Enabling Future Science and Human Exploration with NASA's Next Generation Near Earth and Deep Space Communications and Navigation Architecture

***Richard Reinhart*, Glenn Research Center, Principal Investigator, Next Generation Earth Relay Pathfinder**

James Schier, Headquarters, Chief Architect, Space Communication & Navigation

David Israel, Goddard Space Flight Center, Principal Investigator, Laser Communications Relay Demonstration

Wallace Tai, NASA Jet Propulsion Laboratory, Caltech, Chief Engineer, Interplanetary Network

Philip Liebrecht, Headquarters, Deputy Program Manager, Space Communications and Navigation

Stephen Townes, NASA Jet Propulsion Laboratory, California Institute of Technology (Caltech) Chief Technologist, Interplanetary Network Directory

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NASA Acronyms

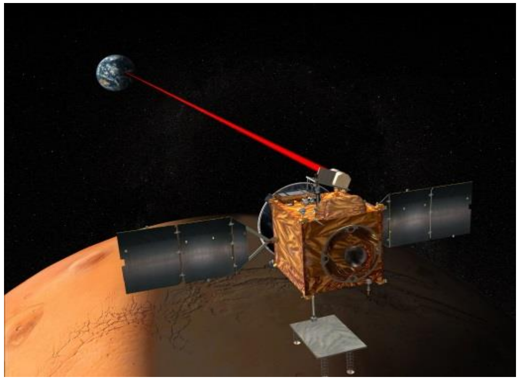
- SCaN = Space Communications and Navigation
- SCaN - A Program Office within the NASA Human Exploration and Operations Directorate @ NASA HQ, Washington D.C.
- SCaN Network/Architecture = NASA's satellite and ground station infrastructure to return science and exploration data to investigators on Earth
  - SN = Space Network (TDRSS = Tracking and Data Relay Satellite System made up of individual TDRS and WSC = White Sands Complex, ground stations)
  - NEN = Near Earth Network (NASA & commercial ground stations)
  - DSN = Deep Space Network (NASA JPL operated ground stations)

Overview

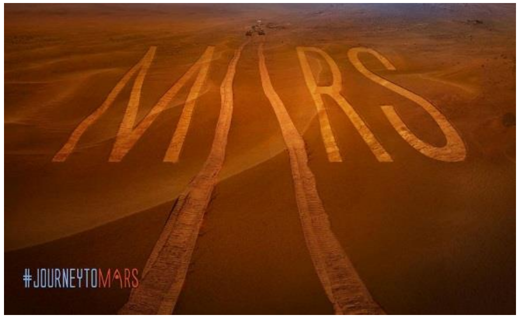
- NASA’s mission & existing SCaN Architecture
- NASA’s Next Generation SCaN Architecture
  - Requirements/Drivers
  - Architecture Characteristics/Services
  - Planetary Networks
  - Technology Investments
  - Approach/Activities

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.



