

UNCLASSIFIED

National Aeronautics and
Space Administration



NASA's Progress on Lunar Communication & PNT Capabilities

James Schier, Chief Architect for Space Communications and Navigation
Presentation to: 2nd Cislunar Summit
April 15, 2021

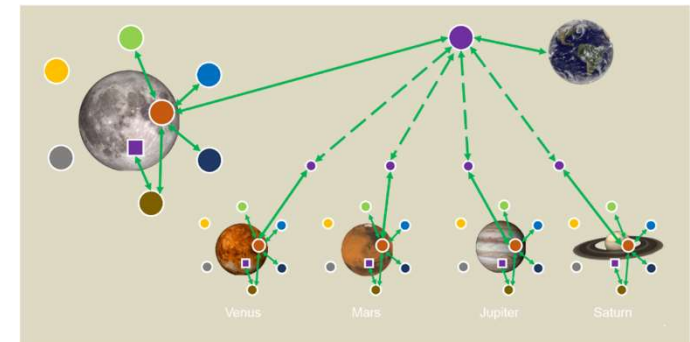
UNCLASSIFIED

www.nasa.gov

Introduction to the Lunar Network, *LunaNet*



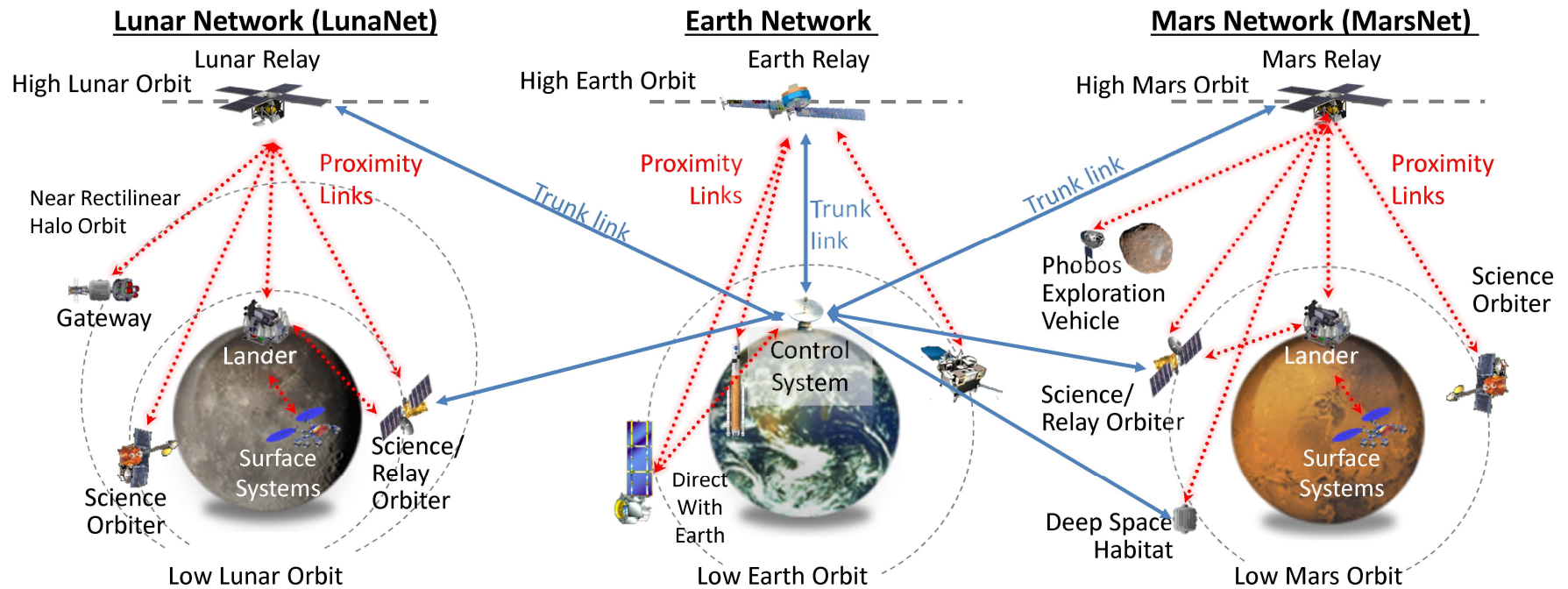
- ***LunaNet*** is envisioned as a **set of cooperating networks providing communications and navigation services for users on and around the Moon**. The ***LunaNet*** concept is **based on a framework of mutually agreed-upon standards, protocols, and interface requirements that enable interoperability**. ***LunaNet*** is intended to allow many lunar mission users to engage the services of diverse commercial and government service providers in an open and evolvable architecture.
- Service-Oriented: ***LunaNet*** services can include data transmission and distribution of position, navigation, timing (PNT), and situational awareness information.
- Scalable: ***LunaNet*** can be introduced as part of the earliest missions and accommodate expansion as new users and service providers come online.
- Open: ***LunaNet*** is based on open international standards like the Internet
- Resilient: As ***LunaNet*** grows into many networks and users, it becomes steadily more resilient to individual failures and outages
- Secure: ***LunaNet*** protects sensitive and proprietary data while preventing or rapidly recovering from cyber threats
- Extensible: The ***LunaNet*** concept is applicable to any planetary body.
- ***LunaNet*** is not a particular satellite or constellation of satellites, nor is it a project, program, or organization.



