SBIR Technology Applications to Space Communications and Navigation (SCaN)

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August 26, 2010

Outline

- SCaN Overview
- SCaN Architecture
  Near Earth Domain
  Lunar Network
  Mars and Other Deep Space Capabilities
  Ground Network - Integrated Services Portal
- SCaN Technology Development

Background

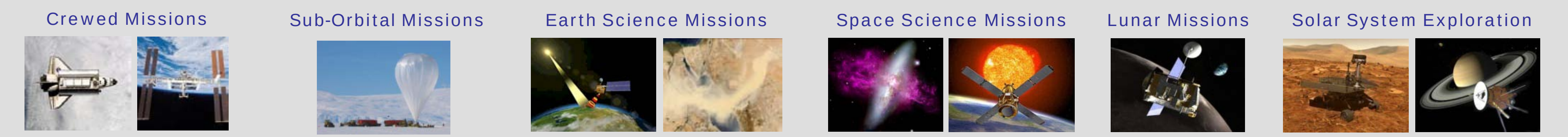
- In 2006, NASA Administrator assigned roles and responsibilities for the Agency's space communications and tracking assets to the SCaN Office.
- This mandate centralized the management of NASA's space communications and navigation networks: the Near Earth Network (NEN), the Space Network (SN), and the Deep Space Network (DSN).
- In a September 2007 memo, the Associate Administrator described the concept of an integrated network architecture.
- The new SCaN integrated network architecture is intentionally capability-driven and will continue to evolve as NASA makes key decisions involving technological feasibility, mission communication needs, and funding.

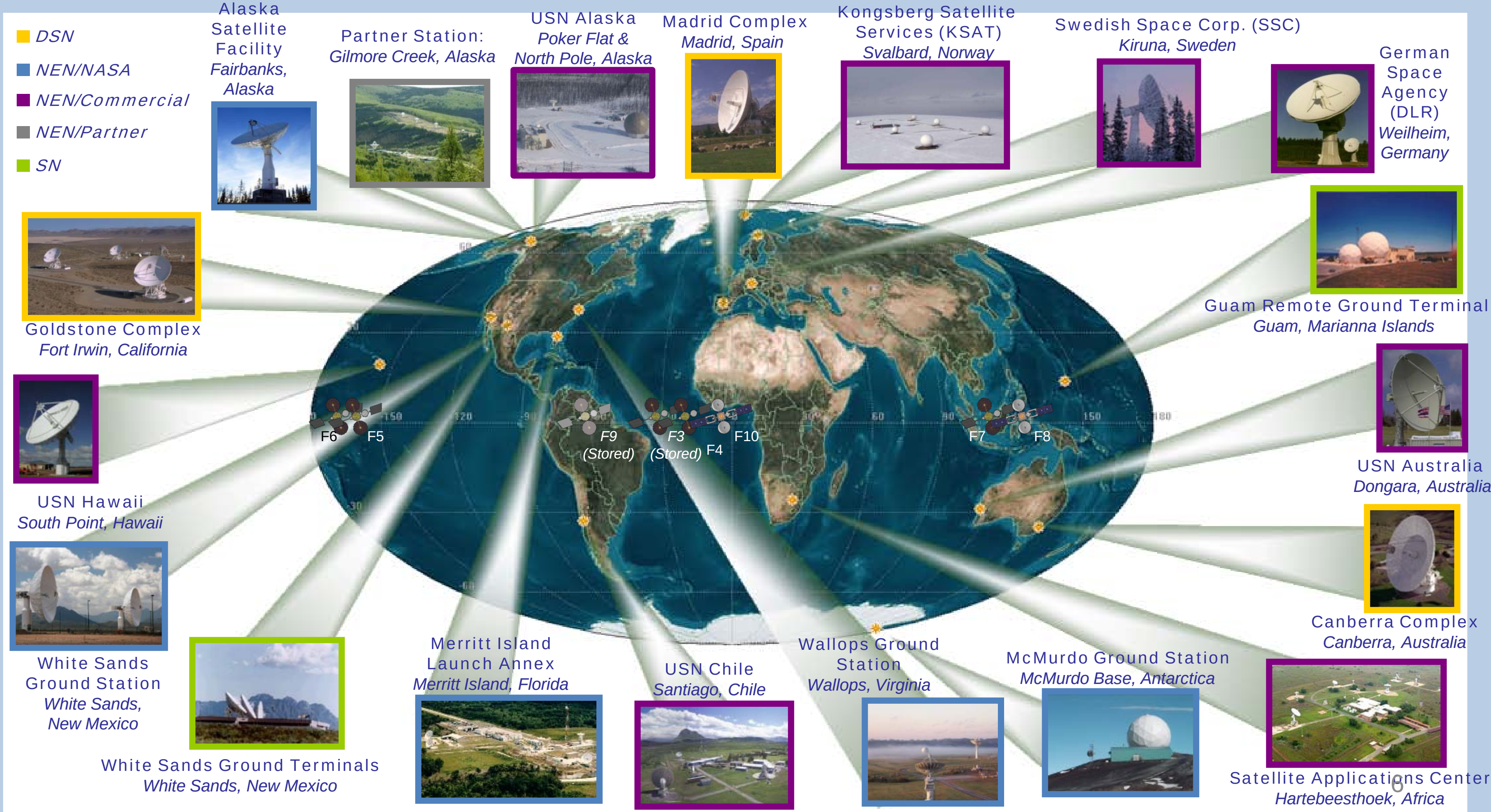
NASA Level 0 Requirements (Baselined on January 28, 2010)

- SCaN shall develop a unified space communications and navigation network infrastructure capable of meeting both robotic and human exploration mission needs.
- SCaN shall implement a networked communication and navigation infrastructure across space.
- SCaN's infrastructure shall provide the highest data rates feasible for both robotic and human exploration missions.
- SCaN shall assure data communication protocols for Space Exploration missions are internationally interoperable.
- SCaN shall provide the end space communication and navigation infrastructure for Lunar and Mars surfaces.
- SCaN shall provide communication and navigation services to enable Lunar and Mars human missions.
- SCaN shall continue to meet its commitments to provide space communications and navigation services to existing and planned missions.

SCaN Organization Chart

SCaN Network





SCaN Architecture

Architectural Goal and Challenges

Goal

To detail the high level SCaN integrated network architecture, its elements, architectural options, views, and evolution until 2025 in response to NASA's key driving requirements and missions. The architecture is a framework for SCaN system evolution and will guide the development of program requirements and designs.

Challenges

- Forming an **integrated** network from three pre-existing individual networks
- Resource constraints
- Addressing **requirement**-driven, **capability**-driven, and **technology**-driven approaches **simultaneously**
- **Interoperability** with U.S. and foreign spacecraft and networks
- **Uncertainty** in timing and nature of future communications mission **requirements**
- Requirements for **support** of missions already in **operation**, as well as those to which support commitments have already been made
- Changes in high level requirements and direction

Key Requirements, Mission Drivers, and Capabilities Flowdown

	Today	2015	2018	2025+

Level 0 Requirements

- Provide space communications and navigation services to existing and planned missions.
- Develop a unified space communications and navigation network infrastructure
- Implement internationally interoperable communication protocols
- Provide the highest data rates technically and financially feasible
- Implement a networked communication and navigation infrastructure across space
- Provide anytime/ anywhere communication and navigation services for Lunar and Mars human missions




	Today	2015	2018	2025+
Mission Drivers	• Shuttle/ISS • Mars Landers • Great Observatories • Coordinated Earth Observation • LRO	• Commercial/Orion/ISS • Mars – Coordinated and Complex Science Missions • Lunar Robotic Missions • High Data Volume Hyper Spectral Missions • SAR Earth Observation	• Multiple Cooperating Robotic Missions • Outer Planet – 1	• Hyper spectral imaging at Mars and beyond • Human Lunar Missions • Earth Sensor Web • Mars Exploration • Mars Sample Return
Capabilities	• Up to 300 Mbps (SN) • Up to 150 Mbps (NEN) • Up to 6 Mbps at 1 AU • Radiometric Services	• Up to 1.2 Gbps (SN/NEN) • Standard TT&C Services • Up to 150 Mbps (DSN) – 1 AU • Radiometric Enhancements	• Integrated Network Management • Integrated Service Execution • Space Internetworking	• Up to 1.2 Gbps from the moon (optical) • Optical Communications to 100 Mbps (planetary) • Lunar far side coverage • High capacity multi-node • Inter-networking interoperability

