
Space Communications
and Navigation
Overview

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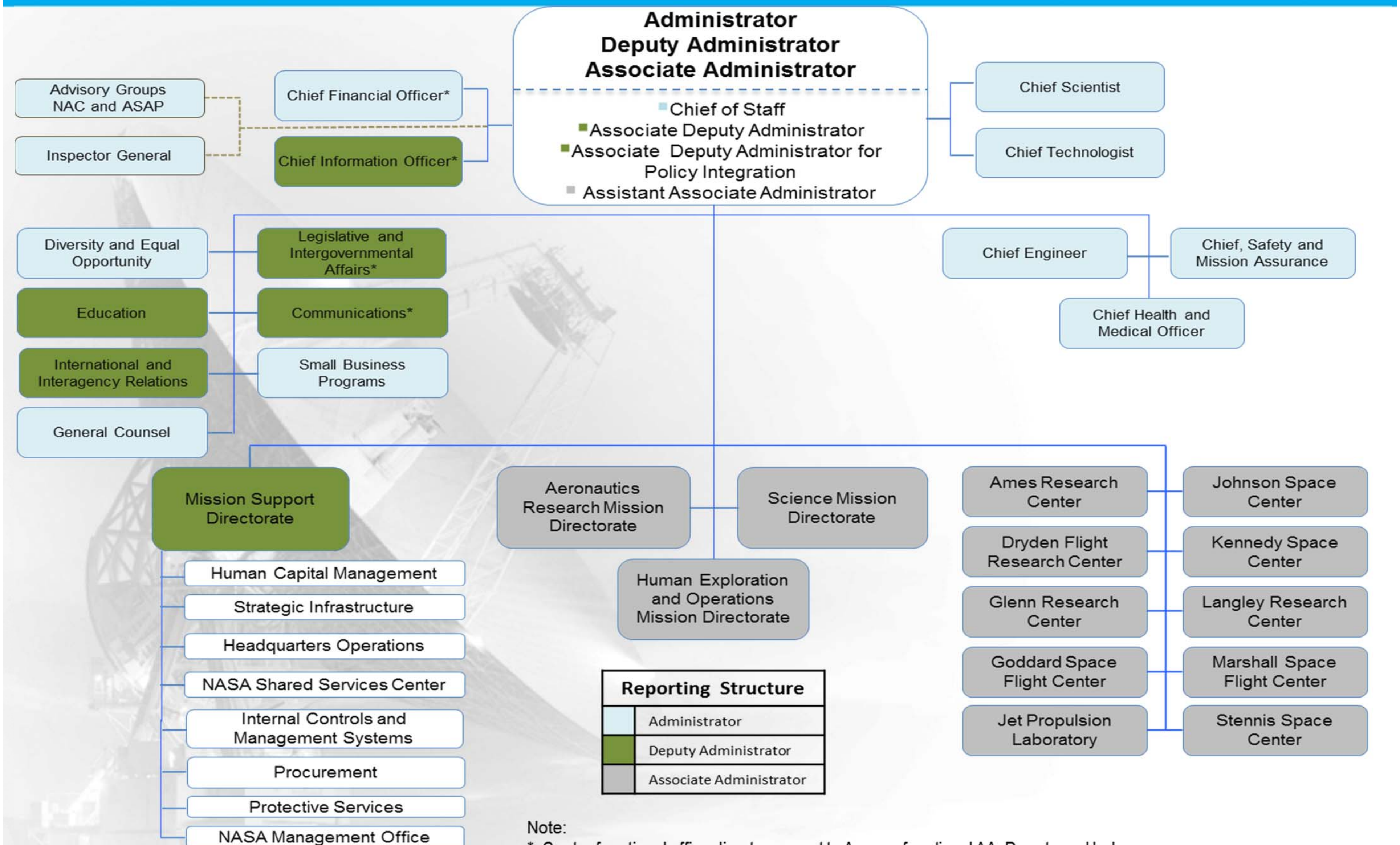
NASA Organization



Note:
* Center functional office directors report to Agency functional AA. Deputy and below report to Center leadership.