There is broad interest in developing and implementing lunar communications & PNT services among industry (US and foreign), international partners, and NASA.

Planetary Networks: Earth, Moon and Mars – One Architecture

UNCLASSIFIED

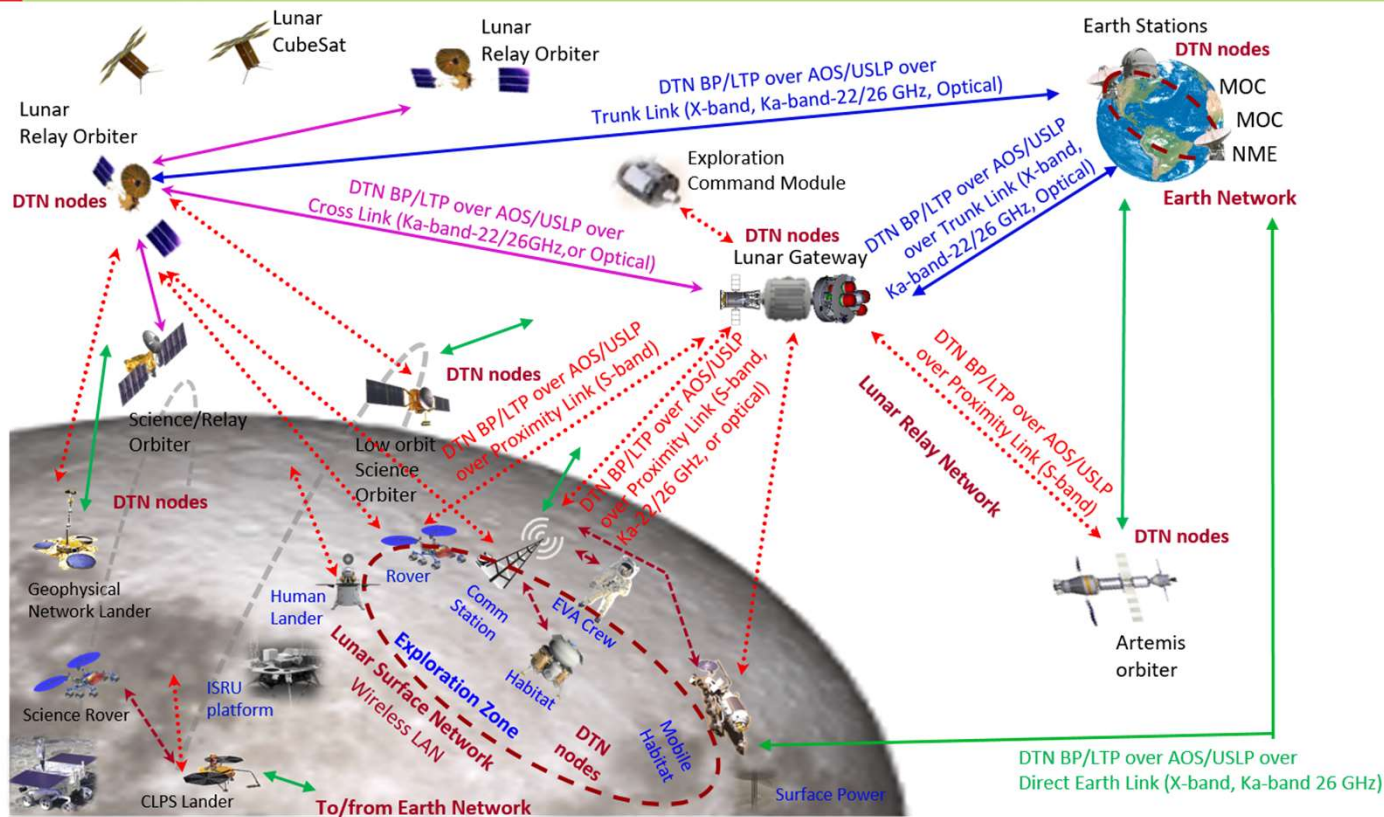


- Strategy: Develop a flexible *planetary network* architecture adaptable to any celestial body to reduce development & operation cost
- **User-network proximity links** (space-space & space-ground/surface) provide standardized services & design for users of planetary networks
- **Network-network Trunk links** are internal network space-ground connections for long distance “back haul”

- **International Partners have approved: Service Catalogs; International Standards; Lunar Architecture**
