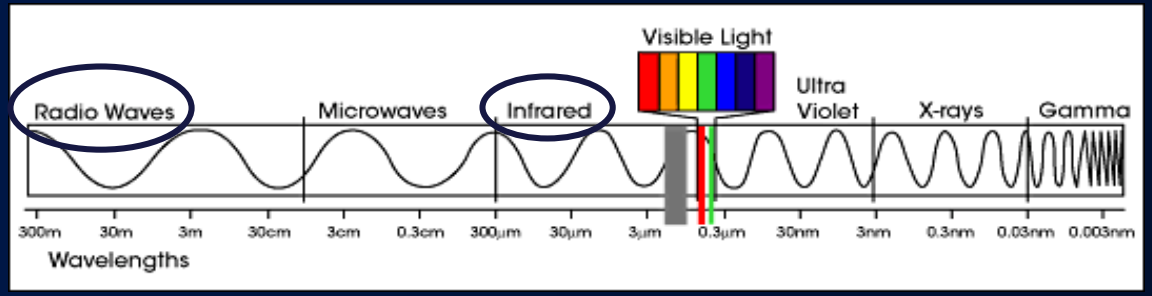
Optical communications systems are under development to enable unprecedented volumes of data return with quicker response times.

Optical communications will enable:

- Greater Speed and Volume
- Less SWaP
- Greater Availability



SWaP

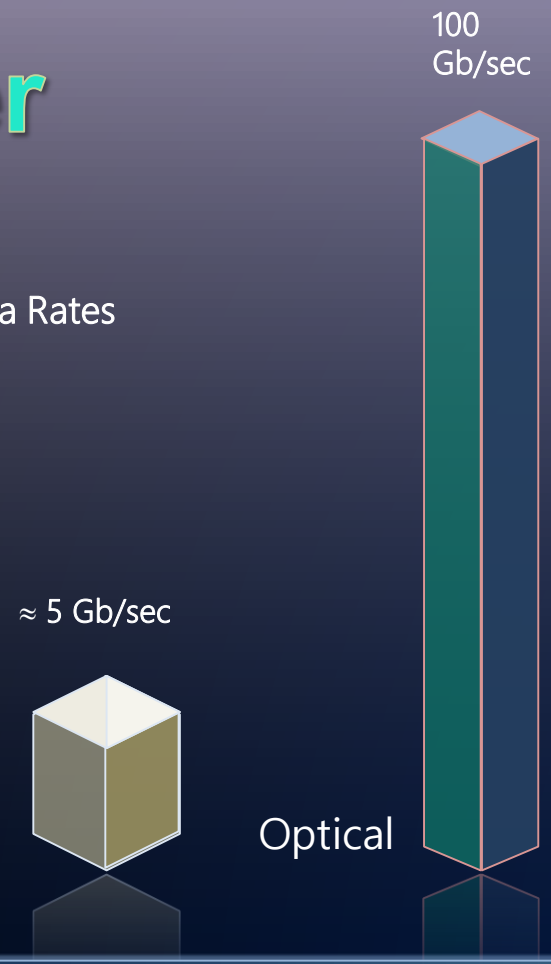


