Strategy and Architecture for Evolution of Space Comm and Navigation Networks

Jim Schier, Chief Architect & Dep. Director System Engineering
Space Communications and Navigation (SCaN) Program
September 14, 2016

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 audience
- **Improve the *mission's experience*** and **reduce *mission burden*** – the effort and cost required to design and operate spacecraft to receive services from the SCaN Network
- **Reduce *network burden*** – the effort and cost required to design, operate, and sustain the SCaN Network as it provides services to missions with the collateral benefit of increasing funding for C&N technology
- **Apply new and enhanced capabilities** of terrestrial telecommunications and navigation to space leveraging other organizations' investments
- **Enable growth of the domestic commercial space market** to provide – and NASA to use – commercial services currently dominated by government capabilities
- **Enable greater international collaboration** and lower costs in space by establishing an open architecture with interoperable services that foster commercial competition and can be adopted by international agencies and as well as NASA

Shift: RF to RF + Optical

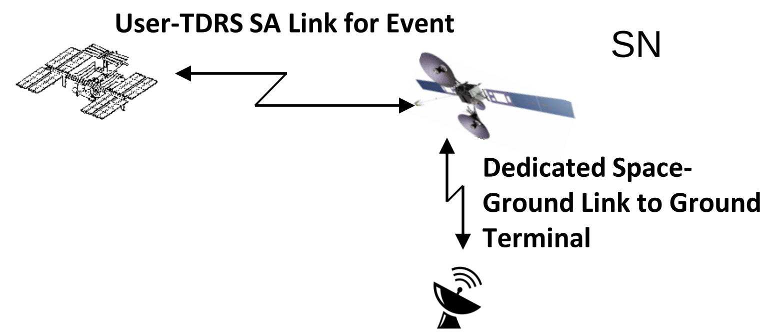
- Transition Laser Comm Relay Demo (LCRD) to operations after 2019-2021 demonstration phase for initial Earth Network optical capability by ~2021
- LEO terminal being developed for ISS as 1st user
- Discovery AO incentivized bidders for deep space optical
  - 3 of 5 bids selected chose to include an optical payload
- Optical technology promises
  - High data rates with low SWaP & cost for users & relays
  - Optical platform's built-in vibration isolation reduces impact on spacecraft bus of gimbaled antenna

Shift: Single Access to Multiple Access

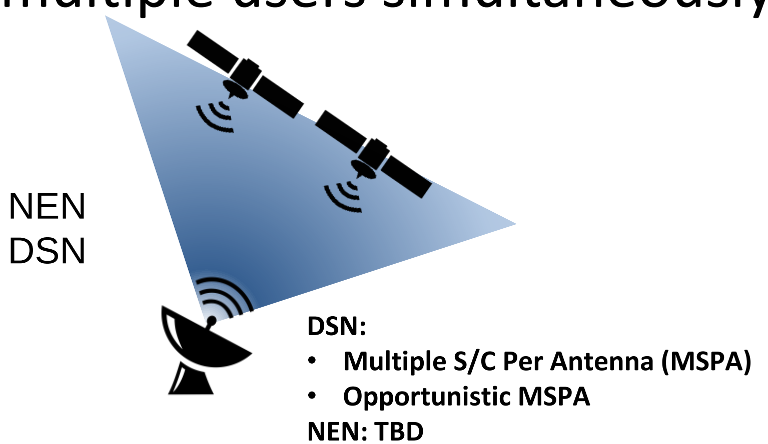
- Under-utilizing network: Missions use TDRSS Single Access at a fraction of capacity
  - HST uses S-band SA at 1 Mbps – TDRS max rate is 300 Mbps
- Approach: Match structure of network services to mission usage characteristics by expanding use of Multiple Access & reducing use of Single Access
  - Introduce demand access service: user requests access when he needs it & gets BW that he needs