- **ESA has initiated Moonlight Program for lunar Communication & Navigation services consistent with LunaNet**
- **International Mars Ice Mapper study is proposing MarsNet with dedicated relay satellites**

UNCLASSIFIED

LunaNet Architecture (~2030)

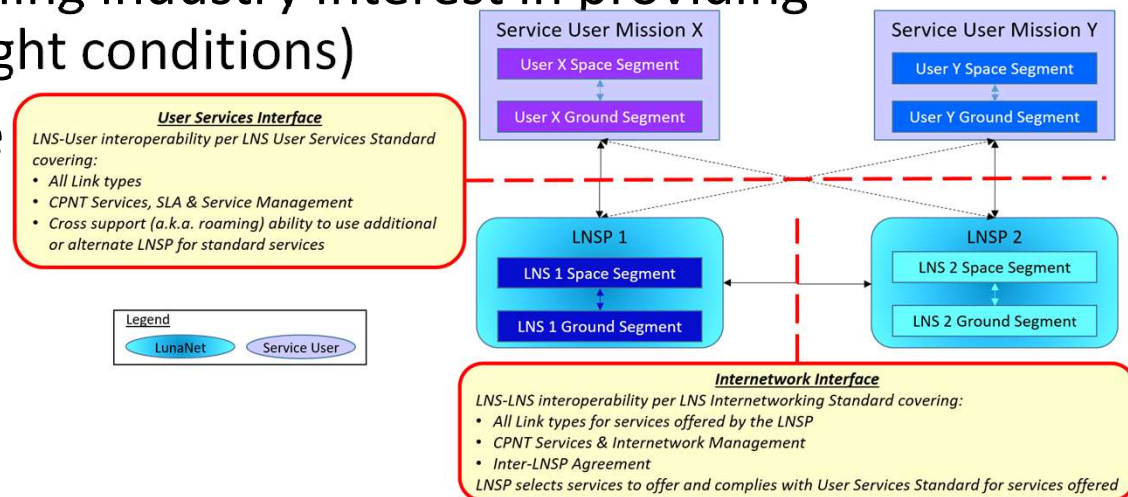


- ↔ Moon-to/from-Earth trunk link:
Between relay orbiter and Earth station
- ↔ Moon-to/from-Earth link:
Between Lunar orbiter/landed vehicle and Earth station
- ↔ Proximity link:
Between relay orbiter and landed vehicle/orbital vehicle
- ↔ Cross link:
Between two relay orbiters
- ↔ Lunar surface-to-surface link:
Wireless link between surface elements
- ⊖ Lunar Relay Network;
Lunar Surface Network;
Earth Network