SCaN Current Networks

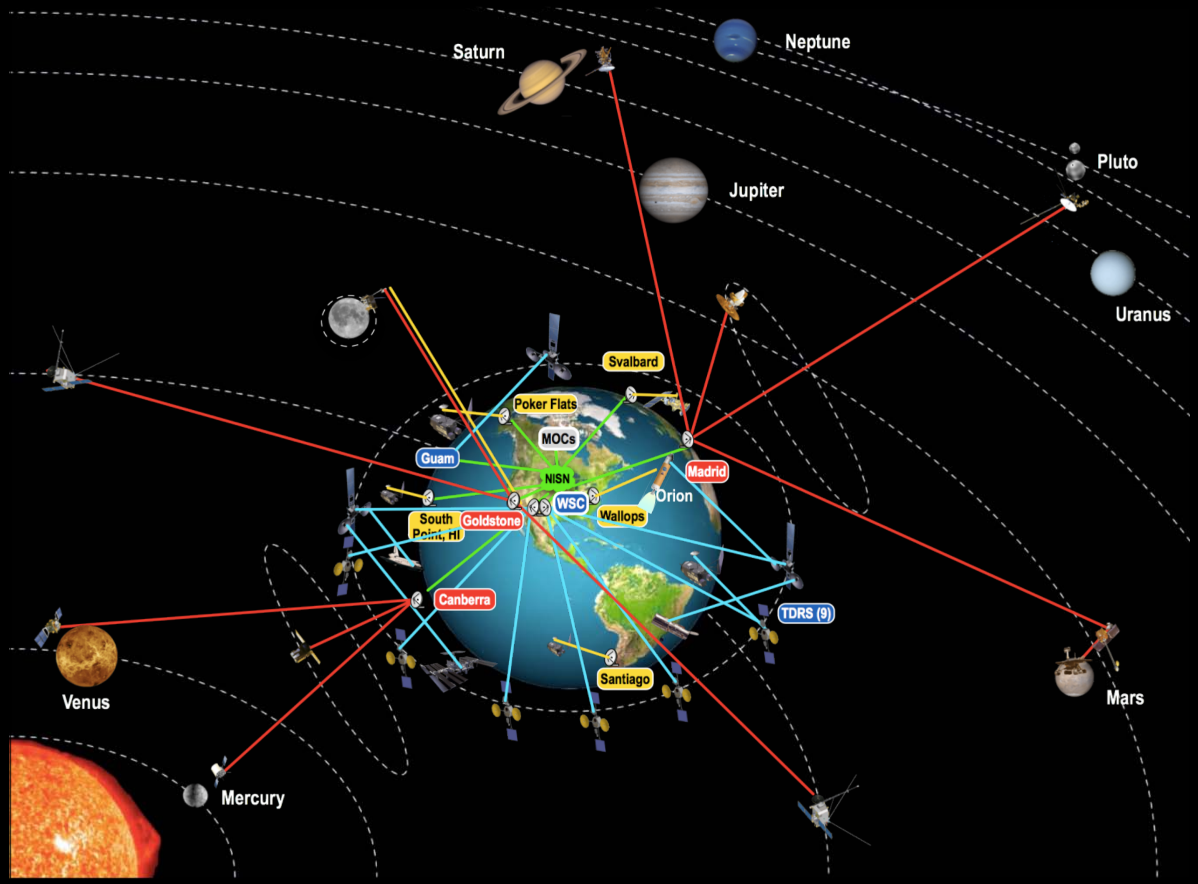
The current NASA space communications architecture embraces three operational networks that collectively provide communications services to supported missions using space-based and ground-based assets

Near Earth Network
and partner ground stations and integration systems providing space communications and tracking services to orbital and suborbital missions

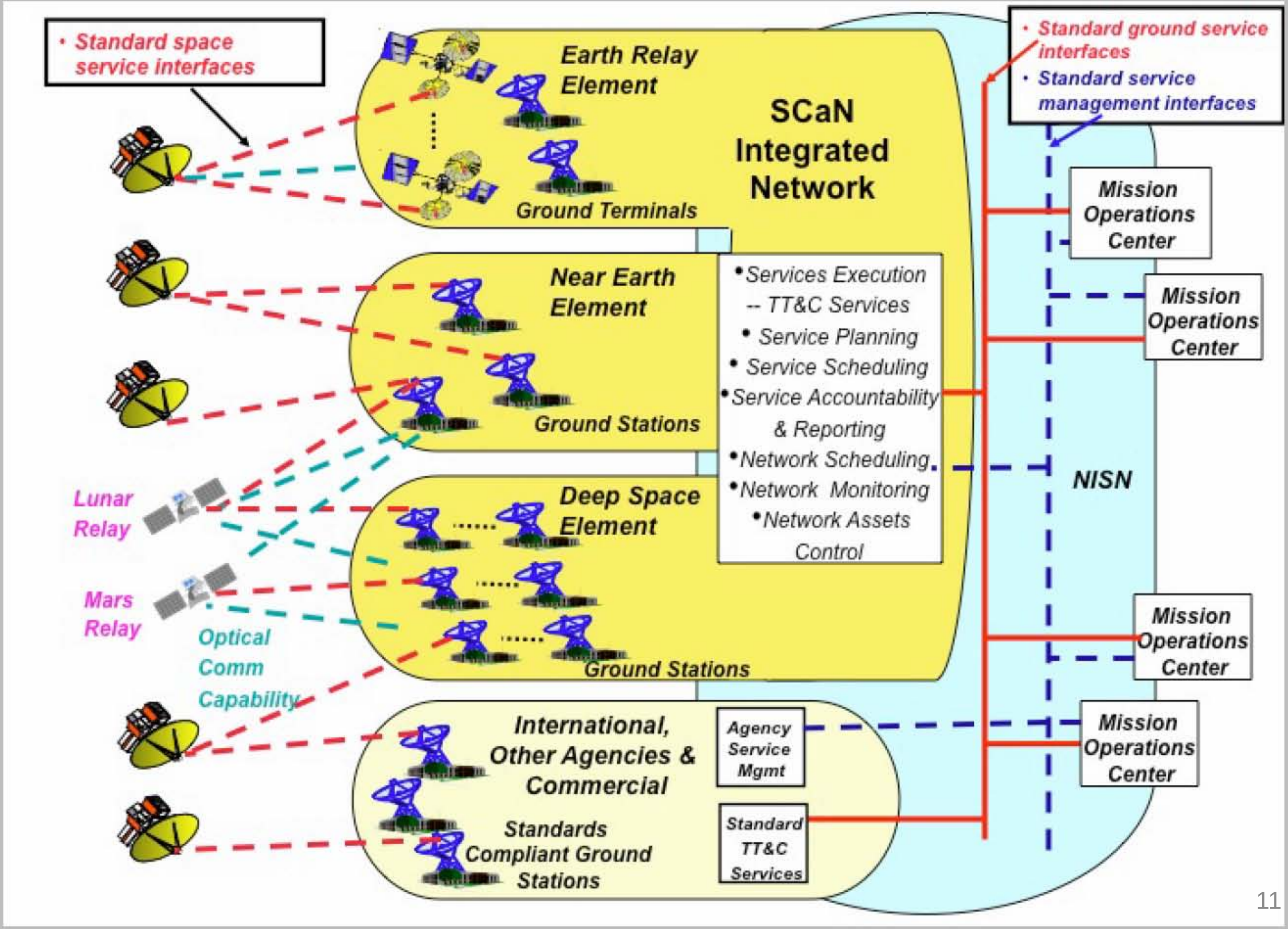
Space Network
geosynchronous relays (TDRSS) and associated ground systems

Deep Space Network
spaced around the world providing continuous coverage of satellites from Earth Orbit (GEO) to the edge of our solar system