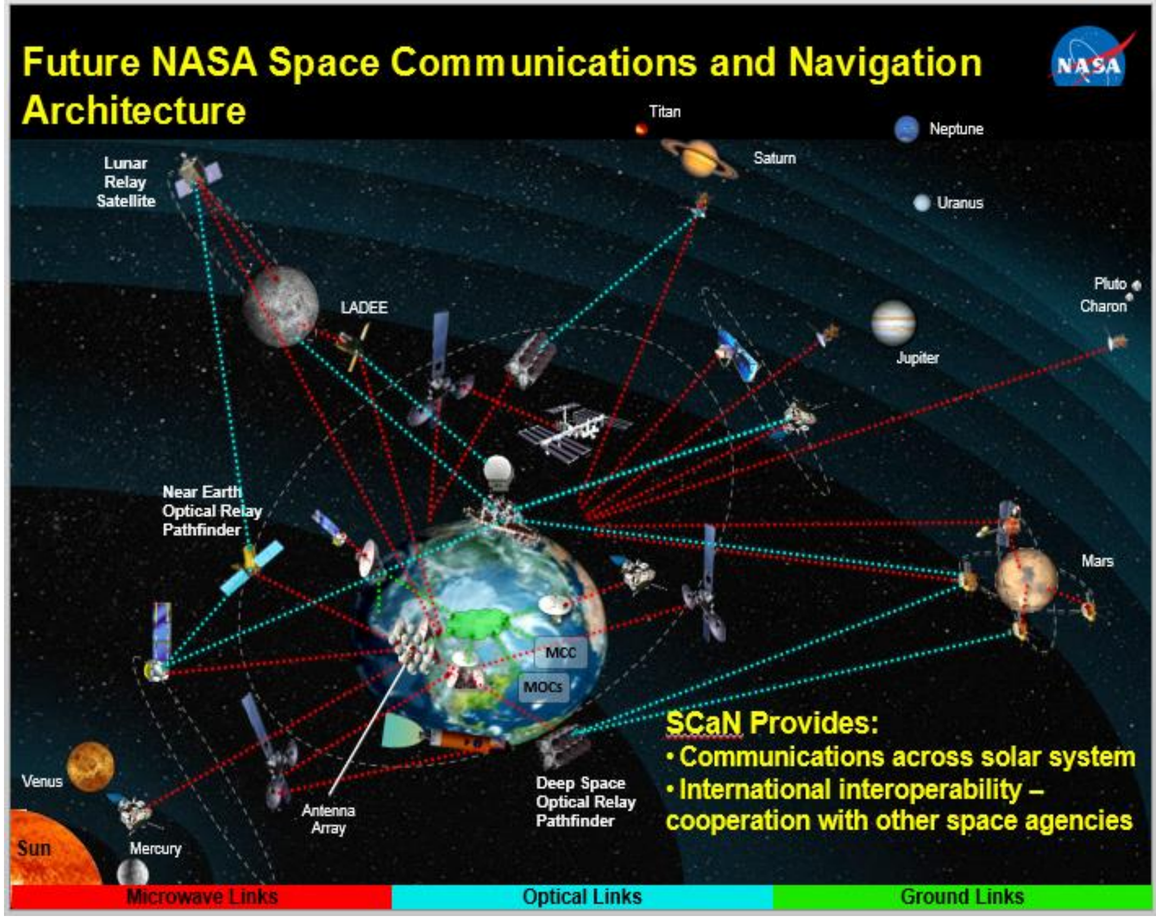
- Manage spectrum and represent NASA on national and international spectrum management programs.
- Develop space communication standards as well as Positioning, Navigation, and Timing (PNT) policy.



- 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 Requirements for SCaN

- A unified space network for both robotic and human exploration.
- A networked comm/nav infrastructure across space.
- Highest data rates feasible for both robotic/human missions
- Internationally interoperable communication protocols
- Infrastructure and services for Lunar and Mars surfaces and human missions
- Meet comm and nav service commitments to existing and planned missions.



Study of Earth, Sun, planetary, human exploration

NASA Networks Span the Globe

Deep Space Network | Near Earth Network | Space Network

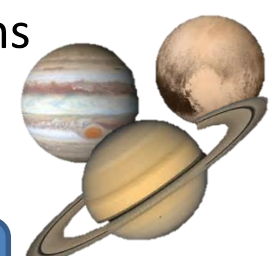
Note: Network details in presentation backup

Main Drivers of the Next Gen Architecture

- Augment Earth relay satellite infrastructure with optical communications
  - Provide unprecedented data throughput enabling new science opportunities
  - Replenish Earth Relays beginning 2025 - TDRS are nearing their design lifetime

- Lunar communications – focused on Moon vicinity, polar, far-side coverage
  - Driven by human exploration and coordination with international partners
  - Deep Space Gateway space vehicle with Power Propulsion Element

- Build-up Mars comm/nav infrastructure for robotic and human exploration
  - Augment science satellite relays with dedicated Mars relays for greater availability
  - Mars Reconnaissance Orbiter (MRO) reaching end of design life in 2025 timeframe