Progress: LunaNet

- Artemis Program baselined need for South Pole relayed communications
- Science Mission Directorate is using Commercial Lunar Payload Services (CLPS) to deliver a far-side landing in 2024 that requires relay support
- LunaNet effort in formulation for this budget cycle
- Lunar Communications Relay and Navigation Services RFI (Oct 2020) received numerous inputs confirming industry interest in providing commercial services (under the right conditions)
- Establishing GSFC Project office
- Refining LunaNet Architecture, ConOps & requirements



Planned Upgrades



- Acquisition strategy is being developed for new lunar relay and navigation services to provide initial LunaNet service to orbiters and surface systems by 2024.
- Deep Space Network (DSN)
 - Upgrade Six 34-meter antennas (Readiness: FY 2023)
 - Include X-band commercial upgrades and Ka-band risk reduction test
- Low Cost Optical Terminal (LCOT)
 - Develop optical ground station design
 - Upgrade one ground station for optical capability with plans for 2 more



Plan for Commercial Communications Services

“Divide and Conquer” approach is tailored to market capabilities and risks...



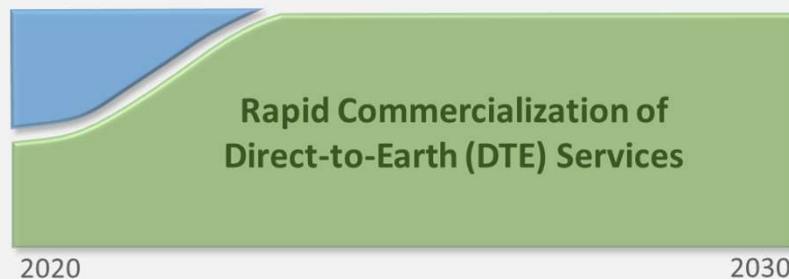
Space Network:
Commercialization Target



- NASA will no longer build/deploy Tracking and Data Relay Satellites (TDRS); current network can support users into the early 2030’s
- Time required to gradually transition future NASA users
- New commercial SATCOM capability used only for new missions; legacy missions fly out on the Space Network
- Glenn Research Center (GRC) is assigned responsibility for demonstration and initial planning for acquisition of SATCOM services



Near Earth Network:
Commercialization Target



- Near-term increase in services provisioned by current commercial & partner ground sites
- Infuse new vendors drawing on vibrant, growing market
- Targeting 2023 for 100% commercial service; applies to existing and new missions
- Responsibility assigned to Goddard Space Flight Center (GSFC)

- NASA-owned service capability
- Commercially-provided



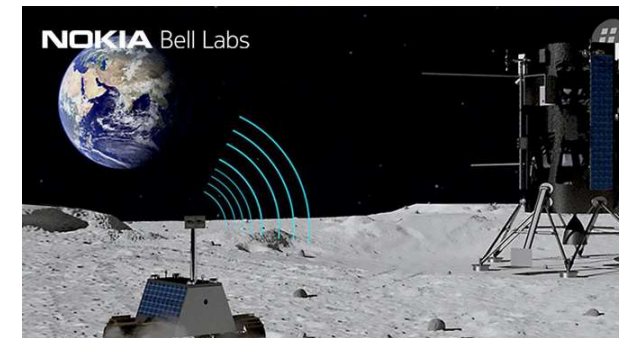
Planned: Lunar Exploration Ground Sites (LEGS)

