National Aeronautics and
Space Administration

The Space Mobile Network

Goddard Engineering Colloquium,
February 6, 2017

Dave Israel
Code 450 ESC Division Architect
dave.Israel@nasa.gov

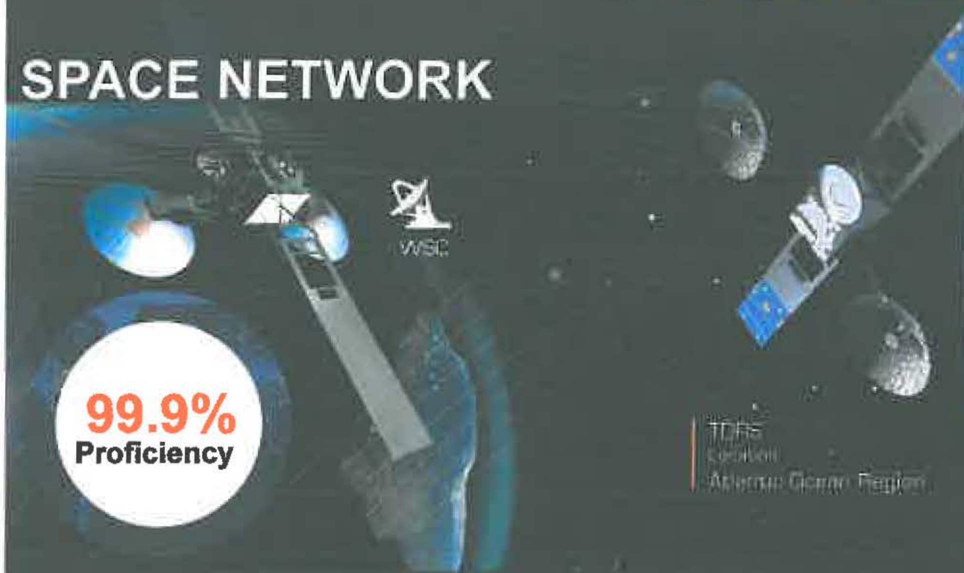
SCaN is Responsible for all NASA Space Communications

- Responsible for Agency-wide operations, management, and development of all NASA space communications capabilities and enabling technology.
- Expand SCaN capabilities to enable and enhance robotic and human exploration.
- Manage spectrum and represent NASA on national and international spectrum management programs.
- Develop space communication standards as well as Positioning, Navigation, and Timing (PNT) policy.
- Represent and negotiate on behalf of NASA on all matters related to space telecommunications in coordination with the appropriate offices and flight mission directorates.

NASA Networks Span the Globe

ESC OPERATIONS

SPACE NETWORK



99.9%
Proficiency

NEAR EARTH NETWORK

98%
Proficiency

NETWORKS INTEGRATION MANAGEMENT OFFICE

>100
Supported ELV Launches

SPECTRUM MANAGEMENT

600
Licenses for NASA Spectrum Managed by 450

COMMUNICATION ANALYSIS GROUP

25
RFICDs & Dynamic Analyses Annually

MISSIONS SUPPORT

98%
The percent of NASA communications that go through ESC each day as of July 2016

23
Average number of launches supported per year. Expected to double with increased HSF and cubesat missions

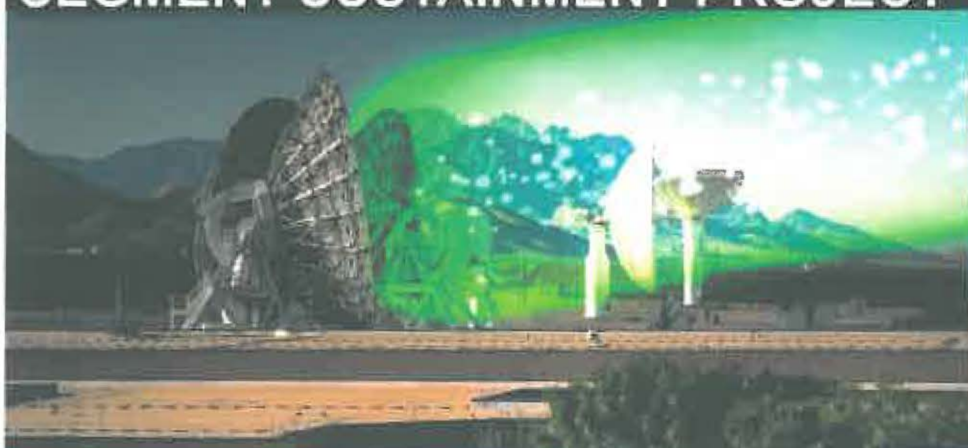
1,200
The number of Blu-ray disks worth of data SN and NEN handle every day