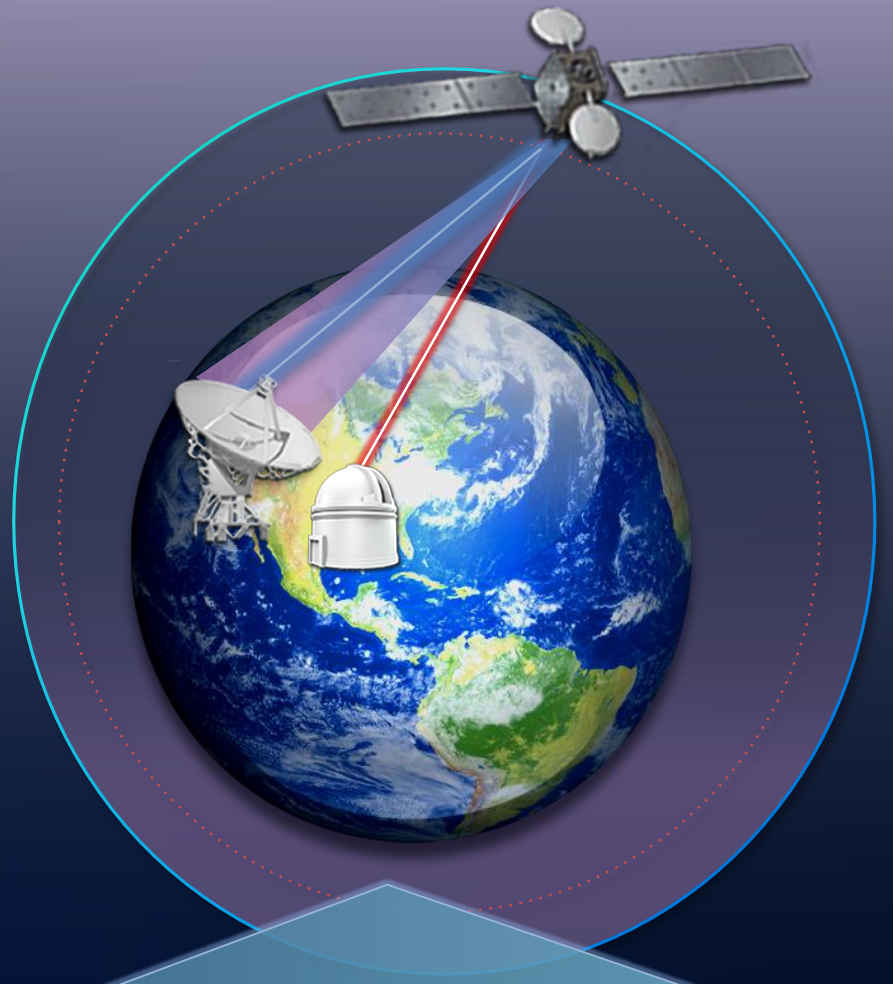
Advantages of Optical

Faster

40% more

Higher Data Rates



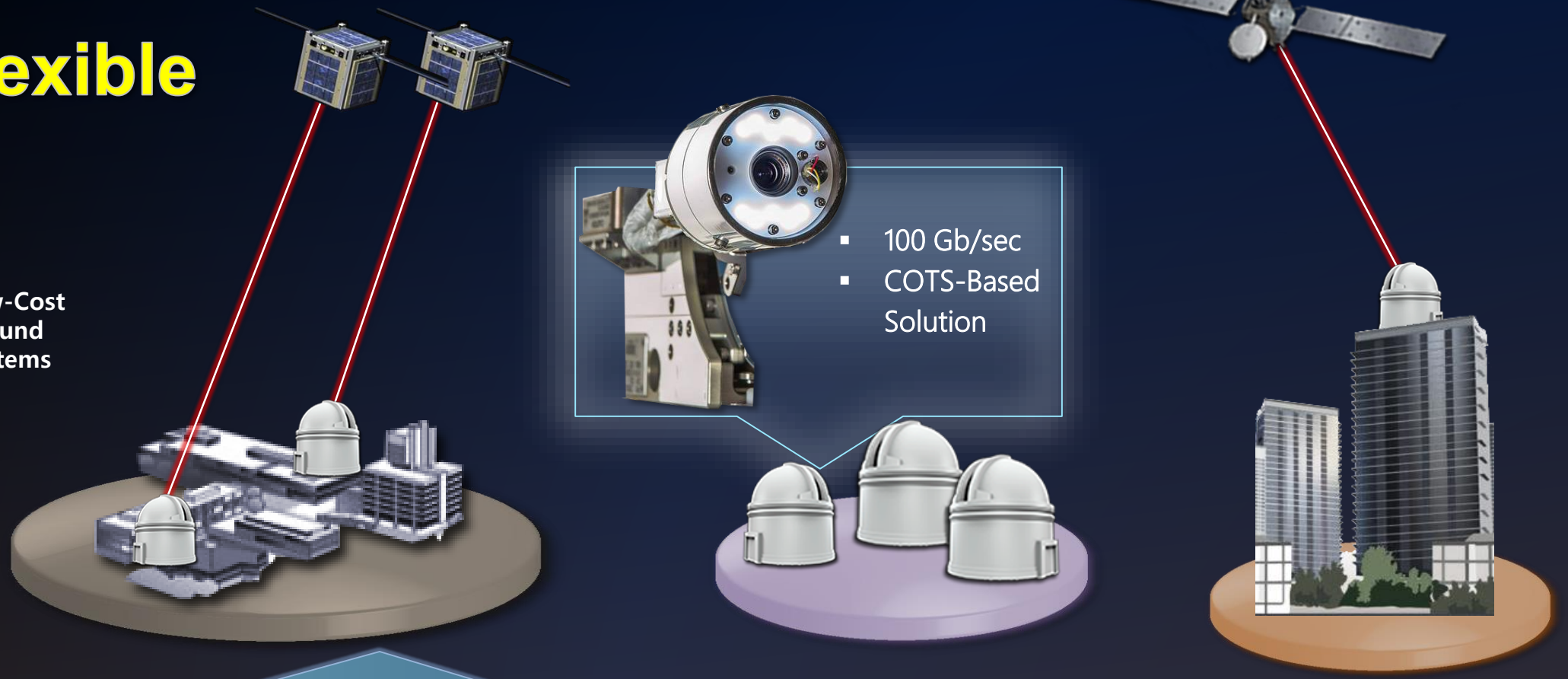


Higher bandwidths enable mission data to be downloaded using shorter contact times, decreasing the number of relay terminals and ground sites.

Advantages of Optical

Flexible

Low-Cost Ground Systems



- 100 Gb/sec
- COTS-Based Solution

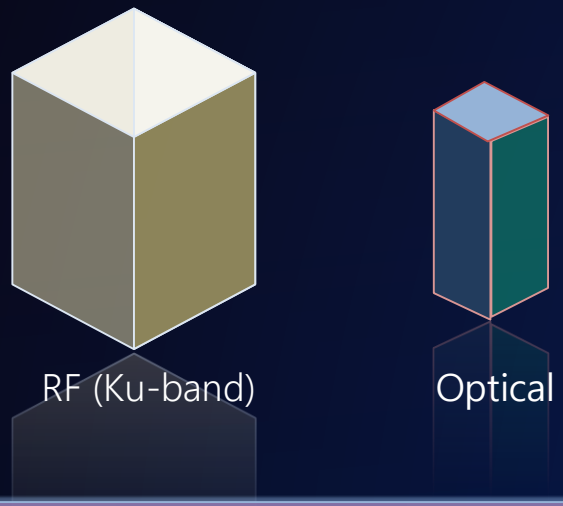
Low-cost ground segments located at mission sites or data centers lower costs, enable direct control and create decreased ground data transport expenses.