- LEGS provides LOS transmit and receive RF communications in S, X, and Ka bands to user missions ranging in distance from the Geostationary orbit (min 36,000 km), through cis-lunar orbits, to Sun-Earth-Lagrange orbits (max 2,000,000 km).
 - Develop new 18-meter class Antenna (CDR: FY24; LEGS subnet readiness: FY26)
 - Three sites located $\sim 120^\circ$ apart provide global coverage & reduce DSN loading
 - Upgrade existing antennas at White Sands (site 1)
 - Obtain commercial service providers for sites 2 & 3
 - Backup plan for government implementation if necessary
 - Array antenna pairs to provide lunar & Lagrange orbits support using smaller antennas

Lunar Strategy: Technology



- Demonstrate & infuse technologies to enable Space Mobile Networking (SMN):
 - High Performance and High Availability Link Technologies
 - Wideband SW-Defined Radio for frequency & waveform agility
 - Position Navigation and Timing (PNT) Technologies
 - Internetworking Technologies
 - Demand Access Technologies, e.g., User Initiated Services (UIS)
 - Novel Hosted Services driven by mission requirements
 - Autonomy from Earth control
- Demonstrate optical communications & PNT capabilities
 - Initial demonstration on Artemis II (2023)
- 4G Long Term Evolution (LTE): Nokia to demonstrate the first LTE system in space by late 2022
 - Nokia's lunar network consists of an LTE Base Station with integrated Evolved Packet Core (EPC) functionalities, LTE User Equipment, RF antennas and high-reliability operations and maintenance (O&M) control software.
 - Evaluating post-mission use of 5G Non-Terrestrial Network (NTN) technologies



Nokia's rover talks to the base station on the lander via LTE

Photo: Nokia Bell Labs

Progress: PNT



- Global Navigation Satellite System (GNSS)
 - Lunar GNSS Receiver Experiment (LuGRE) funded for Commercial Lunar Payload Services (CLPS) mission in FY23 to characterize weak-signal GNSS reception (GPS & Galileo)
- Autonomous navigation
 - Computed robotic lunar landing trajectory using scenario to maneuver spacecraft, e.g., from 100 km orbit to 50 m altitude using Terrain Relative Navigation (TRN) and weak signal GNSS measurements
 - Working to integrate lunar surface image simulation that renders LRO Digital Elevation Map images into the software simulation testbed
- Optical Navigation: working LuNaMaps as part of the STMD Game Changing Development Program
- Search and Rescue (LunaSAR):
 - Began discussions with safety and medical community on requirements
 - Began software defined radio (SDR) design for transmitting distress message
 - Defined distress message format fields for suit, biomed & customized text



Firefly Aerospace's Blue Ghost lander will carry Next Gen Lunar Retro-reflectors (NGLR), Reconfigurable, Radiation Tolerant Computer System (RadPC), & LuGRE
Credit: Firefly Aerospace

Gaps and Seams in a Coordinated Effort



- Define lunar network acquisition strategy & open LunaNet architecture definition with industry partners
- Resolve spectrum use of UHF & L-band while preserving the far-side Shielded Zone of the Moon for radio astronomy
- Infuse multi-GNSS & lunar PNT capabilities into operations
- Standardize Optical comms & PNT & infuse into operations
- Coordinate architecture & R&D to leverage DoD's Fully Networked C3 (FNC3) & Joint All Domain C2 (JADC2) efforts
 - Focus areas on security and multi-network service management
- Develop interoperable Joint military, intelligence & civil lunar capabilities
 - Good progress to date on international interoperability among civil agencies & supporting industry
 - Excellent international agreement on emerging LunaNet & MarsNet architectures
 - Communications standards more mature than PNT but dominated by government

A detailed grayscale image of the Moon's surface, showing numerous craters and lunar maria. The word "Summary" is overlaid in a light blue, sans-serif font.

Summary

- NASA's networks are undergoing rapid change which will continue through the 2020s driven by major initiatives in Human Exploration and Science
- Planetary networking approach offers a path to flexible, scalable, interoperable architectures across the solar system open to all who participate
 - NASA & international partners starting to move out on LunaNet
- Accelerating transition to commercial service providers who will increasingly introduce new standards & technologies
- Opportunity exists *now* to coordinate military, intelligence & civil government needs for more capable, less costly future
 - Needs to be secure & resilient
 - Needs to mature PNT technologies
 - Needs to mature optical communications & PNT technologies
 - Needs to integrate communications, networking, & PNT capabilities

UNCLASSIFIED



Questions?