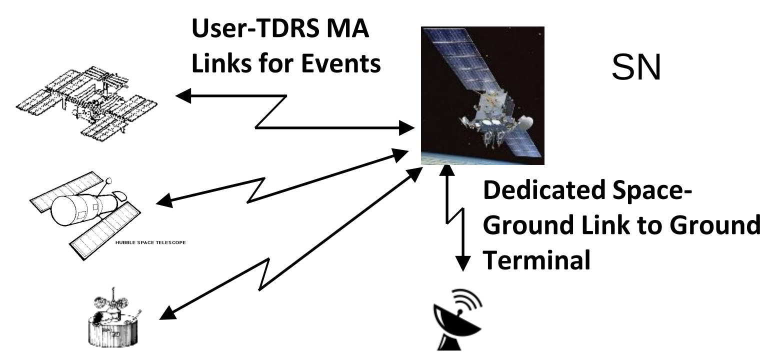
Single Access vs. Multiple Access

- Single Access points one network antenna to one user antenna & commits both for duration of event → *connection-oriented* like telephone switchboards



- Multiple Access enables one network antenna to talk to multiple users simultaneously in same overall system bandwidth





Shift: Scheduled to Unscheduled Access

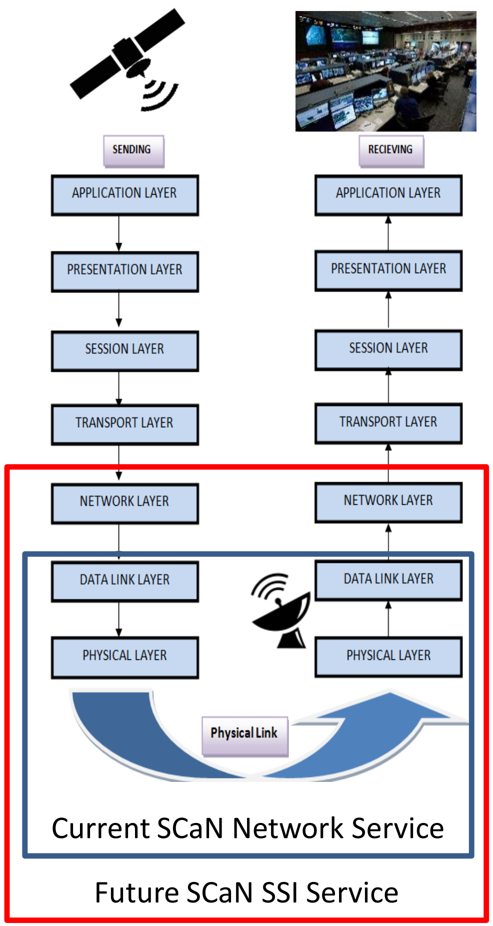
- All missions schedule events (passes) days-weeks in advance
  - Process is labor-intensive
- Unreliable data delivery forces missions to schedule extra events & repeat transmissions
  - Scheduling is NP-hard – TDRSS schedules ~60% efficient
- Approach:
  - Expand use of Multiple Access; reduce Single Access
  - Introduce demand access services
  - Shift from (unreliable) link layer to (guaranteed) network layer service using Disruption Tolerant Networking (DTN)
- Result: Eliminate scheduling for most missions
  - Enables further system automation & operations cost reduction