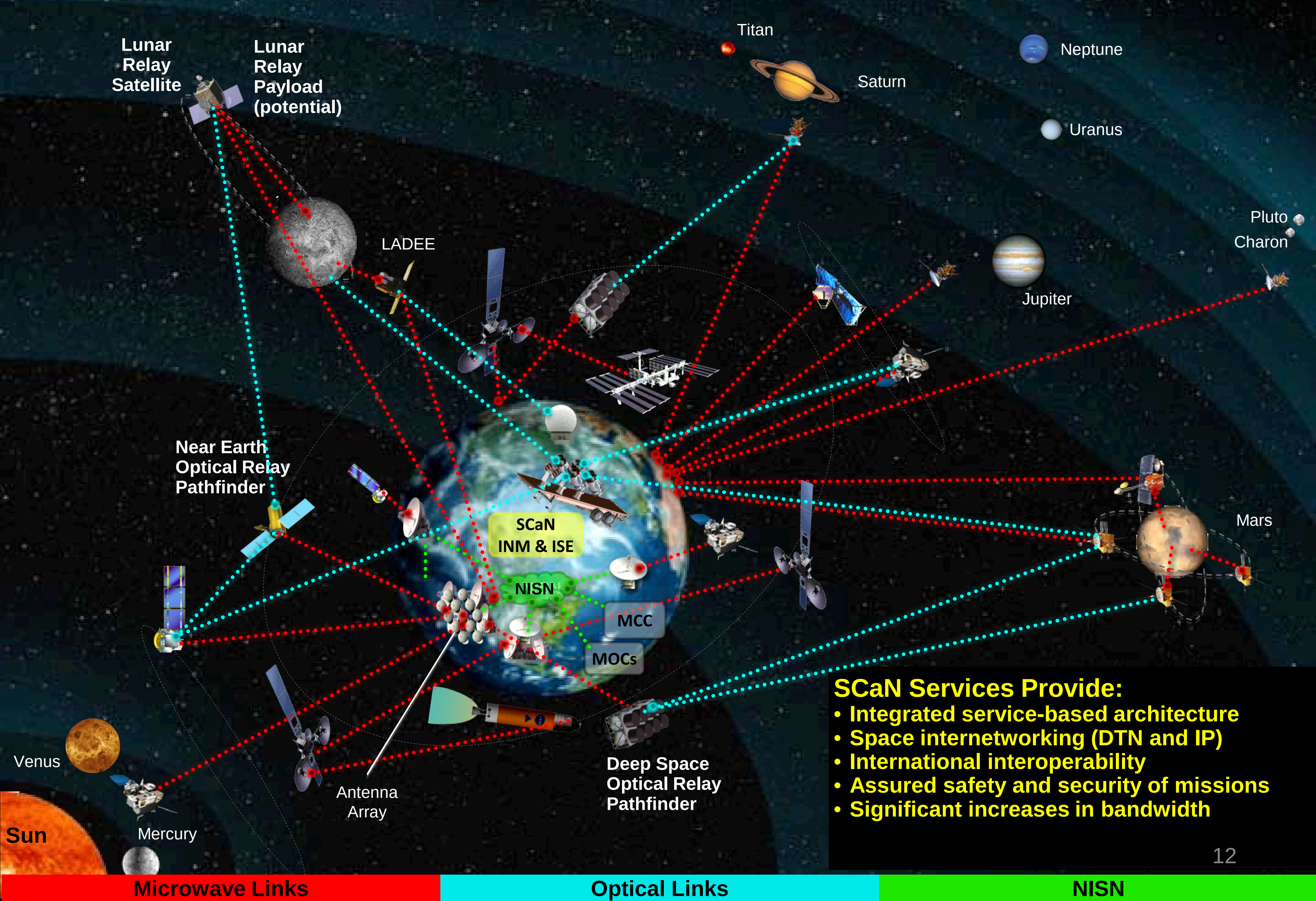
NASA Integrated Services Network (NISN) - not part of SCaN; provides terrestrial connectivity



SCaN Integrated Network Service Architecture



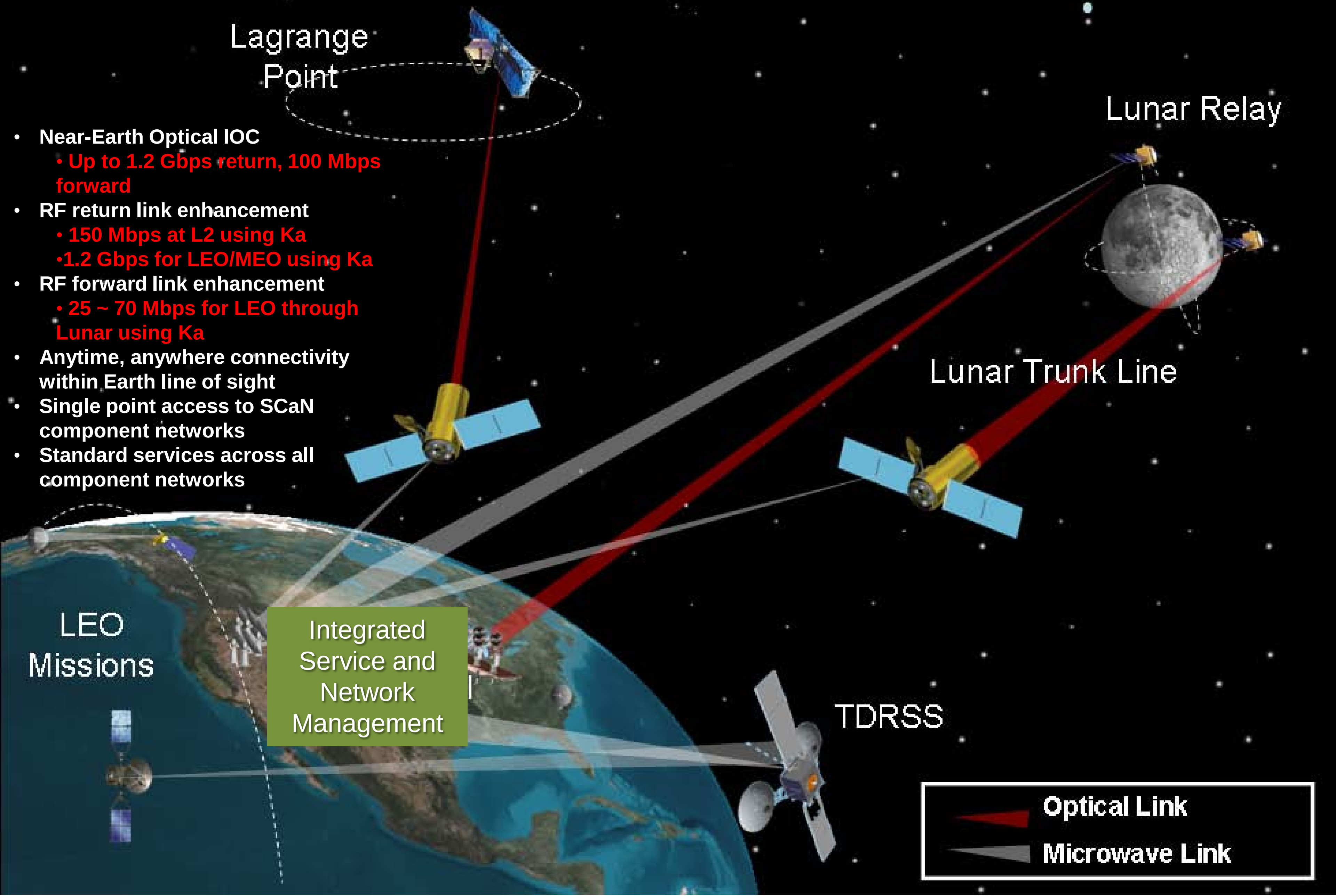
SCaN Notional Integrated Communication Architecture



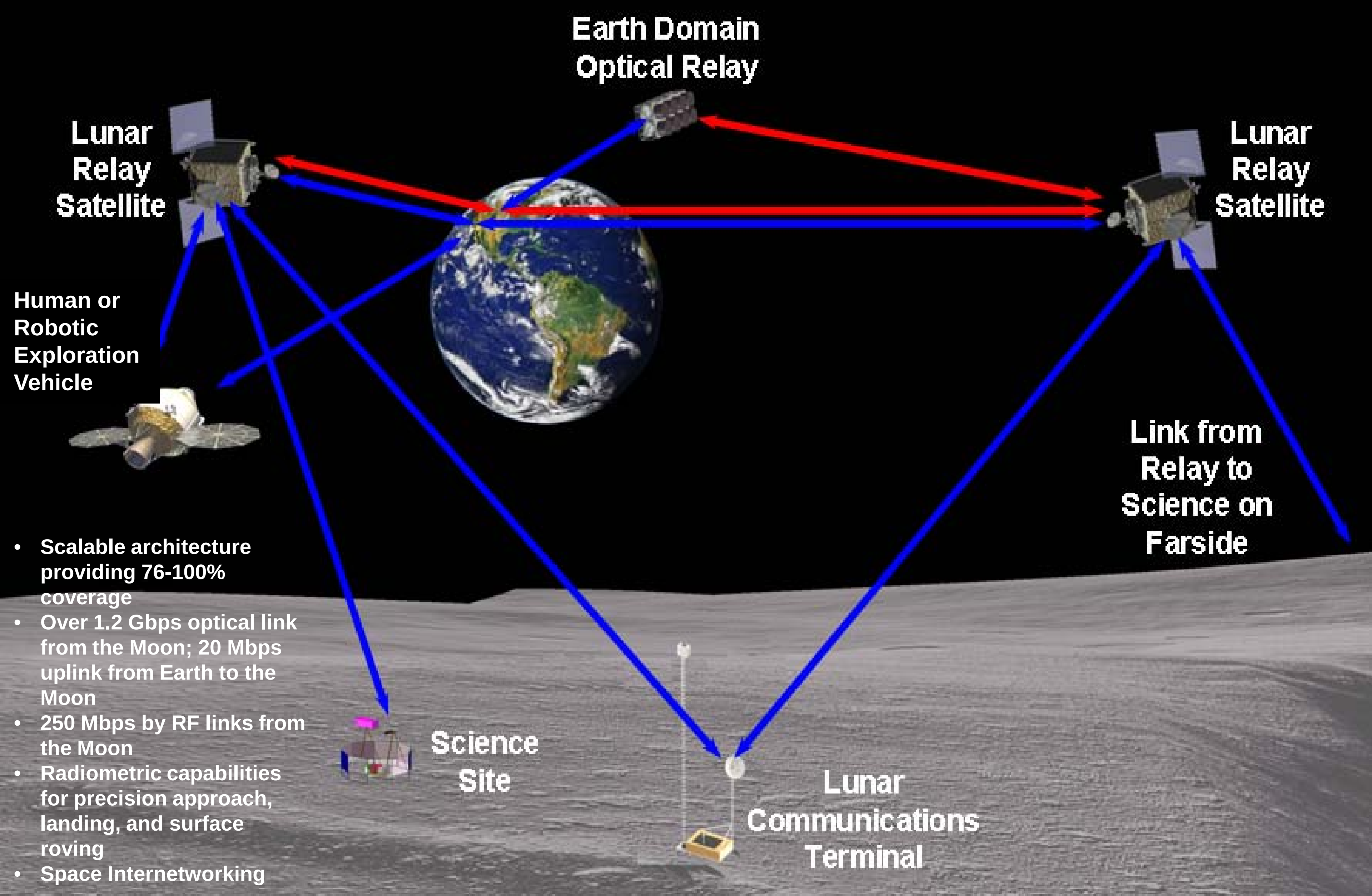
SCaN Services Provide:
- Integrated service-based architecture
- Space internetworking (DTN and IP)
- International interoperability
- Assured safety and security of missions
- Significant increases in bandwidth