ESC DEVELOPMENT

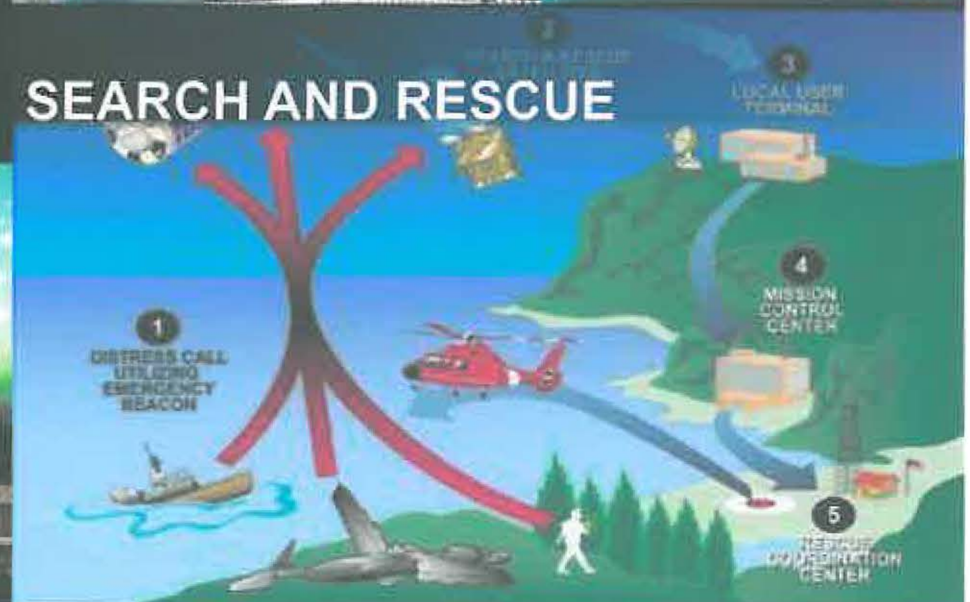
TRACKING AND DATA RELAY SATELLITE

LASER COMMUNICATIONS RELAY DEMONSTRATION

SPACE NETWORK GROUND SEGMENT SUSTAINMENT PROJECT

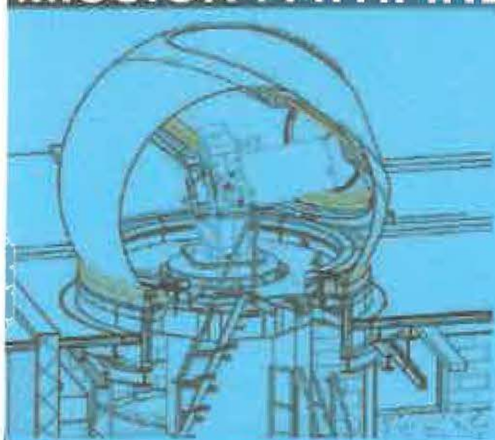


SEARCH AND RESCUE



ESC INNOVATION

TECHNOLOGY ENTERPRISE AND MISSION PATHFINDER OFFICE



EXPLORATION SYSTEMS PROJECT

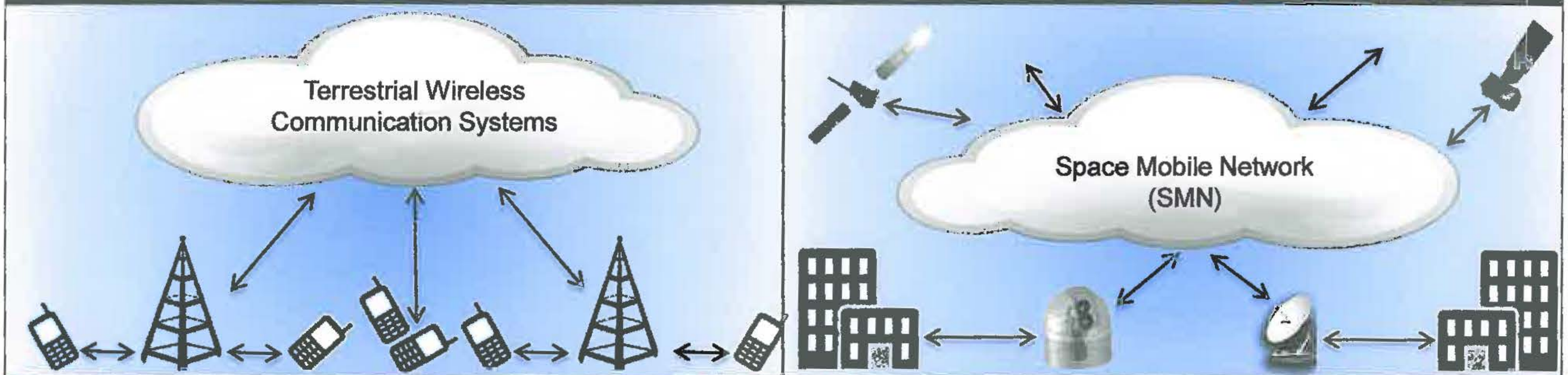
ESC STUDIES

ORION OPTICAL

INTEGRATED LCRD LEO USER MODEM AND AMPLIFIER

SPACE MOBILE NETWORK

The Space Mobile Network



- Architectural framework is named the "**Space Mobile Network (SMN)**" to accentuate the focus on the user experience with analogies to the terrestrial mobile wireless smartphone user experience
  - Increased availability and accessibility of services
  - Enable increased user autonomy
  - Once connected to "the cloud," services, sources, and destinations are available
  - Minimize user burden including the Size, Weight, and Power (SWaP) required for the flight systems.
- Key Features
  - On demand low data rate links
  - Scheduled high data rate links
  - Internetworking services
  - Advanced position, navigation, and timing services
- Key Enabling Technologies
  - Optical Communications
  - Delay/Disruption Tolerant Networking
  - User Initiated Services
  - Position, Navigation, and Timing Technologies