Shift: Switch from Ku- to Ka-band

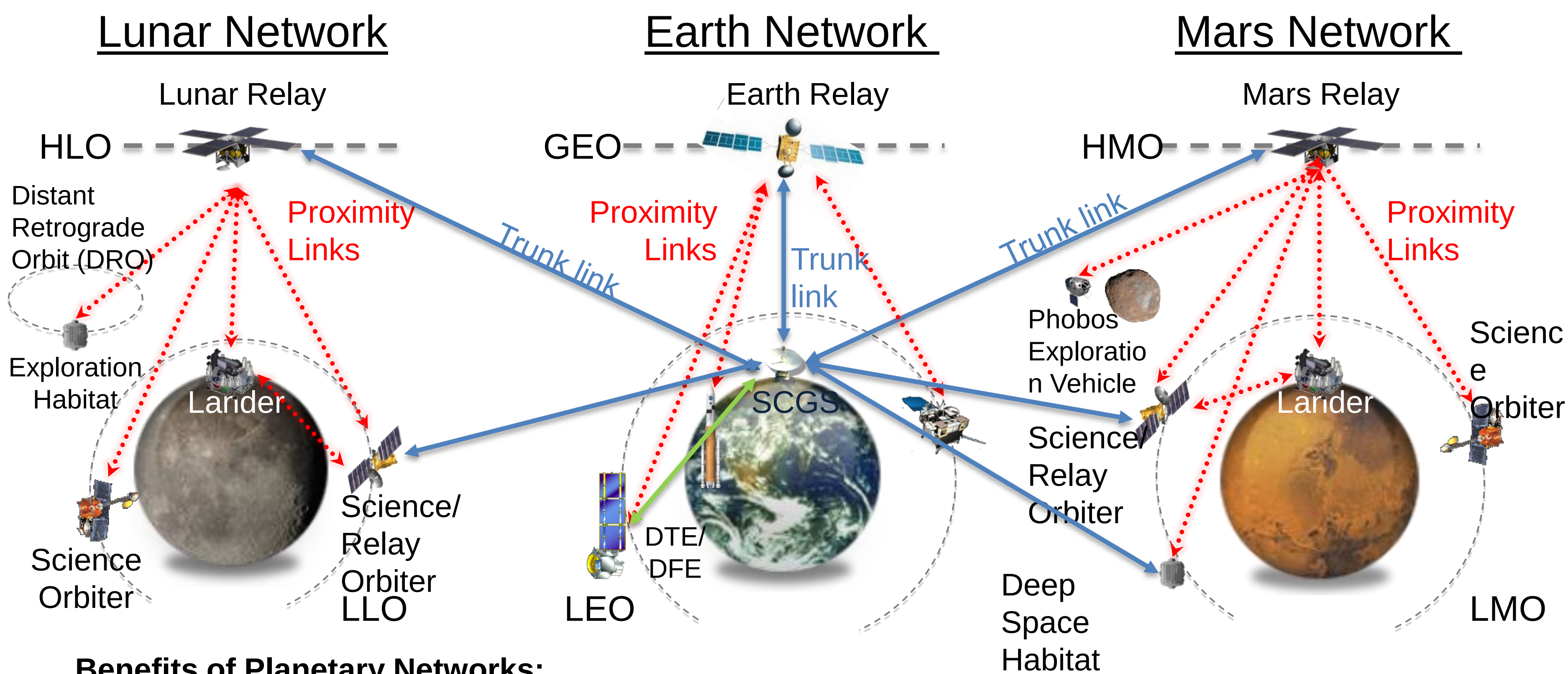
- Spectrum pressure: NASA agreed to NTIA direction to move out of Ku-band space-to-space (eventually)
  - NASA incorporated Ka-band starting with TDRS H (2000)
  - NASA also obtained Ka-band space-to-ground allocation
- Ka-band can provide higher data rates at higher frequencies with lower spacecraft SWaP
  - Need to invest in user terminals to bring cost down & overcome user community reluctance to adopt Ka
- Eliminate Ku-band from Next Gen Earth Relay

Services: Link Layer to Network Layer

- Link layer services don't guarantee data delivery
  - Mission Operations Centers (MOC) develop SW to process data for errors, resend data, command s/c when to delete data from memory
  - Application layer protocols such as CCSDS File Delivery Protocol (CFDP) with Automatic Repeat Request (ARQ) provide reliable delivery over unreliable link layer protocols such as Space Packet
- Expand services to include space internetworking (Solar System Internet, SSI, using IP & DTN)
  - DTN guarantees delivery obviating need for MOC processing & retransmission reducing burden on both user ground & flight segments
- SSI enables a Service-Oriented Architecture (SOA) that can provide many added apps
- Data can move directly from MOC/MCC to PI or directly from spacecraft to PI



Planetary Networks: Earth, Moon and Mars – One Architecture



Benefits of Planetary Networks:

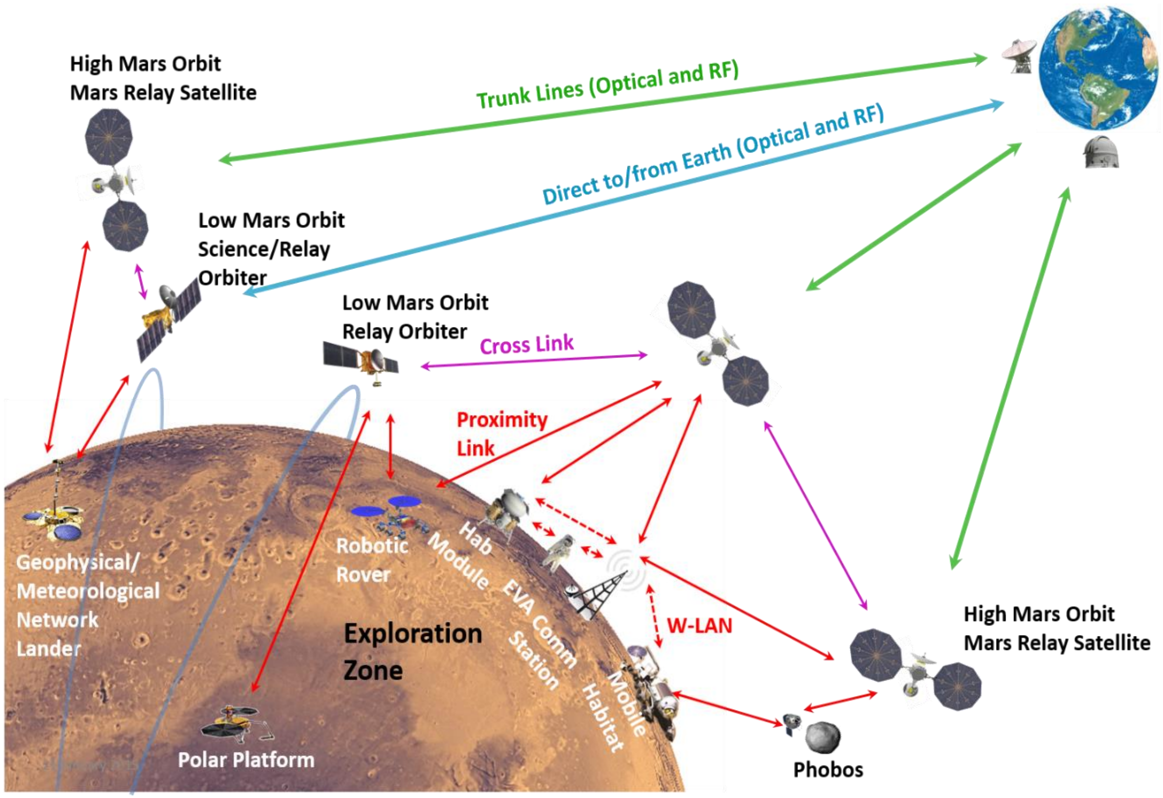
- **Reduced mission burden with short links for in-system communications - enables in-system telerobotics**
- **Common architecture reduces technology and development costs**
- **Reuse of HW and SW: Family of products includes variants for different environments**
- **Reuse of spectrum**

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

A New Mars Network for Human Exploration and Science

New/enhanced Services

- Network layer service using DTN
- Timing service
- Celeslocation service: positioning service upgraded to provide GPS-like surface location
- Inter-agency service management based on the CCSDS CSSM standard
- Optimetric data & tracking services
- SOA services: Application layer services such as look-up, directory, caching, storage, messaging, alarms/alerts



Mars Network architecture

- Network with dedicated relay orbiters in high Mars orbit and/or relay payloads on science orbiters
  - Coverage focused on Mars Base
  - Coverage includes Phobos and Deimos
- Continuous trunk line availability to Earth for low end-to-end forward/return data latency
- Deep Space Optical Capability (DSOC) terminals deployed on mission spacecraft, the dedicated relay orbiter, and surface elements
- Relay orbiters support return trunk line at ~150 mega-bits per second (Mbps) (Ka-band) and ~300 Mbps (optical) as well as 50 Mbps for the forward trunk line

Tying Next Gen Architecture to SBIR

SBIR Topics	Mapping to Vision	Mapping to Next Gen Paradigm Shifts
Long Range Optical Communications	• "Shrink" the solar system • Improve mission's experience & reduce mission burden • Reduce network burden • Apply new & enhanced capabilities • Enable growth of domestic comer-cial space market • Enable greater international collaboration	• RF to RF + Optical • Single access to multiple access • Different near Earth & deep space architectures to common architecture (planetary networks)
Intelligent Communications Systems		• Single access to multiple access • Link layer to network layer service provider
Advanced RF Communications		• Single access to multiple access • Switch from Ku-band to Ka-band • Different near Earth & deep space architectures to common architecture (planetary networks)
Flight Dynamics and Nav Tech		• RF to RF + Optical • Scheduled to unscheduled access
Transformational Communications Technology		• Single access to multiple access • Different near Earth & deep space architectures to common architecture (planetary networks)

NASA