Enhanced Earth Domain Capabilities

- Near-Earth Optical IOC
  - Up to 1.2 Gbps return, 100 Mbps forward
- RF return link enhancement
  - 150 Mbps at L2 using Ka
  - 1.2 Gbps for LEO/MEO using Ka
- RF forward link enhancement
  - 25 ~ 70 Mbps for LEO through Lunar using Ka
- Anytime, anywhere connectivity within Earth line of sight
- Single point access to SCaN component networks
- Standard services across all component networks

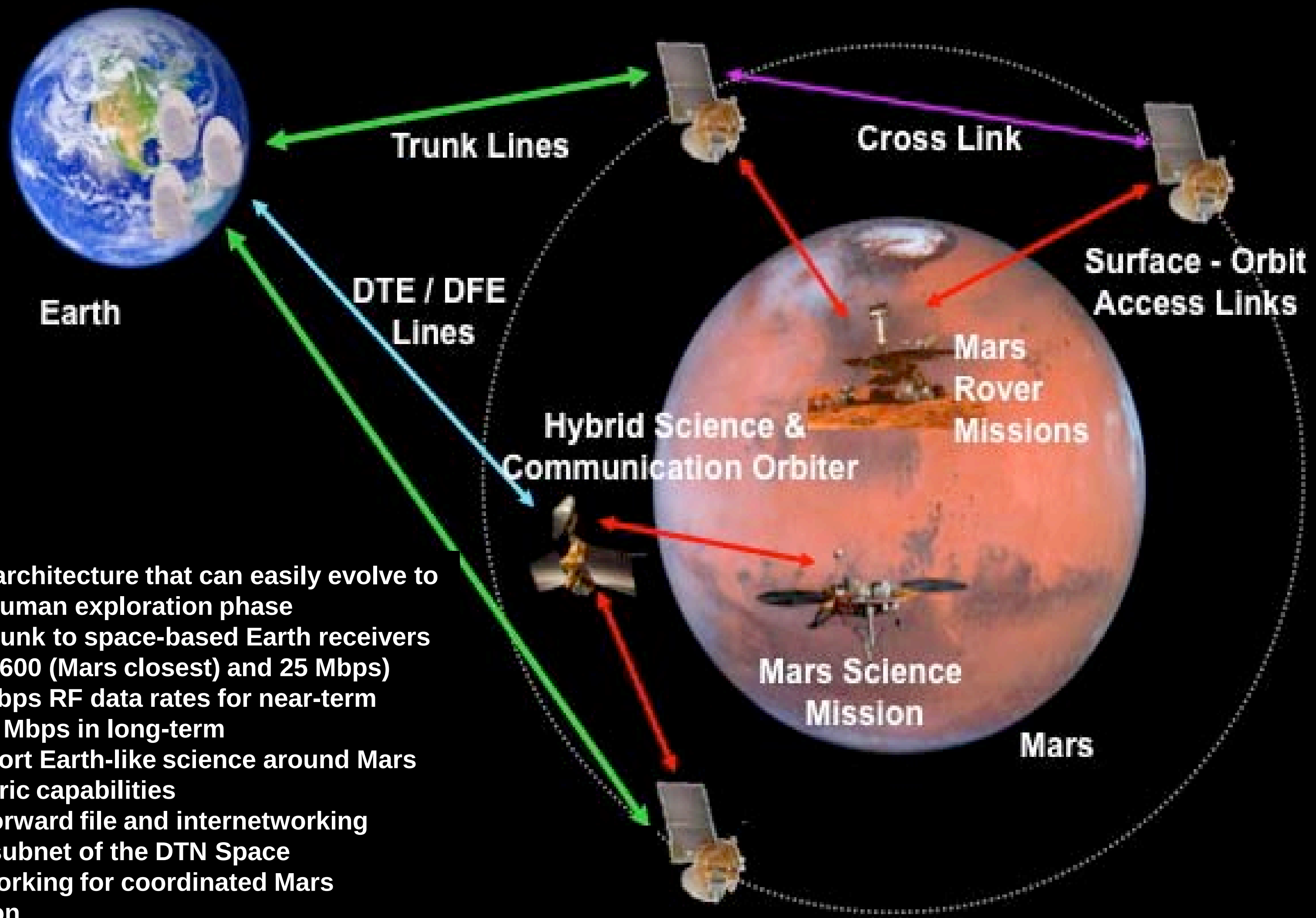


Lunar Network



- Scalable architecture providing 76-100% coverage
- Over 1.2 Gbps optical link from the Moon; 20 Mbps uplink from Earth to the Moon
- 250 Mbps by RF links from the Moon
- Radiometric capabilities for precision approach, landing, and surface roving
- Space Internetworking