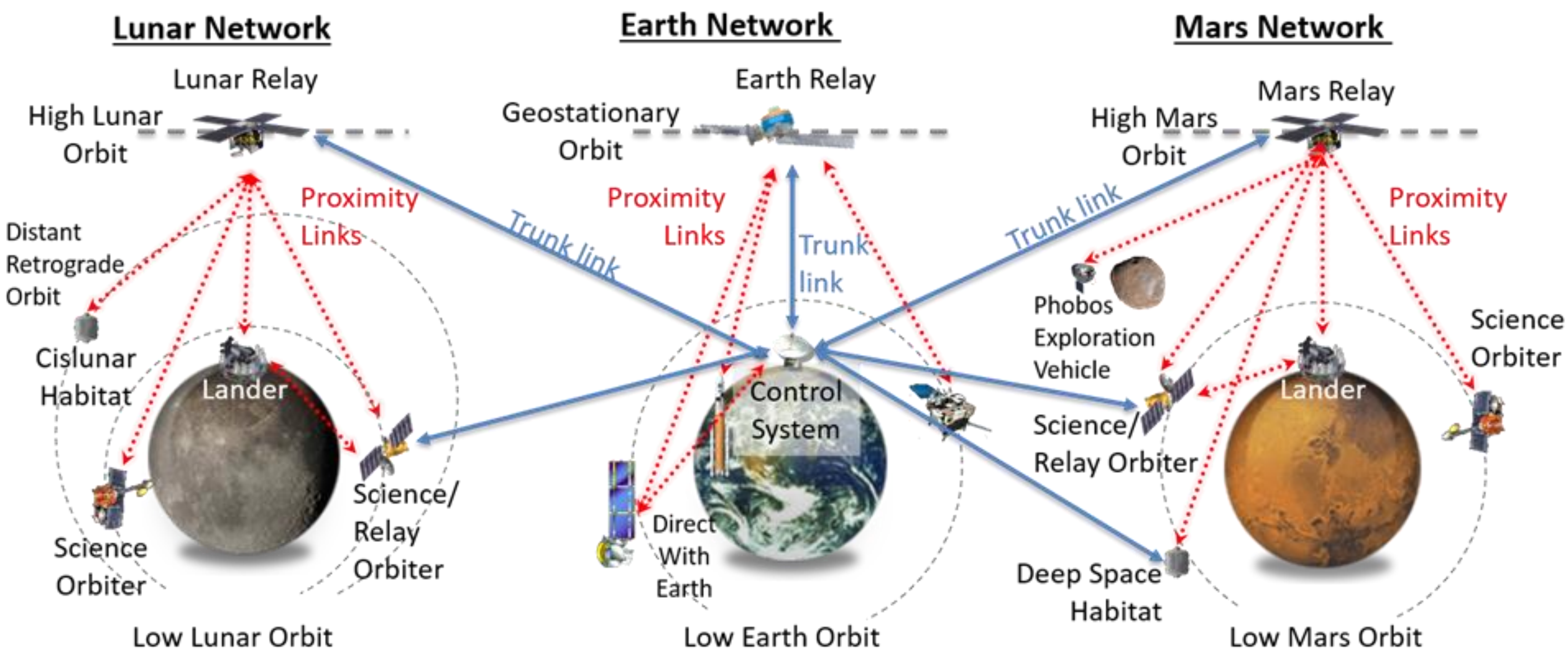
- Extend architecture and planetary advancements to deep space missions
  - Increased capacity, throughput, data rates. New services (e.g optical, DTN)
  - More efficient network (multiple user/antenna) and user spacecraft

Future Com Architecture spans 2025 to 2040+

Next Generation SCaN Architecture Vision

- "Shrink" the solar system by connecting the principle investigator more closely to the instrument, the mission controller to the spacecraft, and the astronaut to the public
- Improve the *mission's experience* and reduce *mission burden* – the effort and cost to design/operate spacecraft to receive services from SCaN Network
- Reduce *network burden* – the effort and cost required to design, operate, and sustain the SCaN Network as it provides services to missions
- Apply new and enhanced capabilities of terrestrial telecommunications and navigation to space leveraging other organizations' investments
- Enable growth of commercial services for missions currently dominated by government capabilities
- Enable greater international collaboration and lower costs in space by establishing an open architecture with interoperable services that can be adopted by international agencies and as well as NASA