2013: NASA's First, Historic Laser Communications Mission

2014 Popular Mechanics Breakthrough Award for Leadership and Innovation for LADEE

2014 R&D 100 Winning Technology in Communications category

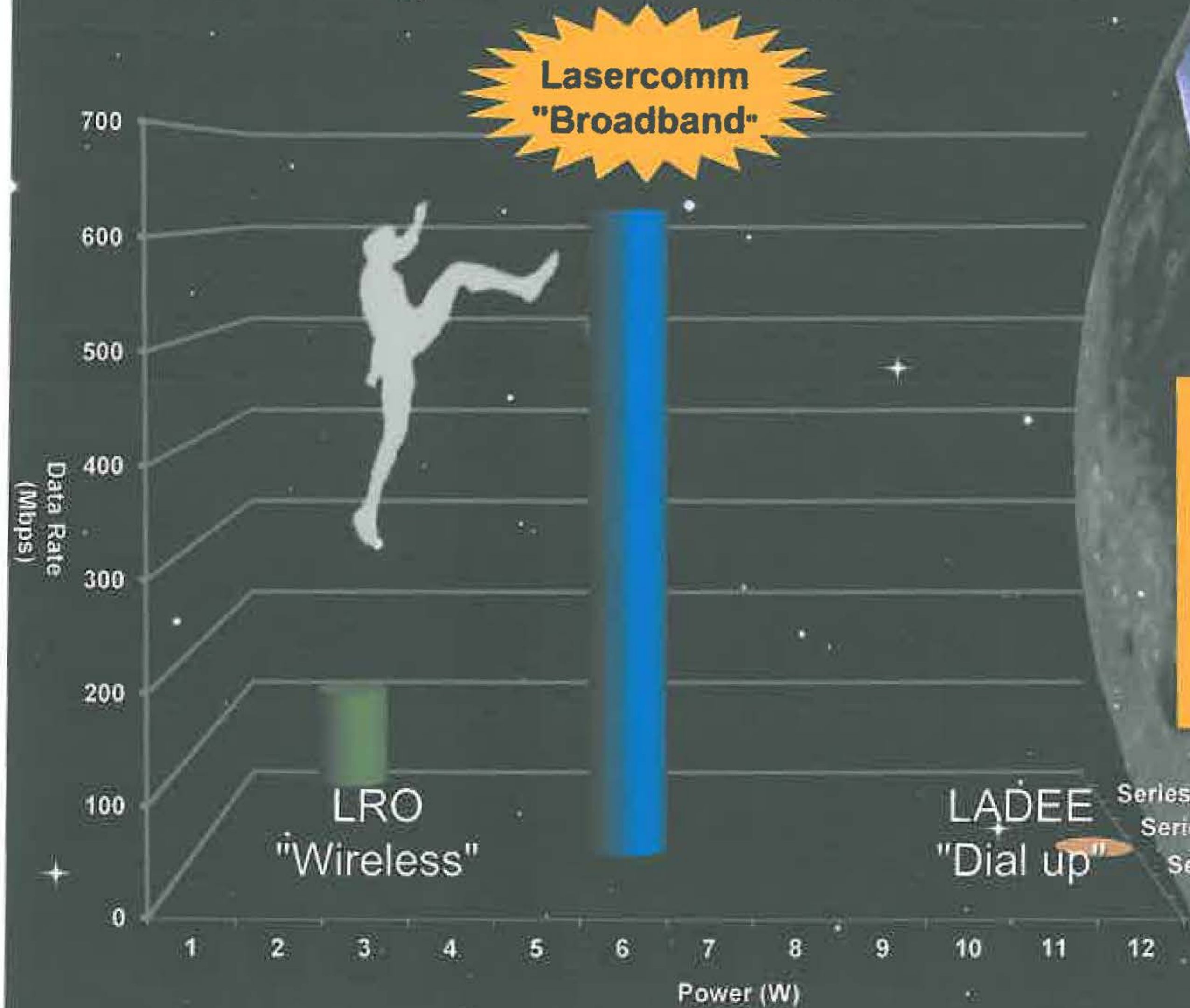
Nominated for the National Aeronautic Association's Robert J. Collier Trophy

Winner of the National Space Club's Nelson P. Jackson Award for 2015

NATIONAL SPACE CLUB
WASHINGTON D.C.

Laser Communications – Higher Performance AND Increased Efficiency

A Giant Leap in Data Rate Performance for less Mass and Power



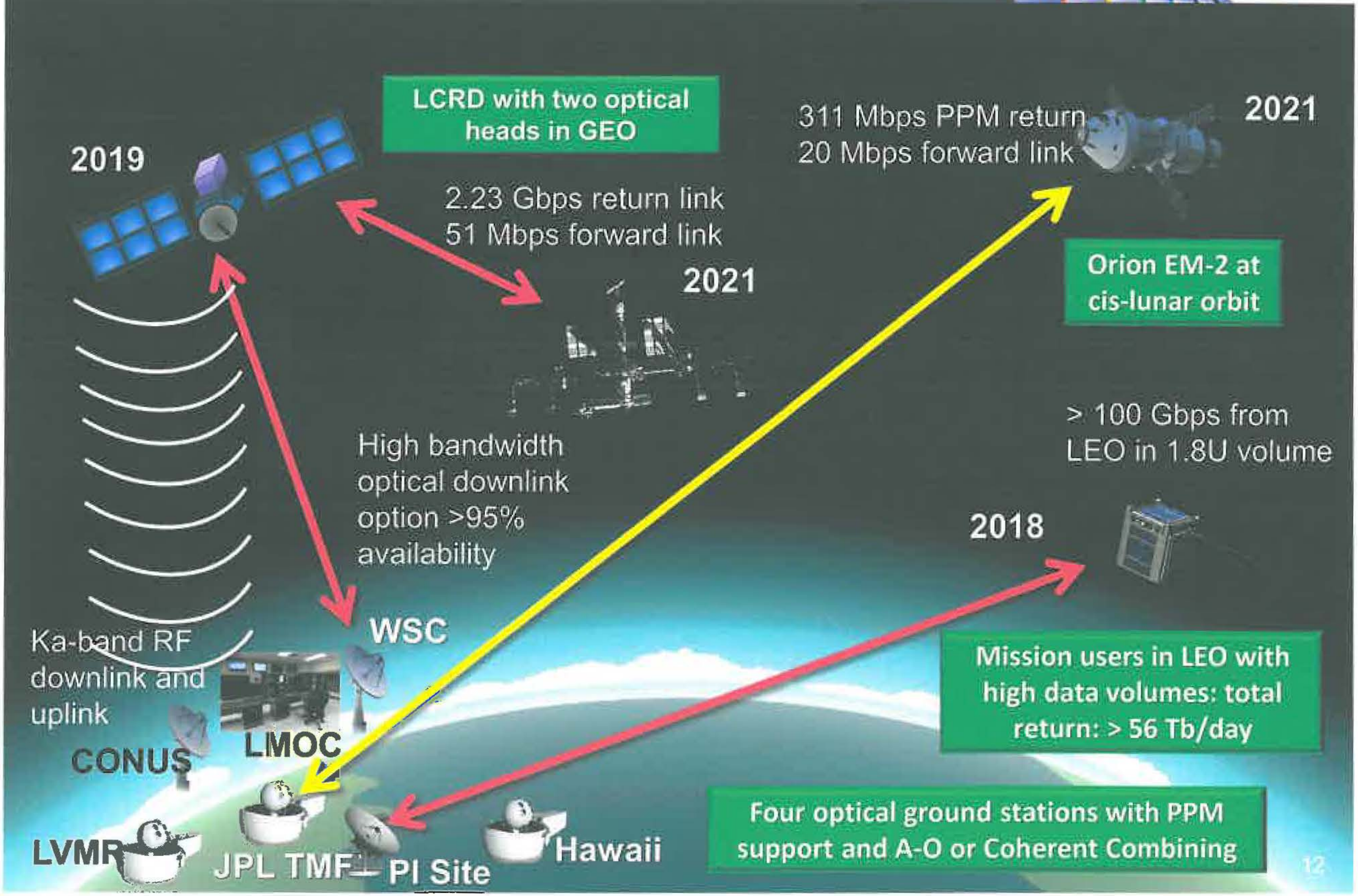
LLCD used:

- **Half the mass**
- **25% less power**
- **While sending 6x more data than radio…**

Optical Communications

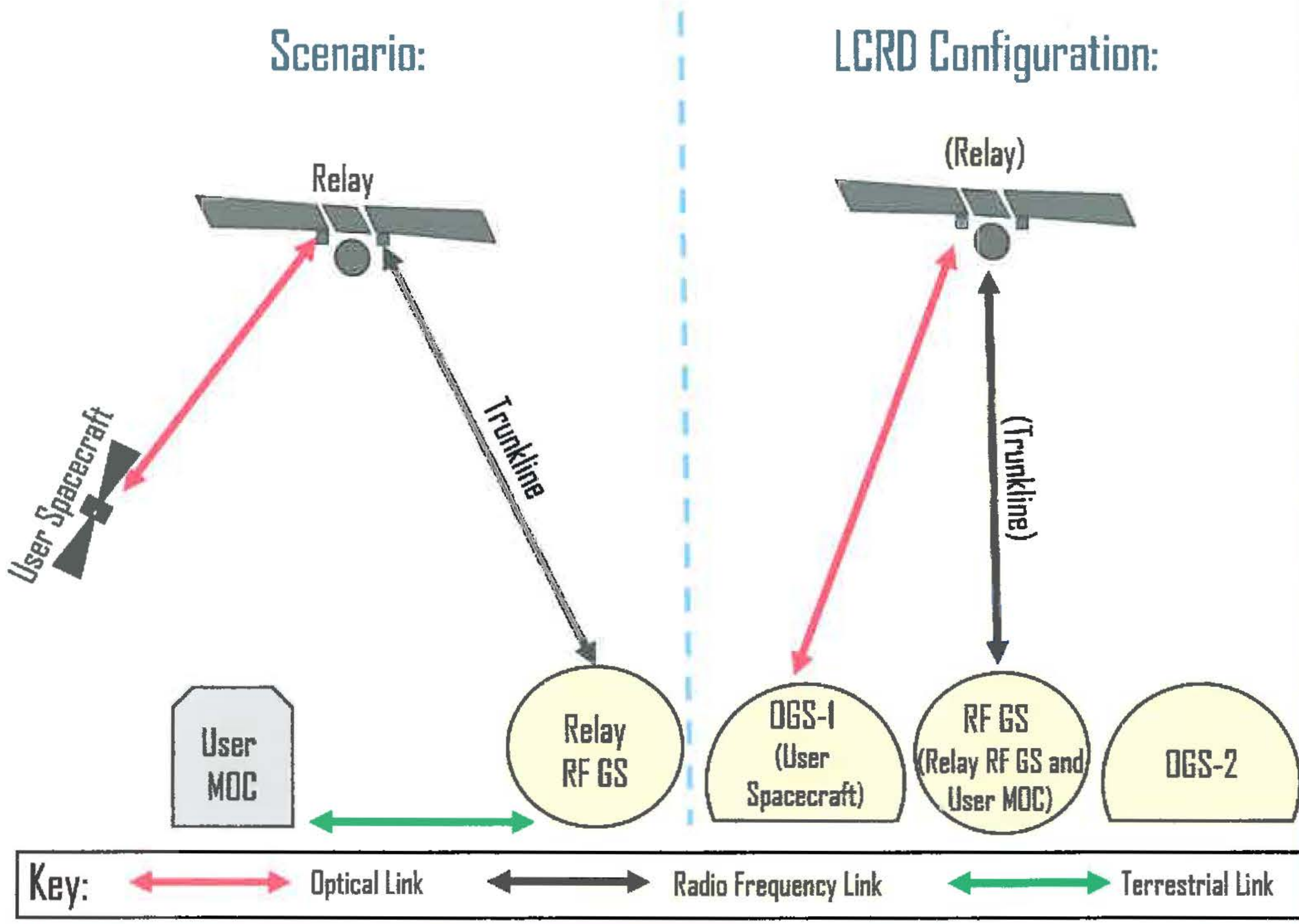
- Relay Applications
  - Single Access links: Higher data rates available via relay with smaller user and relay systems
  - Multiple Access
    - Array of small telescopes could provide 10 Mbps duplex service to 100 simultaneous users
    - A more robust and faster system, though, could be based on a wide field-of-view telescope with its image mapped onto a focal plane array
    - Greatly reduced user burden may allow for ubiquitous use of MA system
- Direct-to-Earth (DTE) Applications
  - Potential for extremely high data rates (10's to 100's of Gbps)
  - Low-cost and small ground terminals may allow for data delivery direct to science centers or other user locations