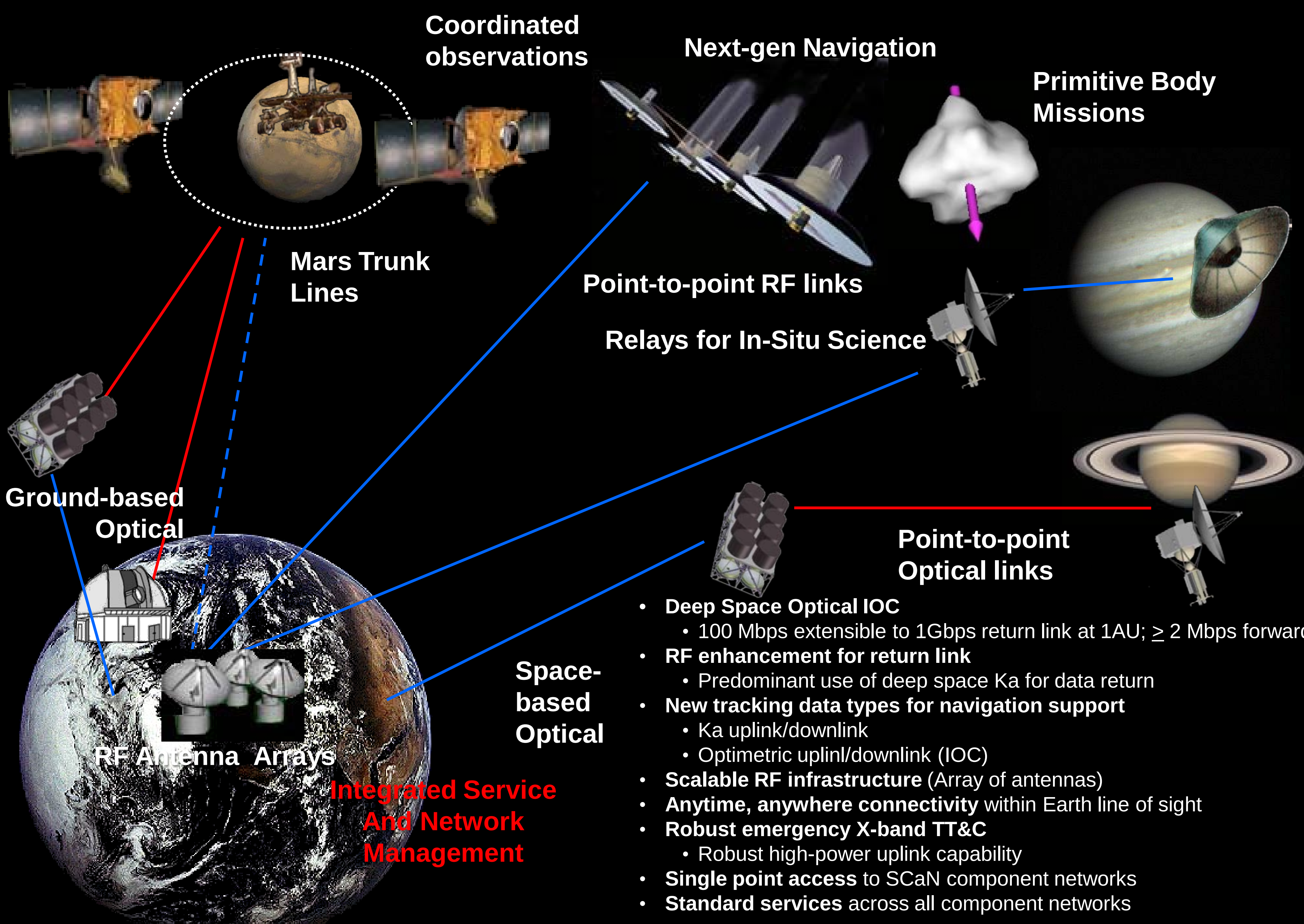
Mars Network



- Scalable architecture that can easily evolve to support human exploration phase
- Optical Trunk to space-based Earth receivers (between 600 (Mars closest) and 25 Mbps)
- Up to 2 Mbps RF data rates for near-term
- Up to 150 Mbps in long-term
- Can support Earth-like science around Mars
- Radiometric capabilities
- Store & forward file and internetworking
- Forms a subnet of the DTN Space Internetworking for coordinated Mars exploration

DTE/DFE Links	Access Links	Trunk Lines	Cross Links

Enhanced Deep Space Domain Capability



- **Deep Space Optical IOC**
  - 100 Mbps extensible to 1Gbps return link at 1AU; $\geq$ 2 Mbps forward
- **RF enhancement for return link**
  - Predominant use of deep space Ka for data return
- **New tracking data types for navigation support**
  - Ka uplink/downlink
  - Optimetric uplinl/downlink (IOC)
- **Scalable RF infrastructure** (Array of antennas)
- **Anytime, anywhere connectivity** within Earth line of sight
- **Robust emergency X-band TT&C**
  - Robust high-power uplink capability
- **Single point access** to SCaN component networks
- **Standard services** across all component networks

SCaN Technology

Goals of the SCaN Technology Program

- Support the SCaN Vision of the Future as Described in the SCaN Architecture Definition Document

- Enable Future NASA Missions with New Communication and Navigation Technology that Enhances their Science Return

SCaN Systems Planning

Oversees Development of Communication and Navigation Technologies

- SCaN
  - Business Management
  - Policy and Strategic Communications
  - Network Services
  - Spectrum Planning
  - Systems Planning
    - Goddard Space Flight Center
    - Glenn Research Center
    - Jet Propulsion Lab
  - Systems Engineering

Centers	Goddard Space Flight Center	Glenn Research Center	Jet Propulsion Lab
Current Technology Focus Areas	•Near Earth Optical Comm •TDRSS Antenna Combining •SN Ground Segment Sustainment	•Ka Band Propagation •Antenna Technology •Software Defined Radios	•Deep Space Optical Comm •Earth-based Antenna Combing •GPS science receivers

SCaN Funds Both “Pull” and “Push” Technologies

- A **Pull Technology** is one that is mission requirement driven, a technology needed to fulfill specific mission objective
    - e.g., a transceiver that provides a specific data rate required to fulfill a specified mission objective
- A **Push Technology** is one that is not directed to or required by a specific mission, but instead would provide a generic capability which could enable or enhance future missions
    - e.g., a high sensitivity receiver that could improve link capability by 20 db
- SBIR technologies may be either Pull or Push technologies

The SBIR Program is Integrated Into the SCaN Technology Selection, Development and Infusion Process

SCaN Architecture Definition Document

Mission Requirements

Mid Level TRL Solicitations

Game Changing Technology Solicitations

SBIR Program Technologies

SCaN/SP Technology Selection and Funding Process

Technology Selections and Funding

Development, Monitoring and Reassessment

Mission Infusion and/or Commercialization

SCaN Communications and Navigation Technology Themes

- **Optical Communications**
- **Antenna Arraying Technology – Receive and Transmit**
- **Advanced Antenna Technology**
- **Advanced Networking Technology**
- **Spacecraft RF Transmitter/Receiver Technology**
- **Software Defined Radio**
- **Spacecraft Antenna Technology**
- **Spectrum Efficient Technology**
- **Ka-band Atmospheric Calibration**
- **Position, Navigation, and Time**
- **Space-Based Range Technology**
- **Uplink Arraying**

Why Use Software Defined Radios?

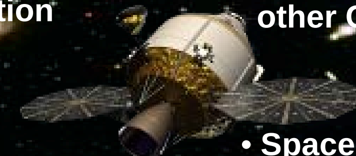
- **SDRs provide unprecedented operational flexibility with software functionality that allows communications functions to be updated in flight**
  - **Functions can be changed within the same SDR across mission phases**
    - **E.g., Range Safety functions in launch phase, mission ops functions in mission phase**
  - **Technology upgrades can be made in flight**
    - **E.g., modulation methods upgrades, new coding schemes**
  - **Failure corrections can be effected in flight**
    - **E.g., MRO corrected EMI problem with SW update in transit to Mars using the Electra SDR**
- **Small size, weight, and power is achievable for all SDRs, esp mobile units (e.g., EVAs, rovers), similar to cell phones**
  - **SDRs have excellent potential for miniaturization compared to conventional radios**
- **Software defined functionality enables standard radios to be tailored for specific missions with reusable software**
  - **Similar to PCs running standard programs like Word and Excel, standardization enables common hardware platforms to run common reusable software across many missions**
  - **Cost reductions are realized with common hardware architecture, reusable software and risk avoidance**

CoNNeCT Provides Broad Relevancy to NASA Programs and Missions

- Ka/S band System for Lunar Relay

- GPS L1, L2c, L5 development and validation
- GPS TASS validation

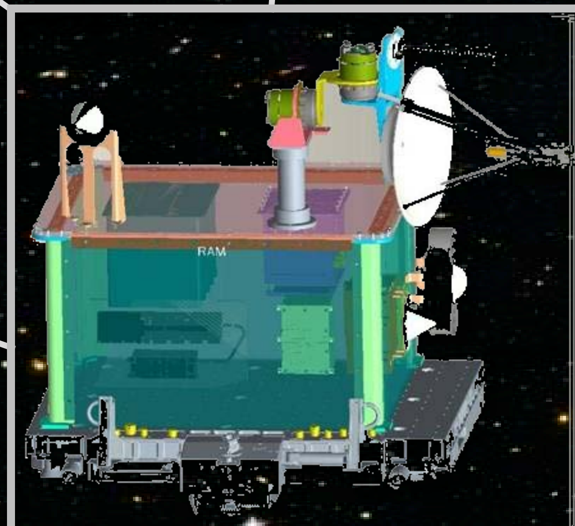
- S band rates for CEV ops testing
- Orion radio prototypes
- Potential SDRs for other Cx applications



- Space based networking, including DTN

- SDRs for Fifth Gen TDRSS User Transponder

- Ka/S System for TDRSS K, L function, performance validation



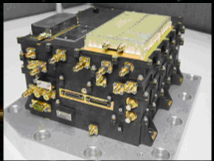
- Potential SDRs for Space Based Range

- Potential SDRs for lunar landers, rovers, EVA

- Ka System HRDL partial backup for ISS (pending CR)

Connect Payload with Ka, S, L band, and JPL Electra, GD Starlite, and Harris SDRs

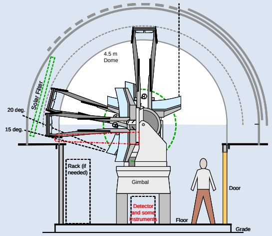
- SDR/STRS technology advancement to TRL-7



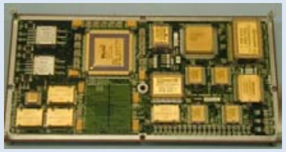
Optical Communications Technology

Objective

- **Develop optical technologies for 10-1200 Megabit per second data links to meet NASA SCaN requirements for 2020 IOC**
  - Low mass and high efficiency implementations are required for deep space optical link scenarios
  - Identify, develop, and validate high ROI ground and flight technologies
  - Create the necessary technical infrastructure to test and validate industry and NASA developed optical communications flight components prior to flight