UNCLASSIFIED

Backup



UNCLASSIFIED

LunaNet RFI Results



- Lunar Communications Relay and Navigation Services RFI results
 - Released: Oct 1, 2020; Responses: Oct 30, 2020
 - 32 Responses – large & small businesses, US & foreign
 - 15 defined a relay architecture approach
 - Several potential providers might meet initial mission comm & PNT needs by 2024 need date
 - There is commercial interest in service contracts and other approaches that might reduce start up costs to NASA
 - Most common technical approach was a 150-300 kg smallsat relay (1 or more satellites)
 - Other interesting approaches involve hosted communications relay & PNT payload
 - Multiple opportunities for international partnerships may exist
 - Commercial Lunar Payload Services (CLPS) & other lunar missions may provide rideshare opportunities for affordable deployment
- SCaN Board of Directors authorized SCaN to begin preparing implementation of initial lunar network capabilities

Report of the
Interagency Operations Advisory Group
Lunar Communications Architecture Working Group



The Future
Lunar Communications Architecture

Final Version, V1.2

1 February 2020

Page | 1

LunaNet RFI Results



- Lunar Communications Relay and Navigation Services RFI results
 - Released: Oct 1, 2020; Responses: Oct 30, 2020
 - 32 Responses – large & small businesses, US & foreign
 - 15 defined a relay architecture approach
 - Several potential providers might meet initial mission comm & PNT needs by 2024 need date
 - There is commercial interest in service contracts and other approaches that might reduce start up costs to NASA
 - Most common technical approach was a 150-300 kg smallsat relay (satellites)
 - Other interesting approaches involve hosted communications relay payload
 - Multiple opportunities for international partnerships may exist
 - Commercial Lunar Payload Services (CLPS) & other lunar missions provide rideshare opportunities for affordable deployment
- SCaN Board of Directors authorized SCaN to begin preparing implementation of initial lunar network capabilities

Report of the
Interagency Operations Advisory Group
Lunar Communications Architecture Working Group



The Future
Lunar Communications Architecture

Final Version, V1.2

Lunar Communications Architecture Working Group - Membership

Co-chairs

Matthew Cosby	UK Space Agency
Wallace Tai	Jet Propulsion Laboratory, California Institute of Technology

Members:

Fabio Damico	ASI
Jean-Luc Issler	CNES
He-Shan Bao	CNSA
Jerome Colinas	CSA
Neal Lii	DLR
Marco Lanucara	ESA ESOC
Andres Grop	ESA ESOC
Takahiro Yamada	JAXA
Durk-Jong Park	KARI
David Israel	NASA GSFC
James Schier	NASA HQ
Gulyaev Iv	ROSCOSMOS

Planetary Network Services



Networked Communication Services

- Critical data transmitted in real time.
- Data aggregated and transmitted in store-and-forward mode from orbiting and surface relays
- Data exchanged among lunar users with no need for transfer to and from Earth
- Data sent on demand by user or scheduled to better manage Earth stations loading & spectrum use

PNT Services

- Precise position, velocity & time for autonomous nav & collision avoidance
- Fusion of multiple data types including radiometrics, optometrics, celestial nav, optical nav, terrain relative nav, & GNSS
- Broadcast service supplies time transfer and metric tracking to synchronize users



Detection & Information Services

- Alerts for events such as space weather, collision avoidance, & surface impact predictions sent to all LunaNet subscribers
- Mission sensors for space weather and other measurements distribute information services to other users via LunaNet information services

Science Services

- Use RF & optical assets (part of) as scientific instruments
- Supports Radio & Radar Sciences, Radio Astronomy / Very Long Baseline Interferometry (VLBI) & other space sciences