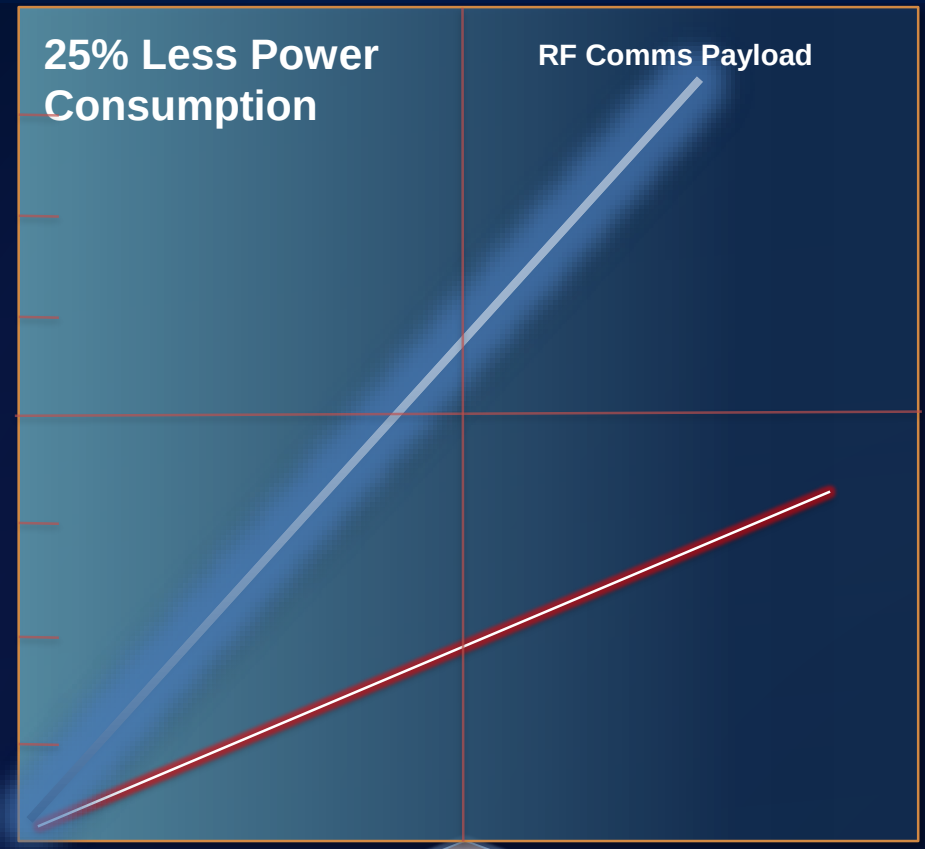
Advantages of Optical

Lighter

50% less Mass

SWaP





Laser communications allow for smaller, lighter flight communications systems that require less power cost savings for missions.