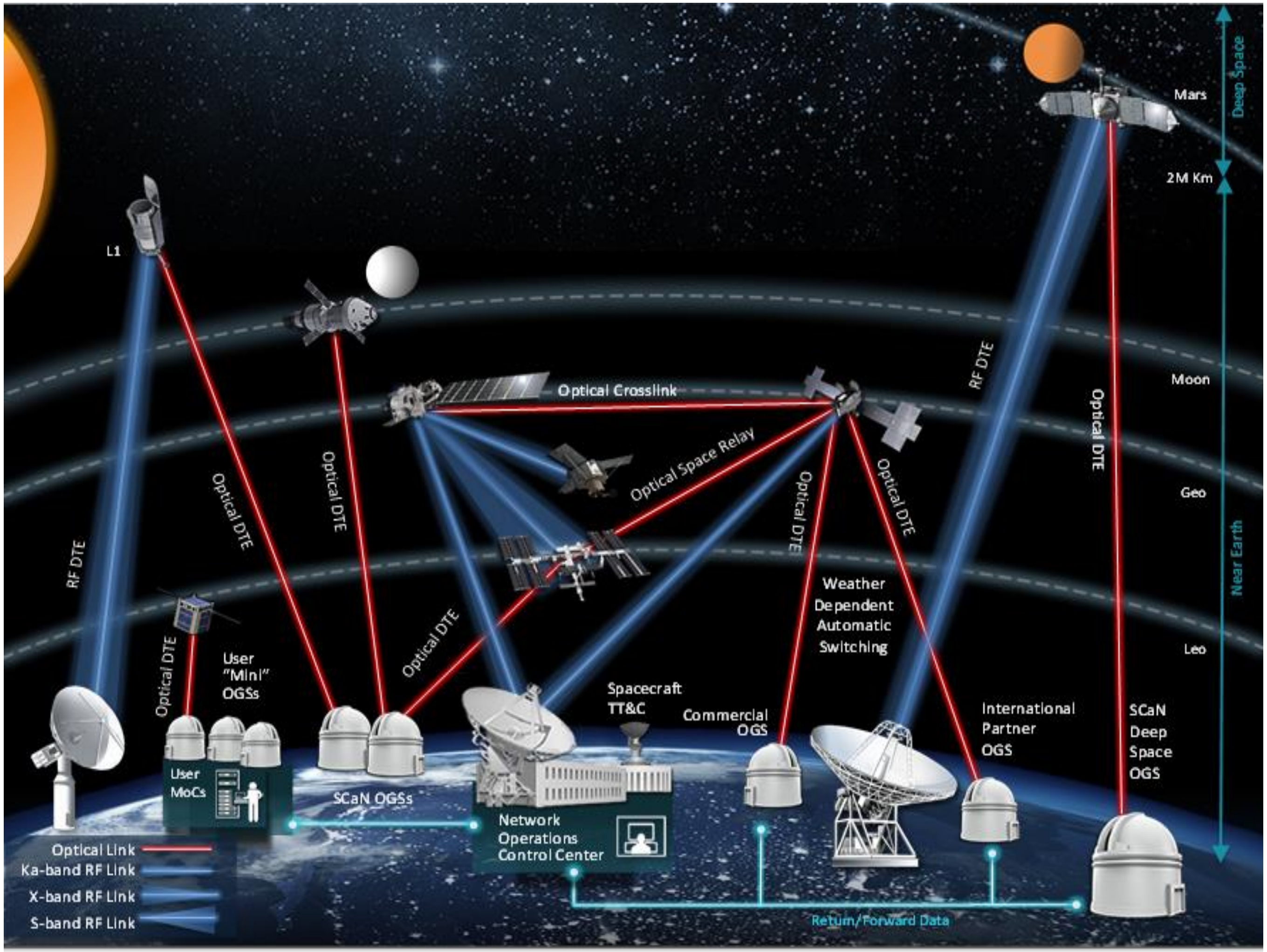
Planetary Networks for Earth, Mars, and Moon



- Common features, functionality, terminals, terminology reduces cost
- Reduced mission burden for proximity links for in-system communications
- International cooperation, cross support, standards
- Reuse of hardware, software, and spectrum where applicable

Architect for Flexibility, Scalability, & Affordability – Implement as required to meet specific mission needs

Initial near Earth Communications and Navigation Architecture Concept



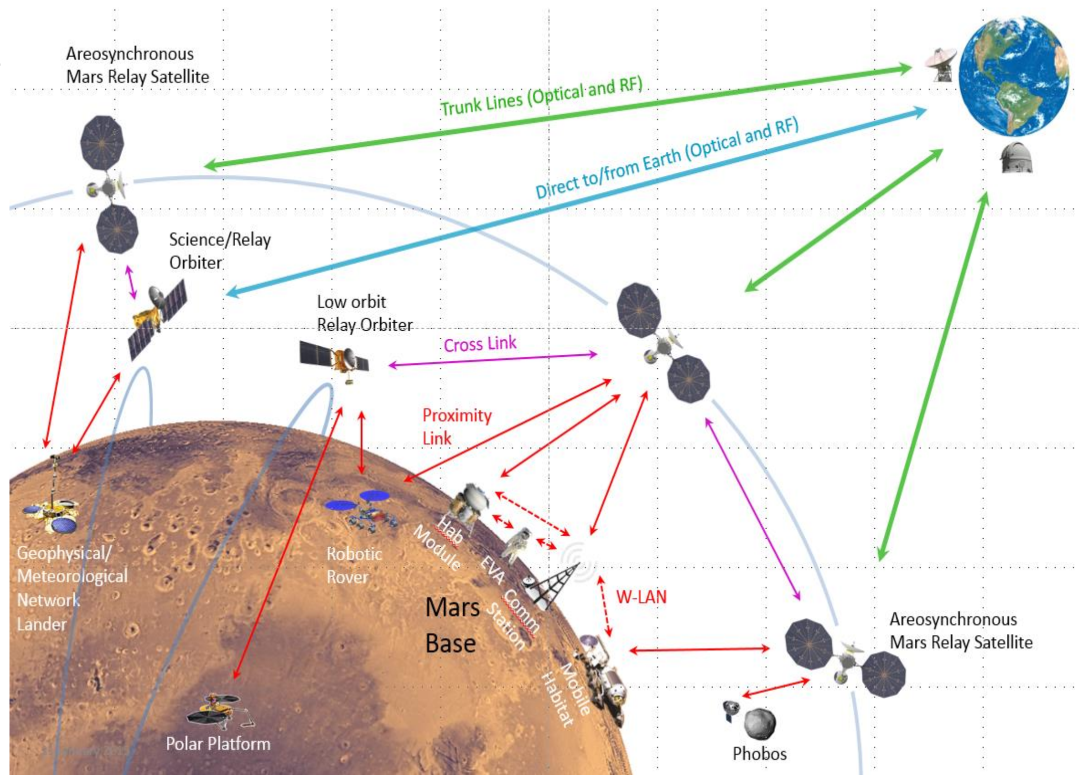
- Full coverage network with relay orbiters in GEO/MEO & possibly other orbits
- Optical user, cross links with ground telescopes provide continuous optical support
- Mix of NASA, commercial, & international service providers
- Ground/space assets for low end-to-end forward/return data latency
- Services provided to 2M km (limit of near Earth spectrum allocation)