Transition To Commercial Services: Communications Services Project

UNCLASSIFIED



- Focus on demonstrating the feasibility of commercial SATCOM* providing data services to space users:
 - Establish public private partnerships to leverage private investment and existing commercial satellite communications infrastructure for the development and demonstration of end-to-end capability
 - Critical step to increasing confidence and ensuring services are ready for operations
 - Rolling wave approach of demonstrating new or expanded services over the 2020's
- Objective is to have multiple providers demonstrate services during each demo period
 - The business case, user burden, performance and security are key aspects to address
 - Nearer term opportunity to meet a subset of user needs with existing commercial capabilities
 - As commercial capabilities are matured and demonstrated, broader set of capabilities and user needs will be met – take advantage of dynamic market capability and evolution
- NASA will evaluate acquisition and operationalization of demonstrated services



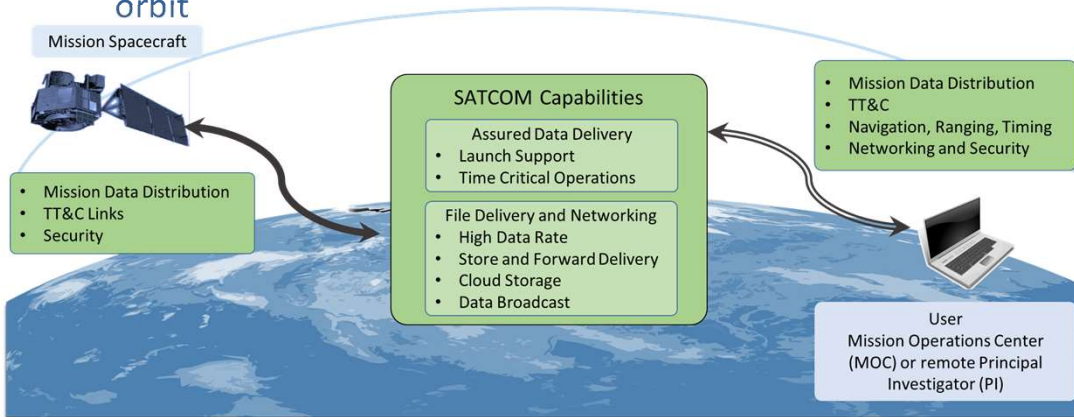
*SATCOM = services provided via space relay

Capability Demonstration Concept



Demonstration Goals

- To facilitate U.S. private industry demonstration of commercial SATCOM capabilities with the goal of achieving robust, reliable, and cost-effective communications to spacecraft in near-Earth orbit



Demonstration Approach

- Two Key Interfaces: service-spacecraft, and spacecraft-MOC
- Commercial services are composed of ground, space, and mission planning capabilities

Demonstration Concept

- Establish multiple public private partnerships (PPPs)
 - Shared resources, cost, and/or risk
- Demonstrate a portfolio of end-to-end commercial capabilities that may meet future NASA mission needs
 - The demonstrations are risk reduction activities to develop multiple capabilities
 - Demonstrations will be agnostic to vendor technology, orbits, and data pathway
 - Demonstrations selected should be extensible for a class of missions
 - Minimize the need for NASA-unique capabilities. CSP seeks to be one of many users
- Capabilities demonstrated in Phase 2 can be considered for the end-to-end services acquisition in Phase 3

Demonstrations will provide performance validation, operational constructs and acquisition models needed to acquire commercial services

Transition To More Secure Architecture & Operations



- NASA is driven by many of the same reasons as DoD towards more resilience: contention, congestion, efficiency, reserve capacity, operational flexibility, cyber threats, partner (joint/allied) operations ...
- Planetary network architecture, particularly introduction of networking services, exposes space networks to the same cyber vulnerabilities as terrestrial networks – need the same attention to mitigate threats
- Need exists for DoD/IC community to enhance civil community's architecture to security level that meets DoD/IC needs
- Architecture is open & known to bad actors – Security must be addressed across the life cycle – architecture, design, development, test, & operations