NASA's Future Space and Near Earth Network with High Rate Optical Communication Services



LCRD Experiment Configuration

Relay Provider for Single User



LCRD Components

Optical Module

Controller Electronics

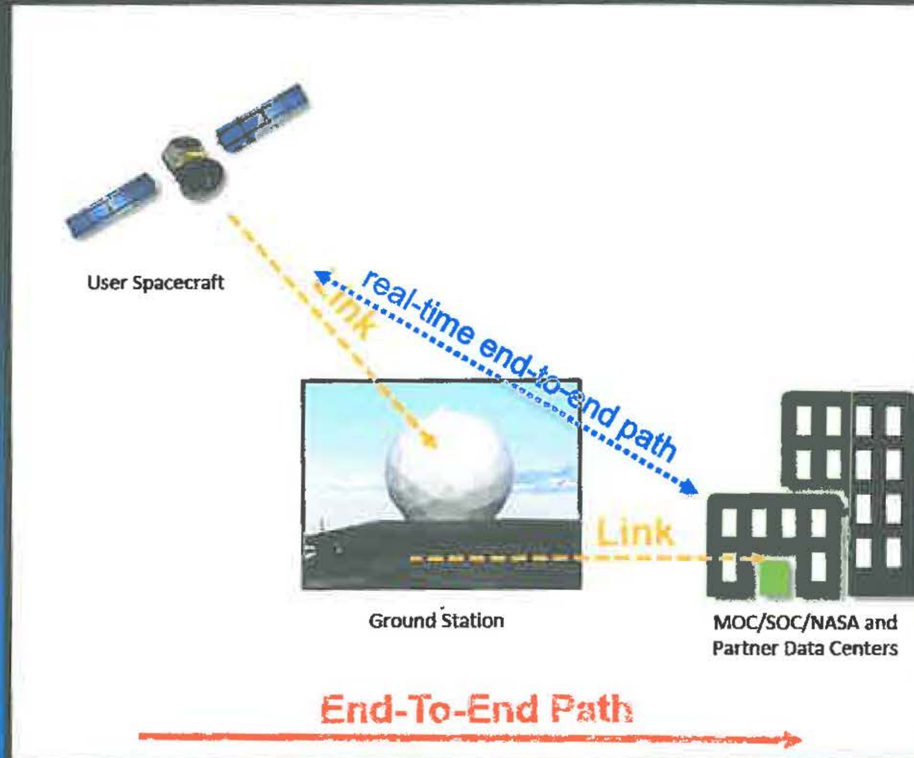
Modem

Switch

Delay Tolerant Users – Two Types of Latency Requirements

- ***"Get this data to its destination"***
  A mission with science data delivery timeliness requirements, possibly real-time (two-way voice /video, commands & telemetry, science alerts, telerobotics, etc.) will be concerned about the effective data rate between the user platform and data destination (i.e. an end-to-end path).

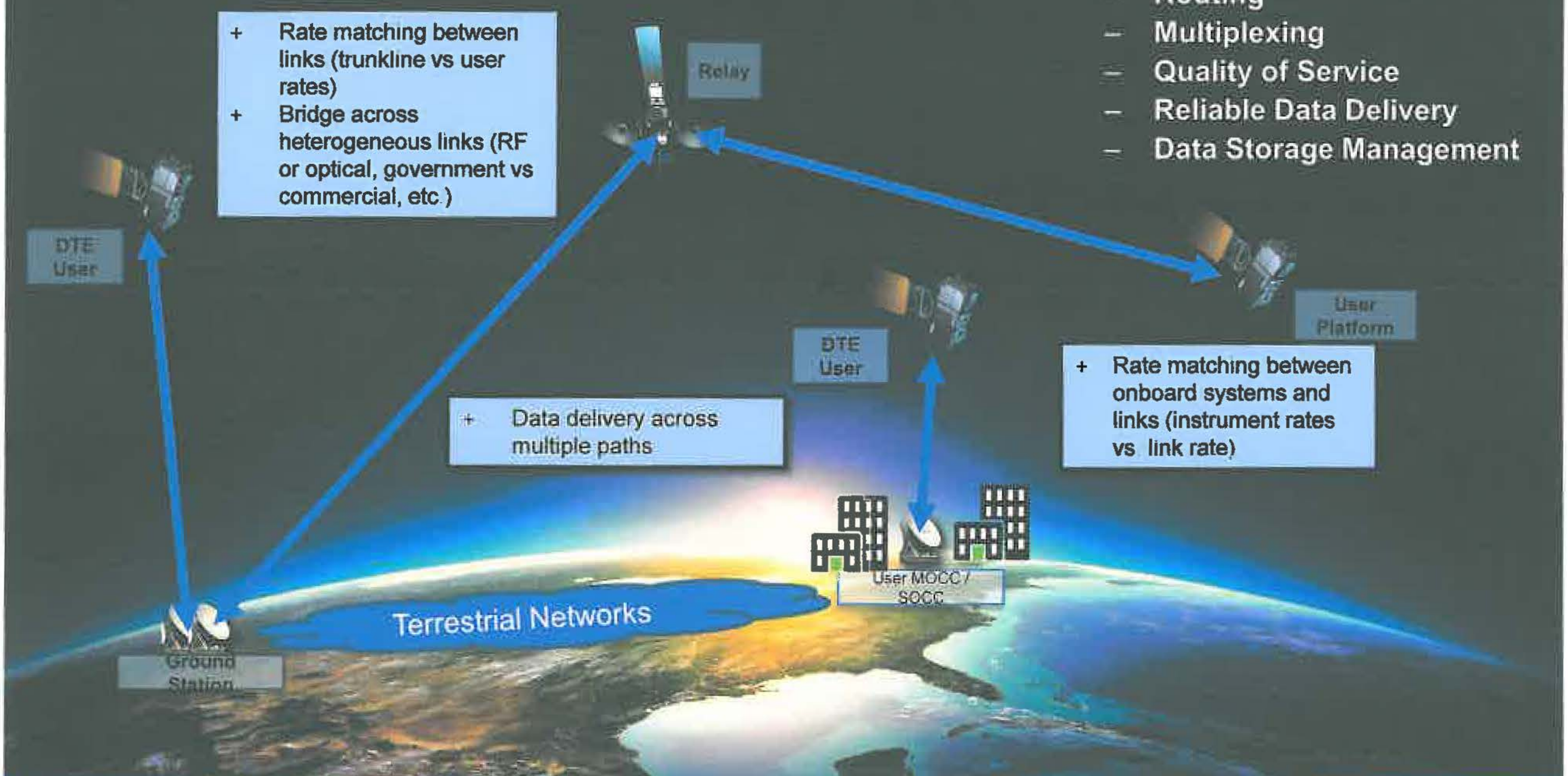
- ***"Get this data off my platform"***
  A mission that needs to offload data in order to free up onboard storage or meet some other operational constraint is only really concerned with the speed of the space link from their spacecraft to the communications asset. The latency requirement through the rest of the end-to-end path is driven by science needs.