Earth Network Architecture Service Highlights

- Service-Oriented Architecture (SOA) – emphasize network and mission goals, interoperability, common services, flexibility, and network evolution
- Existing services: Communications, Navigation, Radio Metric
- New services: Space Internetworking (network layer service using IP v6 & DTN), Broadcast/messaging (e.g user initiated service for automated scheduling), timing
- Application layer services such as look-up, directory, caching, storage, alarms/alerts (e.g. space weather, cosmic events, spacecraft emergencies)
- Orbit determination & Geolocation using GPS within expanded Space Service Volume
- Inter-agency service management based on CCSDS standards

Deep Space Mars Communications and Navigation Architecture Concept

- Mars Network architecture
  - Dedicated relay orbiters in high Mars orbit (areosynchronous?) for full coverage and/or relay payloads on science orbiters
    - Coverage focused on Mars Base
    - Coverage includes Phobos & Deimos
  - Continuous trunk line available to Earth for low end-to-end forward/return data latency
  - Deep space optical terminals deployed on mission spacecraft, the relay orbiter, and surface elements with Earth based telescopes.
- New/enhanced Services Highlights
  - Network layer service using DTN
  - Celeslocation service: positioning service upgraded to provide GPS-like surface nav
  - SOA services: Application layer services such as look-up, directory, caching, storage, messaging, alarms/alerts



Notional Mars Architecture

Technologies for future architecture

Advanced Technologies → **Network Enhancements** → Mission Capability →

Advanced Technologies	Network Enhancements	Mission Capability
Optical communications	**Increased capacity**	**Increased data volume return**
On-board processing and routing	**Improved multiple access service**	**Assured data delivery**
Ka-band and optical multiple access techniques	**Space Internetworking (network layer service including IP & DTN)**	**Reduced user terminal burden (size, mass, power)**
Cognitive communications	**Adaptive/automated link configuration, navigation, and service requests**	**Synchronization, time, automated positioning**
Multiband, multimode Ka-band & optical user terminals	**Enhanced security and resilience**	**Greater control, access, connectivity, efficiency**
Electrically steered Ka-band antennas	**International & commercial cross support**	

Relay Satellite

System

User Terminal

Architecture Approach & Sample of Activities Underway

- In-house studies in 2013-2015 to define NextGen architecture, ConOps, & capabilities
- Industry led studies in 2016 (Boeing, Lockheed Martin, Northrop Gruman, Schafer) for capability to meet specific level of NASA needs (conference references in the paper)
- Promote adoption of interoperable space architecture across NASA, international partners, other government agencies, & commercial entities
  - Actively working with international partners, OGAs, industry (recent RFI for US industry)
- Transition LCRD to operations after demo phase for near-Earth optical capability by ~2021
- Reduce user burden: Develop Ka-band & optical mission s/c terminals for new key services and incentivize initial mission use through funded or shared funded partnerships
  - Use SW Defined Radios (SDR) to promote common radio HW & SW across domains
- Expand use of multiple access service to better match bandwidth structure to mission usage characteristics & reduce use of Single Access services (gain efficiency)
- Introduce on-demand and User Initiated Services → Reduce scheduling for most missions
- Transition from near Earth Ku-band to near Earth Ka-band as primary high rate RF band
- Improve spacecraft autonomous navigation (autonav)
  - Deep Space Atomic Clock for precise time service, autonav, & to reduce need for DSN tracking

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Keeping the Universe Connected