Optical Communications In Action

2013: LLCD
Lunar Laser Comm Demo

2019: LCRD
Laser Comm Relay Demo

2022: DSOC
Deep Space Optical Comm

2014: OPALS
Optical PAyload for Lasercomm Science

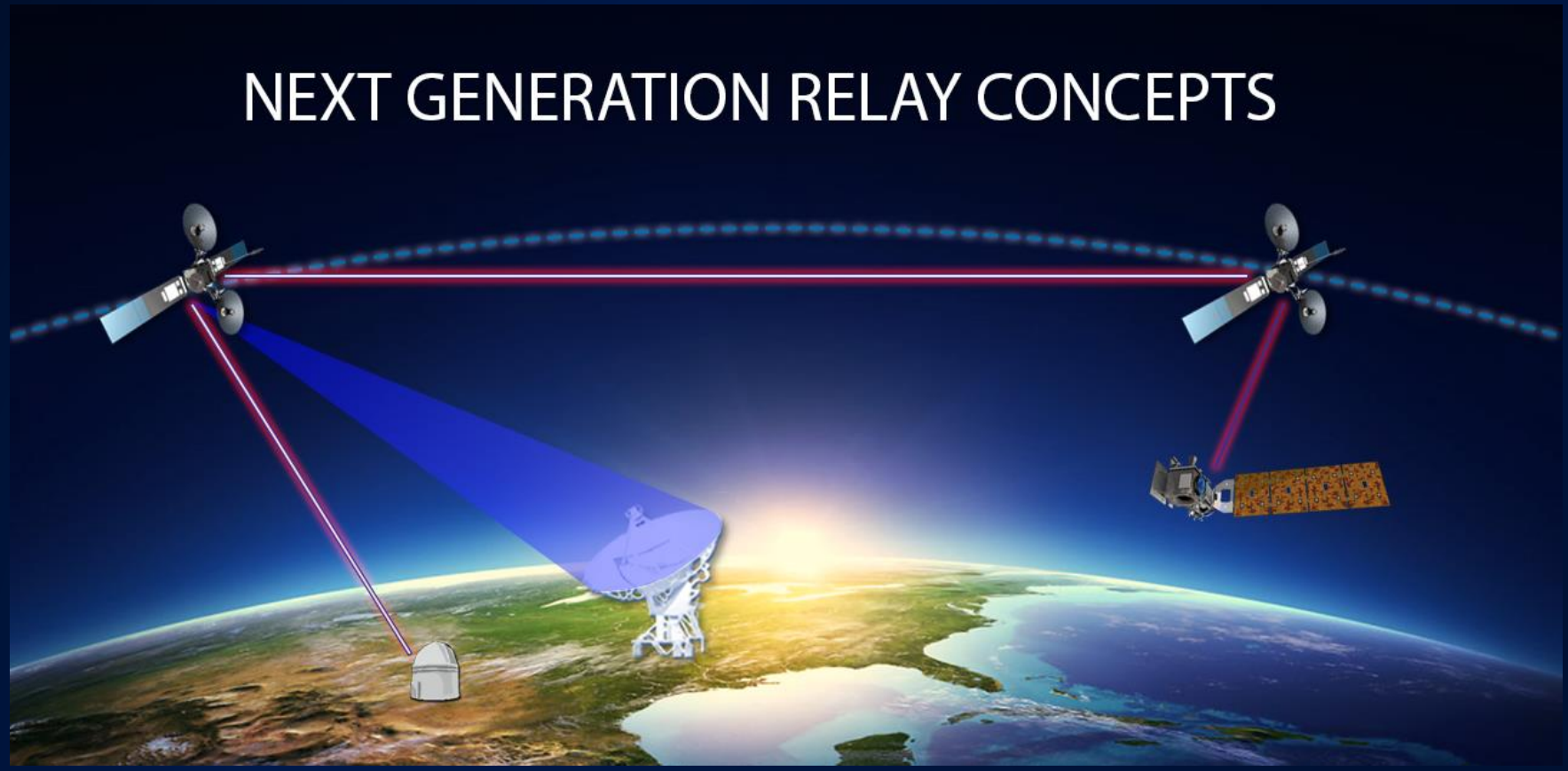
2021: ILLUMA-T
Integrated LCRD LEO User Modem and Amplifier - Terminal