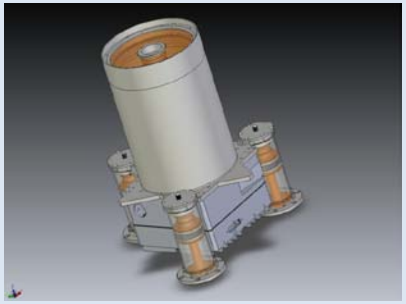


Ground Aperture

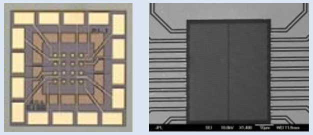


Optical Transceiver Flight Processor

PPM Laser Transmitter

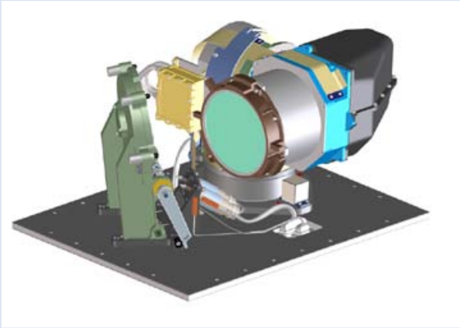


Deep Space Optical Transceiver



Single Photon Detectors

Scalable Receiver/Decoder



Near Earth Ground Terminal

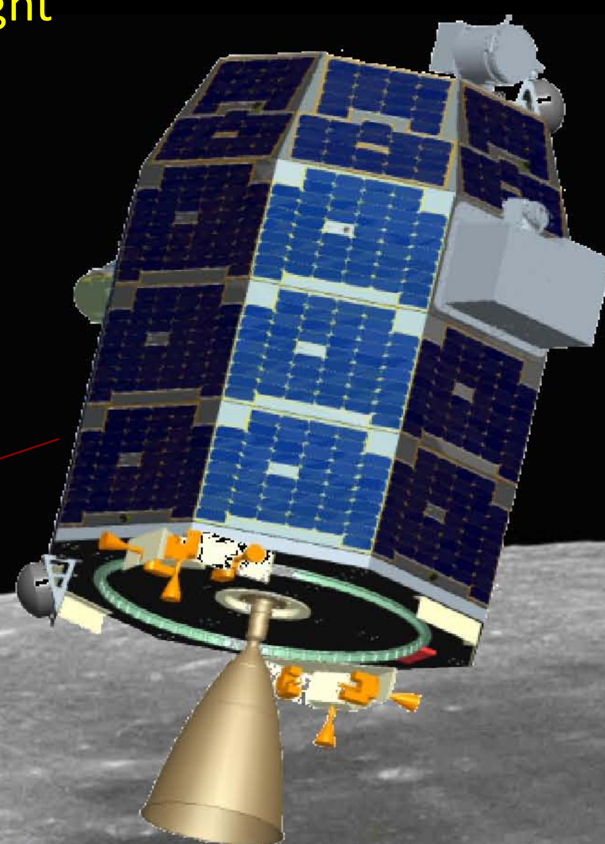
Near Earth Flight Terminal

<u>Some Example Key Challenges:</u>

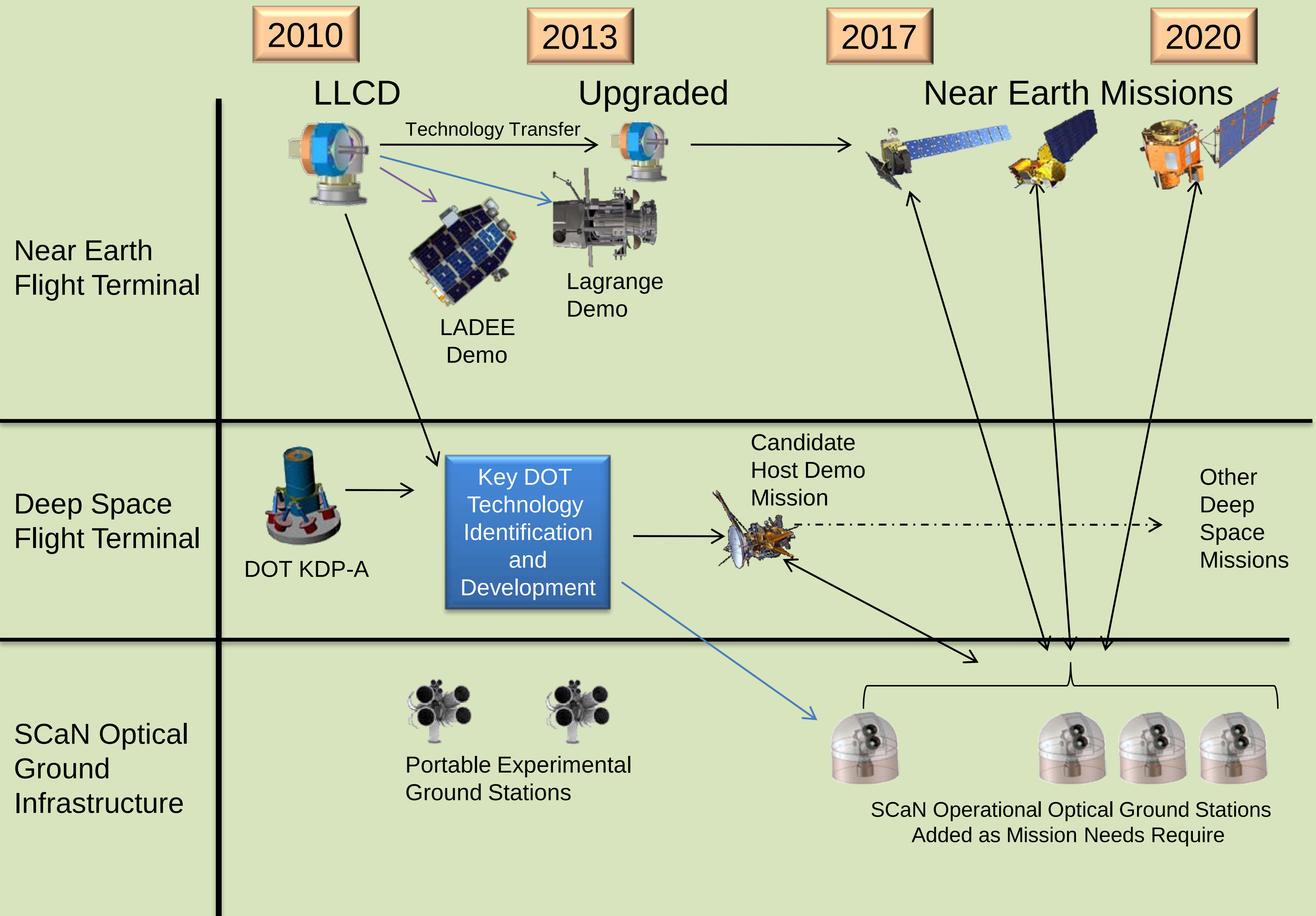
- Sub-Hertz vibration isolator; flight photon counting detector arrays
- Lightweight flight optics; integrated flight photon counting detector arrays with read-out integrated circuit
- Beaconless tracking solutions; high power uplink laser transmitter
- Detector jitter mitigation; efficient narrowband optical filter