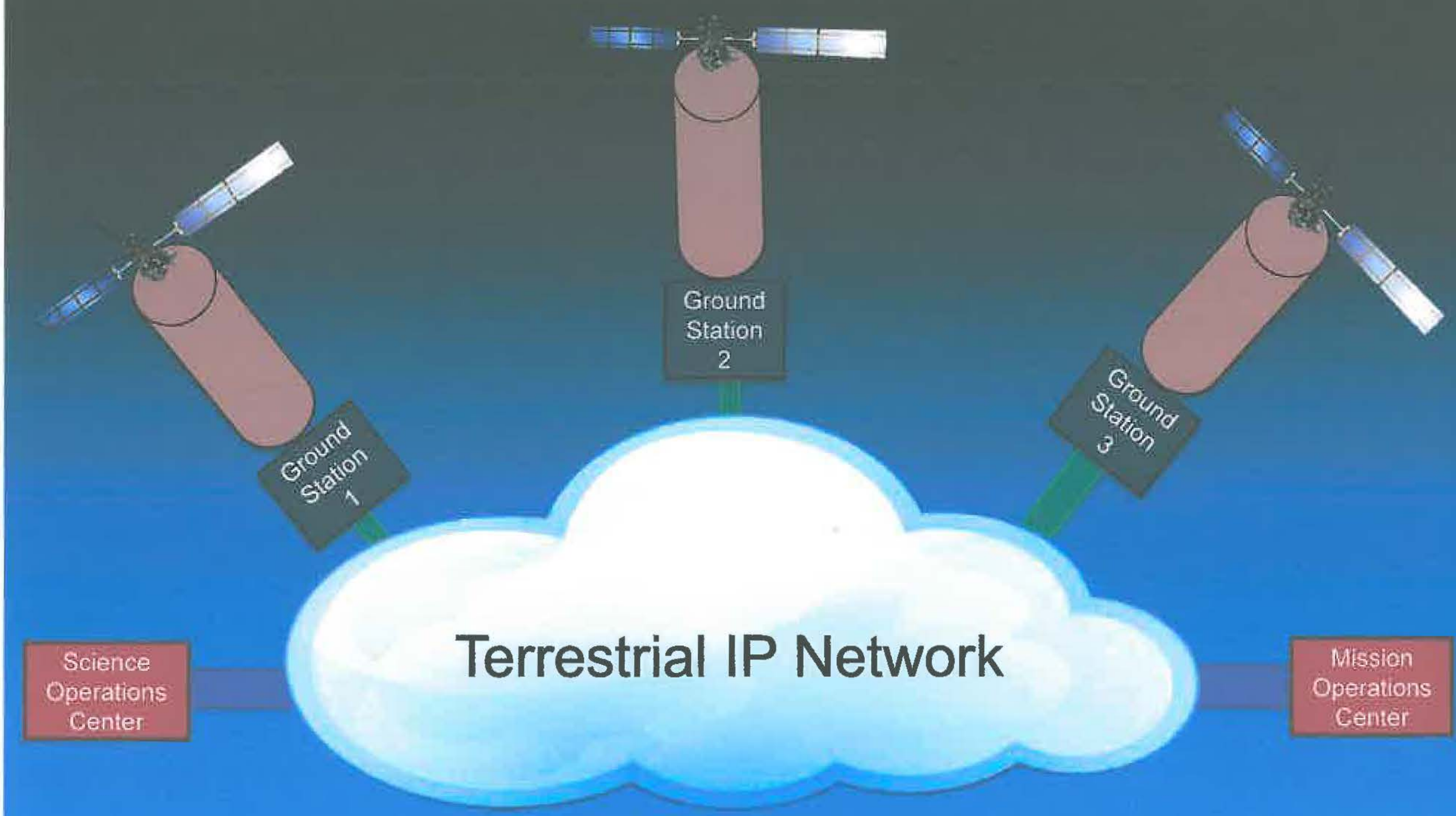
The Space Mobile Network concept leverages the combination of high availability, low latency, low data rate links with delay tolerant users and shared high rate links

DTN Enables SMN

- All nodes benefit from DTN
  - Routing
  - Multiplexing
  - Quality of Service
  - Reliable Data Delivery
  - Data Storage Management