2022: O2O
Optical to Orion

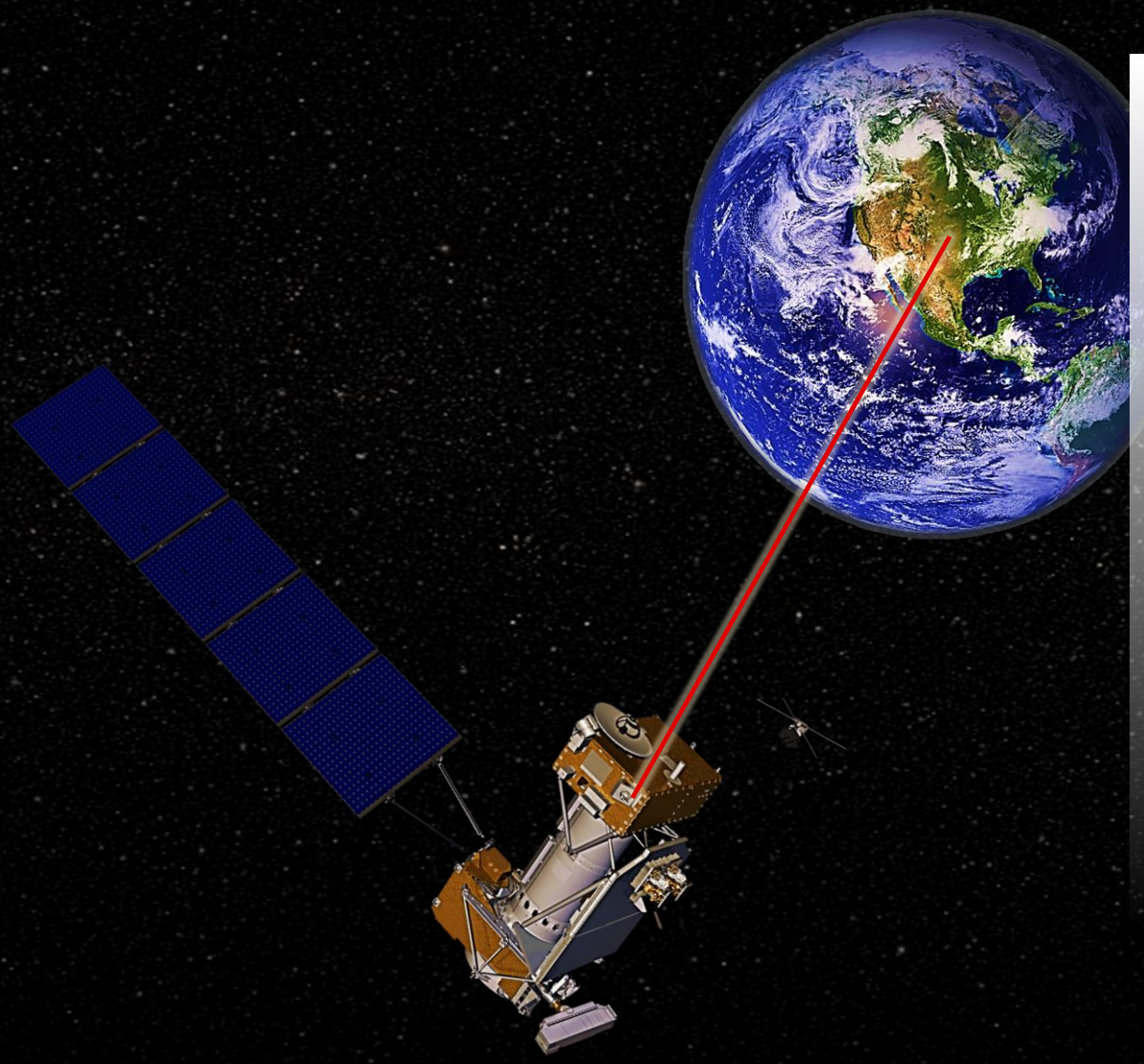
The Future of Space Communication and Navigation Systems

Enhancing upon our current TDRS network, SCaN is working to develop an interoperable optical relay network.

In addition to optical communications capabilities, these relays will also have Ka-band RF capabilities.