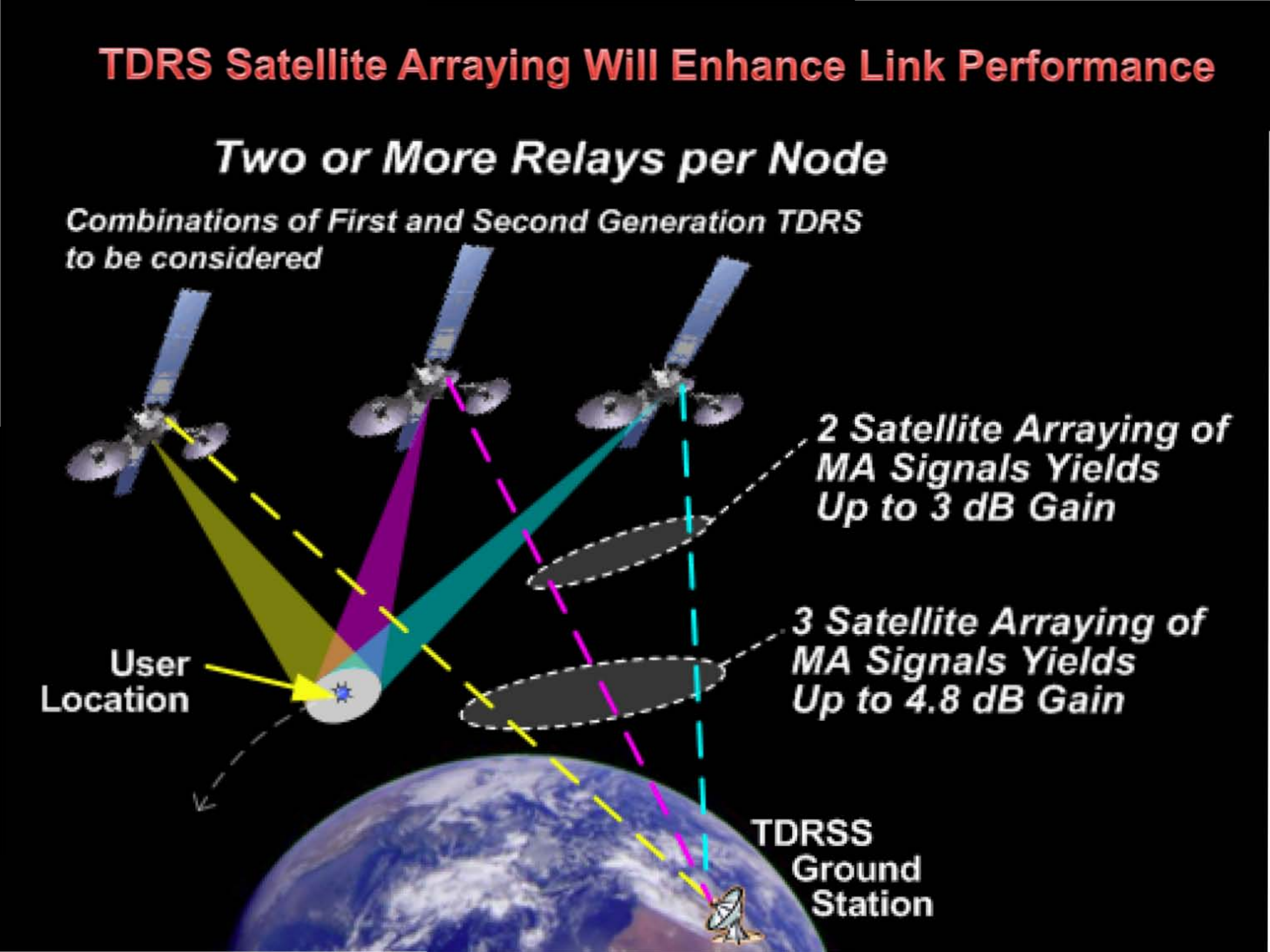
Lunar Lasercom Space Terminal (LLST)

- Lunar Lasercom Space Terminal (LLST) to fly on Lunar Atmosphere and Dust Environment Explorer (LADEE)
- Launch Readiness Date: Mar 2013 from Wallops Flight Facility, VA on Minotaur V
  - 1 month transfer
  - 1 month commissioning
    - 250 km orbit
    - LLCD operation (up to 16 hours)
    - S/C and Science payloads checkout
  - 3 months science
    - 50 km orbit
    - 3 science payloads
      - Neutral Mass Spectrometer
      - UV Spectrometer
      - Lunar Dust Experiment



NASA Strategy for Optical Communication Development




TDRS Satellite Arraying Will Enhance Link Performance
Two or More Relays per Node
Combinations of First and Second Generation TDRS to be considered
2 Satellite Arraying of MA Signals Yields Up to 3 dB Gain
3 Satellite Arraying of MA Signals Yields Up to 4.8 dB Gain
User Location
TDRSS Ground Station

Phase-I of Space DTN Development

Phase-II DTN

Classical Point-to-Point

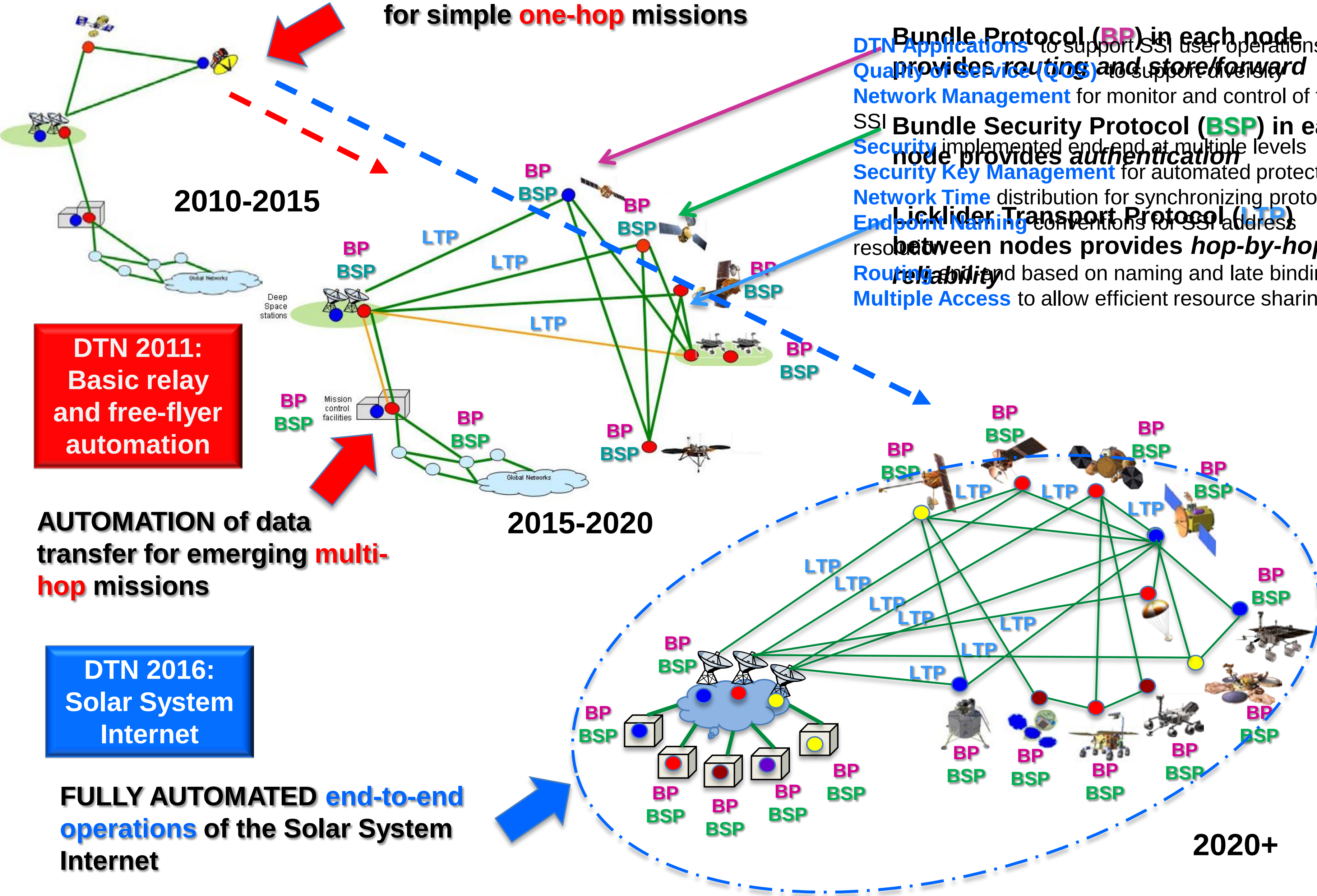
AUTOMATION of data transfer for simple one-hop missions

Bundle Protocol (BP) in each node provides *routing and store/forward*

Bundle Security Protocol (BSP) in each node provides *authentication*

Licklider Transport Protocol (LTP) between nodes provides *hop-by-hop reliability*

DTN Applications to support SSI user operations
Quality of Service (QoS) to support diversity
Network Management for monitor and control of the SSI
Security implemented end-end at multiple levels
Security Key Management for automated protection
Network Time distribution for synchronizing protocols
Endpoint Naming conventions for SSI address resolution
Routing end-end based on naming and late binding
Multiple Access to allow efficient resource sharing