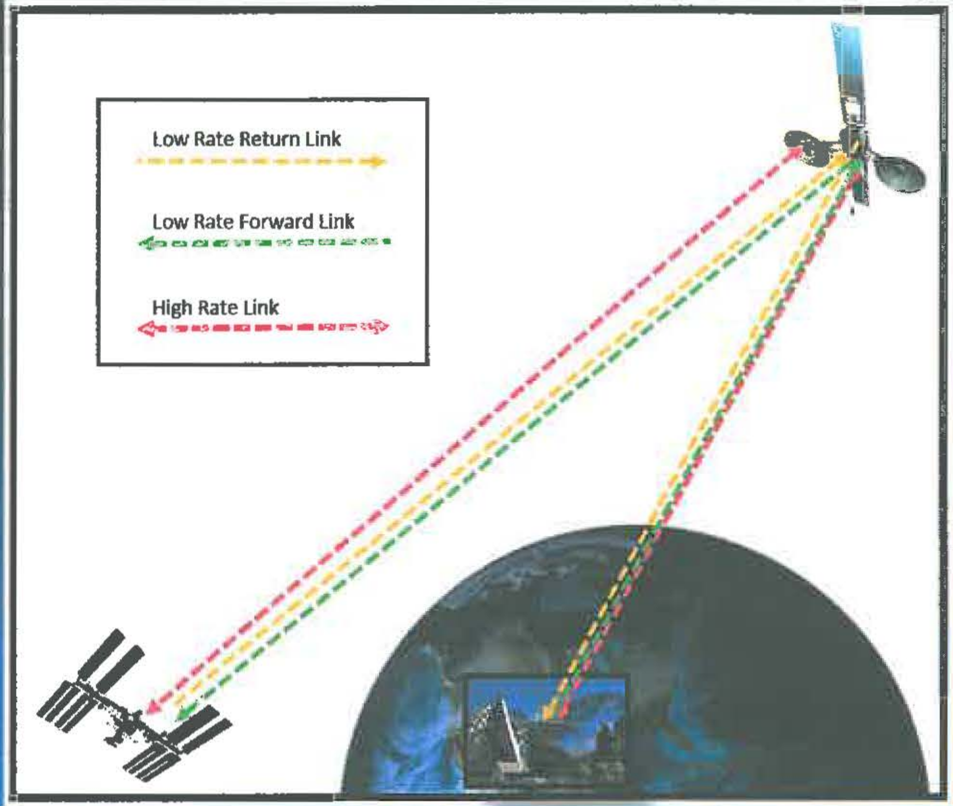


Low Earth Orbit Mission Science Ops Scenario



User Initiated Services (UIS)

- UIS allows platform-triggered acquisition of services through the use of continuously available low rate links
- User can access a high rate or other scheduled service on short notice



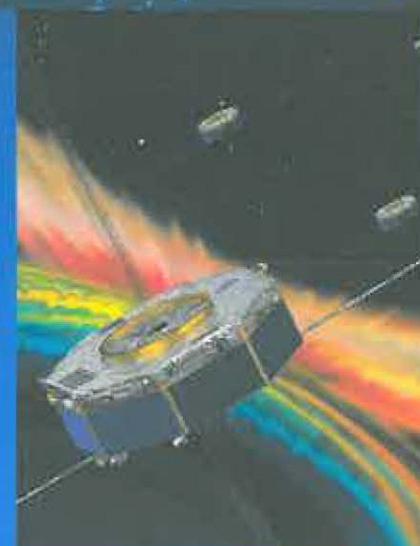
- Provides mission designers the potential to enable new science and reduce operations costs and complexity through fundamentally different concepts in operations execution.

Position, Navigation, and Timing Technologies

- Increased spacecraft autonomy implies a transition from ground based orbit determination processes to onboard processes
- **Flight GPS/GNSS systems**
  - Acquire and track GNSS signals anywhere between LEO and Lunar orbits with hemispherical (low gain) antenna
  - Receivers will continue to decrease in size and increase in capability in accordance with Moore's law
  - Increased signal availability within while also expanding the region of the space service volumes
- **Clock Stability**
  - Stability performance over time as normalized on a per dollar, per mass, or per volume basis also facilitates the autonomous navigation capability
  - More stable clocks will increase GNSS receiver accuracy and availability and also a transition from two-way to one-way radiometric techniques.
- **Optimetrics** and other new types of observations
- **Onboard navigation filters** allow user to self-ascertain and maintain their orbital state given intermittent observations processing GPS, network radiometrics, and celestial navigation observations simultaneously
- **Standards** that allow individual autonomous navigation components to be delivered by multiple vendors while easily integrating into a single onboard system will allow for per-mission customization.