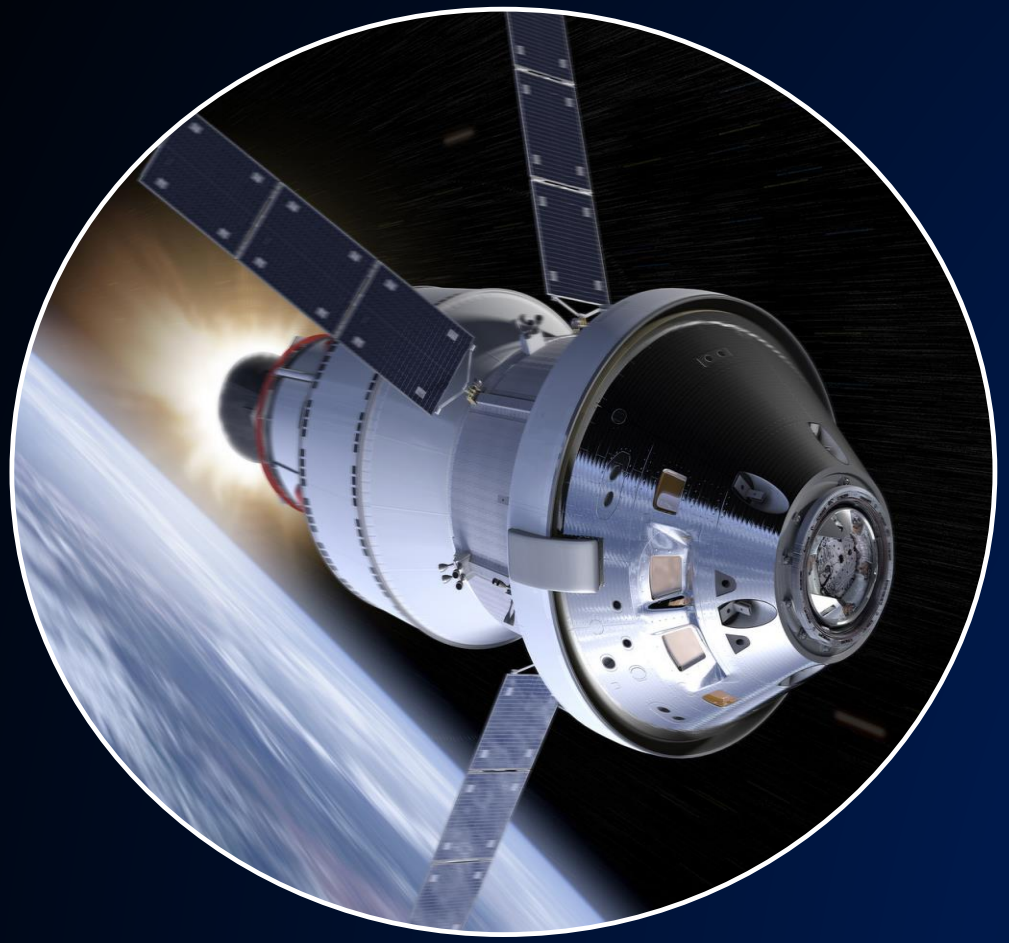


Laser Communications Relay Demonstration



The Laser Communications Relay Demonstration (LCRD) will provide at least two years of continuous high-data-rate optical communications from geosynchronous orbit. The relay demonstration will evaluate technologies for both LEO and deep-space applications. The demonstration will leverage existing systems and designs with minimal modifications to gain operational experience while minimizing cost. The demonstration will showcase a reliable, capable and cost-effective optical communications technology for infusion into future operational systems

Orion Exploration Mission-2



Orion EM-2 will be the first spacecraft in over 30 years to take astronauts beyond the moon.

EM-2 will use optical communication to downlink data to science users and mission control at Johnson Space Center.

EM-2 will enhance upon the capabilities of its predecessor EM-1, which will be using radio frequency.

An Optical Communications Terminal for the Orion Spacecraft

Optical to Orion EM-2

RETURN OPTICAL RATES

256 MBPS

THAT'S EQUIVALENT TO DOWNLOADING 8 SONGS PER SECOND

GET:

ULTRA HD IMAGES AND VIDEOS

UNCOMPRESSED OPERATIONS PRODUCTS

Additional Information

NASA's Pathways / Student Intern Program

- https://intern.nasa.gov/
- https://ossi.nasa.gov/ossi/web/students/login/
  - By creating a new OSSI account you will be able to do the following:
    - Create and maintain student profile
    - Save opportunities of interest
    - Apply for Internships, Fellowships and Scholarships
- http://www.usajobs.gov/
  - NASA's Pathways Student Intern Program
  - Create Resume on USAJOBS Website specify keywords, i.e. NASA, Internship, Engineering, Aerospace, Electrical, Computer, Physics, etc.

Connect with the ESC

Want to learn more about ESC?

Visit us on the web at:

esc.gsfc.nasa.gov

Or follow us on social media at:

- facebook.com/NASA.ESC
- twitter.com/NASALaserComm
- facebook.com/NASA.TDRS
- twitter.com/NASA_TDRS

References and Acknowledgement

1. http://www.nasa.gov/content/scan-presentations/

Back Up Slides

NASA Missions

Example - Browse Missions by Topic

Earth

http://www.nasa.gov/content/earth-missions-list

Universe

http://www.nasa.gov/content/universe-missions-list

Solar System

http://www.nasa.gov/content/solar-missions-list

Humans in Space

http://www.nasa.gov/content/human-missions-list