DTN 2011: Basic relay and free-flyer automation

AUTOMATION of data transfer for emerging multi-hop missions

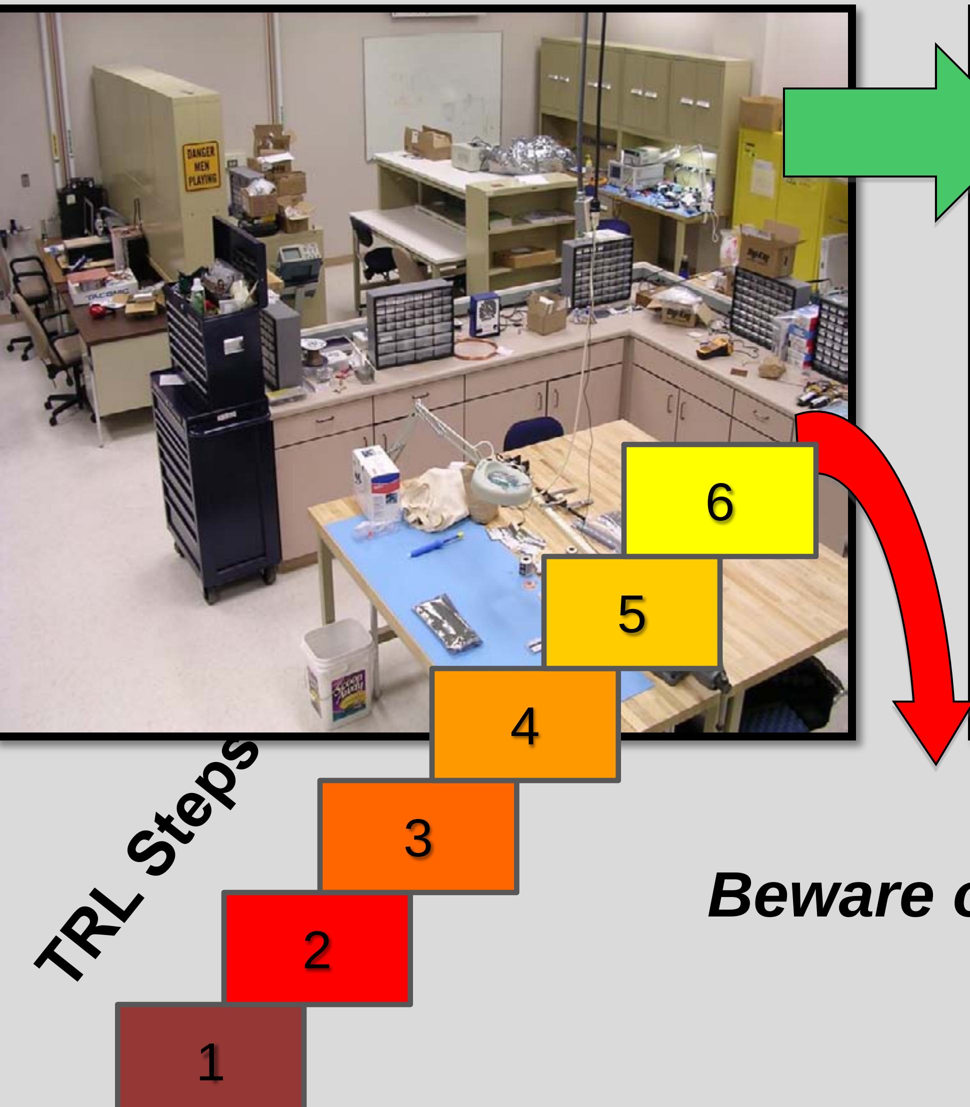
DTN 2016: Solar System Internet

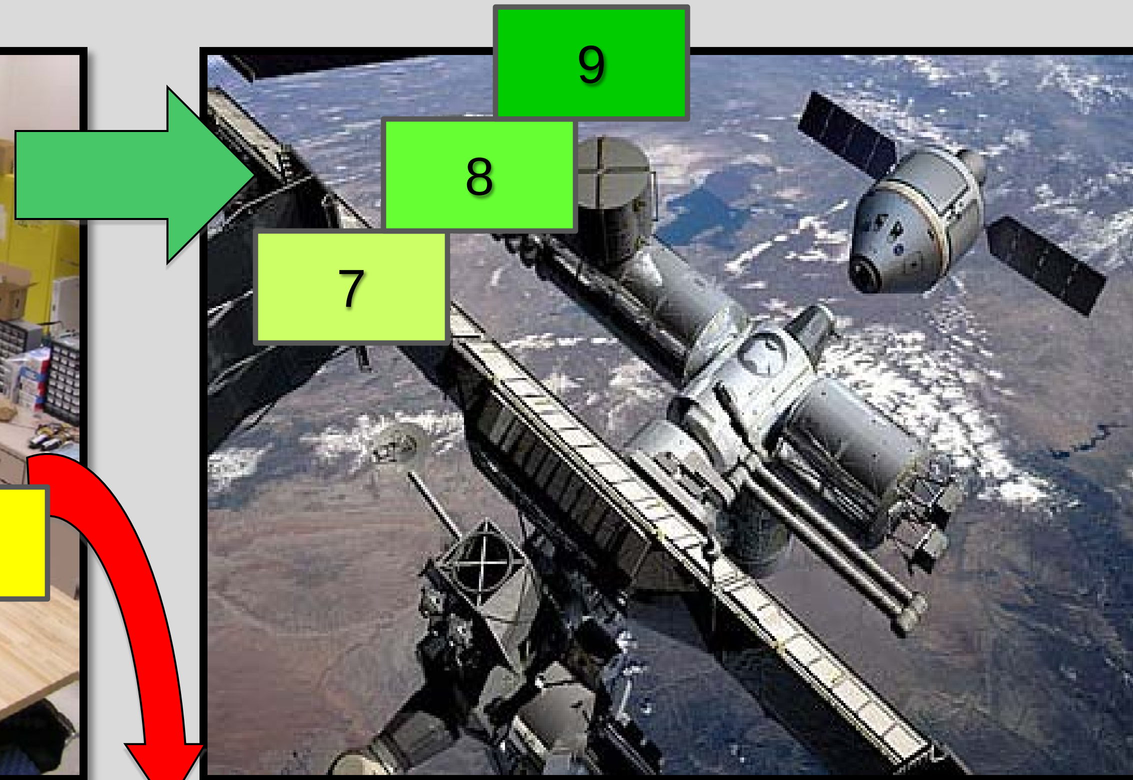
FULLY AUTOMATED end-to-end operations of the Solar System Internet

SCaN Funds Game Changing Technologies to Achieve Radical Improvements in Performance

- Game Changing Technologies (GCT) offer the potential for improving comm. or nav. performance to the point that radical new mission objectives are possible
- GCTs are funded at low levels at first as progress and prognosis are monitored
- SCaN is currently funding three GCTs:
  - Superconducting Quantum Interference Filters may have the potential to improve receiver sensitivities by 60dB through detection of magnetic fields (GRC)
  - Silicon Nanowire Optical Detectors may provide a 10dB increase in single photon detection sensitivity (JPL)
  - Auto-Configuring Cognitive Communications embeds advanced decision making intelligence into communications and networking assets for improved levels of integration and flexible operations (GSFC)

The Transition From Ground-Based TRL 6 to Space Ops TRL 7 is a Major Step

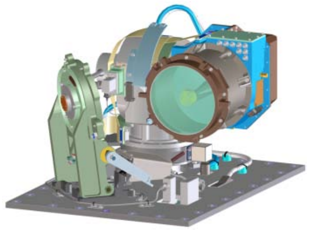


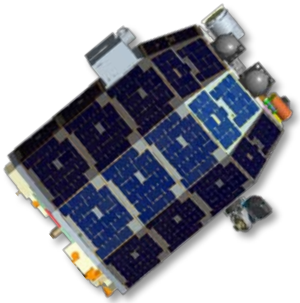


Beware of the Never Use Scrap Heap!

SCaN Technologies Trying to Take the TRL 7 Leap

- Optical Communication

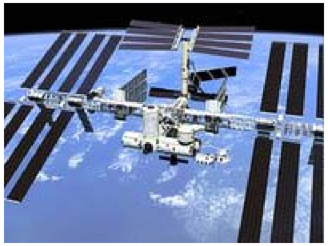




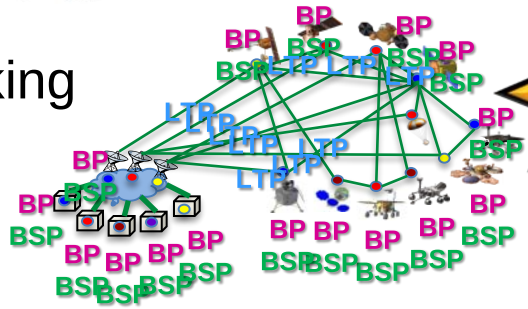
LADEE

- Software Defined Radios

ISS

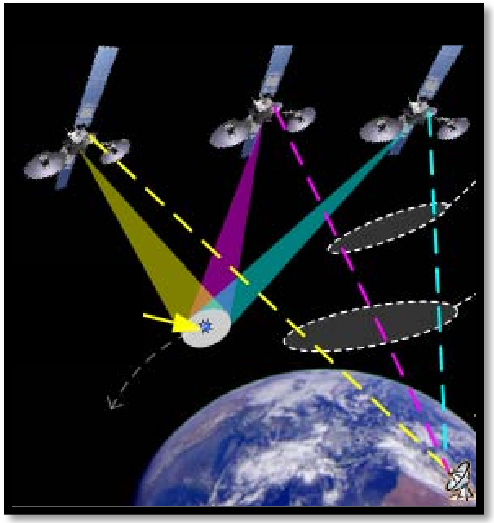


- Disruptive Tolerant Networking



- TDRSS Antenna Combining

TDRSS



For more information visit:

www.spacecomm.nasa.gov