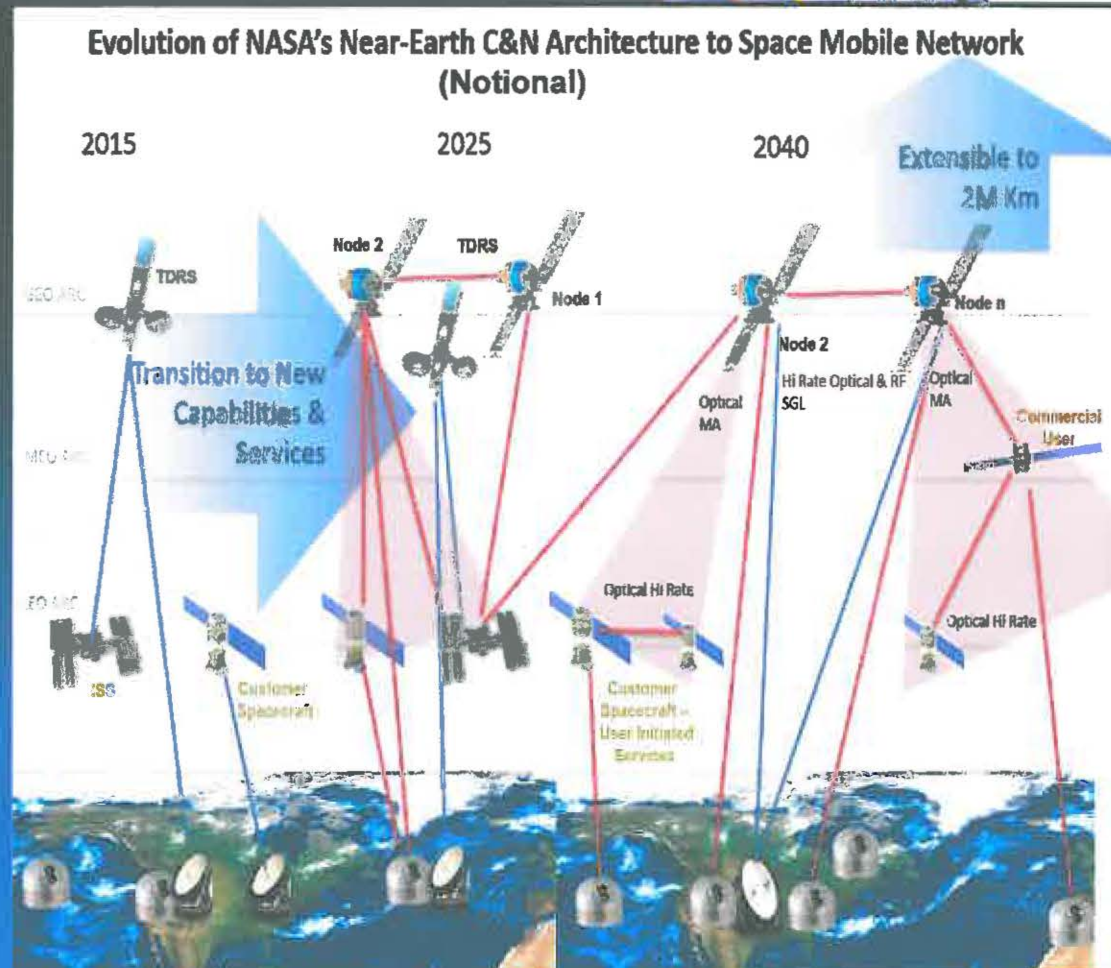
Use Case Examples

- Variable Science Data Collection
  - A mission has a lower rate of science data collection while in a nominal monitoring/baseline data collection mode
  - A science event triggers instruments to collect data at a higher rate by either turning on more instruments or increasing resolution
  - The mission is able to use UIS to acquire the necessary services to delivery all of the data even though the data volume and time of event were not predictable
- Collaborative science platforms.
  - One platform detects an event and transmits a notification to collaborating platforms, while also scheduling up the opportunity to transmit the full data collected
  - Other platforms receive the notifications, begin their appropriate response (repoint an instrument, increase resolution, etc.), and then transmit their data through the available channels
- Satellite Formation Flying
  - Small, micro, and nano satellite buses offer on opportunity to place large numbers of observation platforms into orbit
  - Small satellite maneuvering will be attained as actuator technology scales down to fit within the size, mass, and volume constraints of small satellite buses
  - Formation flying of small satellites will be achieved through the application of precision autonomous orbit determination, maneuver planning, and execution



Conclusions

- The SMN architecture provides a framework for the evolution of the near earth space communications and navigation architecture to enable and enhance the future spaceflight missions
- The technologies presented can begin to be implemented before any new space relay nodes or ground station antennas are deployed
  - Though the performance of initial demonstrations may be limited to lower data rates or longer latency than desired, the implementation will allow for the demonstration of the benefits, the requirements and the challenges of the future systems.



- Further work is already underway to validate and refine the architecture, to develop the associated technology, and to implement the first demonstrations and early operational capabilities.

Acronyms

C&N - Communication and Navigation
DTE – Direct to Earth
DSN - Deep Space Network
DTN - Disruption/Delay Tolerant Network
ERNESt - Earth Regimes Network Evolution Study
ESC - Exploration and Space Communications
GEO - Geosynchronous Orbit
GNSS - Global Navigation Satellite System
GSFC - Goddard Space Flight Center
HSF – Human Spaceflight
LADEE – Lunar Atmosphere Dust and Environment Explorer
LCRD – Lunar Communications Relay Demonstration
LEO - Low Earth Obit\
LLCD – Lunar Laser Communications Demonstration
MA - Multiple Access
NASA - National Aeronautics and Space Administration
NEN - Near Earth Network
NGBS - Next Generation Broadcast Service
PNT - Positioning, Navigation, and Timing
R&D – Research and Development
RF - Radio Frequency
SCaN - Space Communications and Navigations
SMN - Space Mobile Network
SN - Space Network
SWaP - Size, Weight, and Power
TASS - TDRSS Augmentation Service for Satellites Service
TDRSS - Tracking and Data Relay Satellite System
UIS - User Initiated Services

MISSION

As a national resource, the Exploration and Space Communications (ESC) Projects Division enables scientific discovery and space exploration by providing innovative and mission-effective space communications and navigation solutions to the largest community of diverse users.

ACKNOWLEDGEMENTS

The authors thank SCaN, the ERNESt team, the GSFC C&N Community, and Carolyn Crichton, for helping to make this presentation possible.

PRESENTER:

David Israel
david.j.israel@nasa.gov
301-286-5294

GSFC/ESC EXECUTIVE LEADERSHIP TEAM

Bob Menrad, Associate Director
Cathy Barclay, Deputy Program Manager/Execution
Mark Brumsfield, Deputy Program Manager/Implementation
Dave Israel, ESC Architect
Tracy Felton, Program Business Manager
Mike Weiss, Associate Program Manager

STAY CONNECTED: http://esc.gsfc.nasa.gov/ Facebook: @NASA.ESC, @NASA.TDRS, @NASASCaN. Twitter: @NASA_TDRS, @NASALaserComm