September 2011

Human Exploration and Operations Organization

Public Affairs/Communications
Legislative Affairs
Int'l/Interagency Relations
General Counsel

Associate Administrator
Deputy Associate Administrator
Deputy AA for Policy & Plans

Chief Technologist
Chief Scientist
Chief Engineer
Safety & Mission Assurance
Chief Health & Medical Officer

Strategic Analysis & Integration Division

- Architecture studies & analysis
- Mission analysis
- Risk and requirements coordination

Mission Support Services Office

- HR
- E & PO
- IT
- Mgt processes & internal controls

Resources Management Office

Space Comm & Navigation Division

Launch Services Office

Space Shuttle

Exploration Systems Development

- SLS
- MPCV
- 21st Century Ground Systems

Human Spaceflight Capabilities

- Core Capabilities
  - RPT
  - SFCO
  - MAF
  - MOD
  - EVA
  - CHS

ISS

- System O&M
- Crew & Cargo Transportation Services

Commercial Spaceflight Development

- Commercial Crew
- COTS

Advanced Exploration Systems

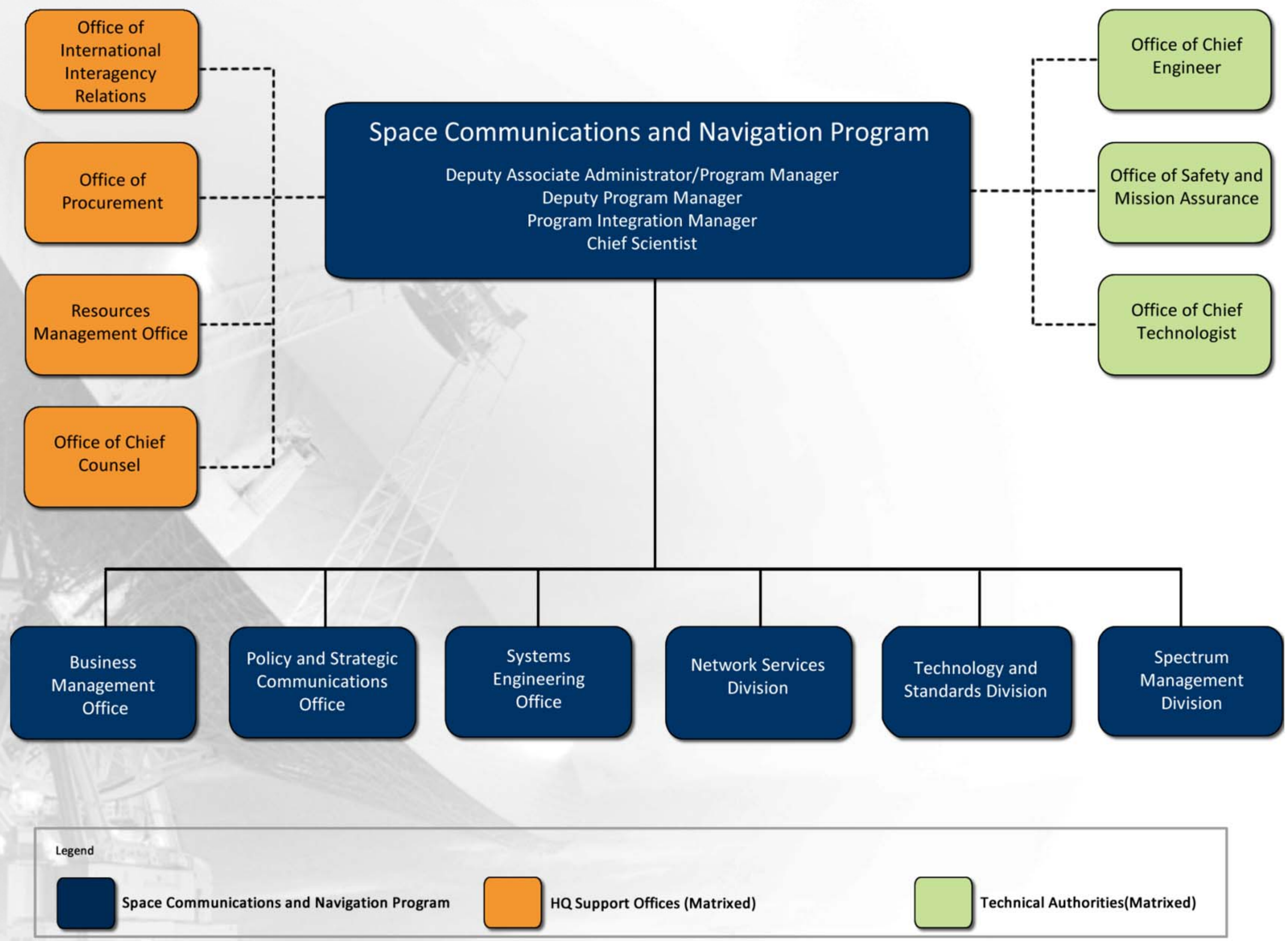
- AES
- Robotic precursor measurements

Space Life & Physical Sciences Research & Applications

- HRP
- Fund. Space Bio
- Physical Sciences

ISS Nat'l Lab Mgt.

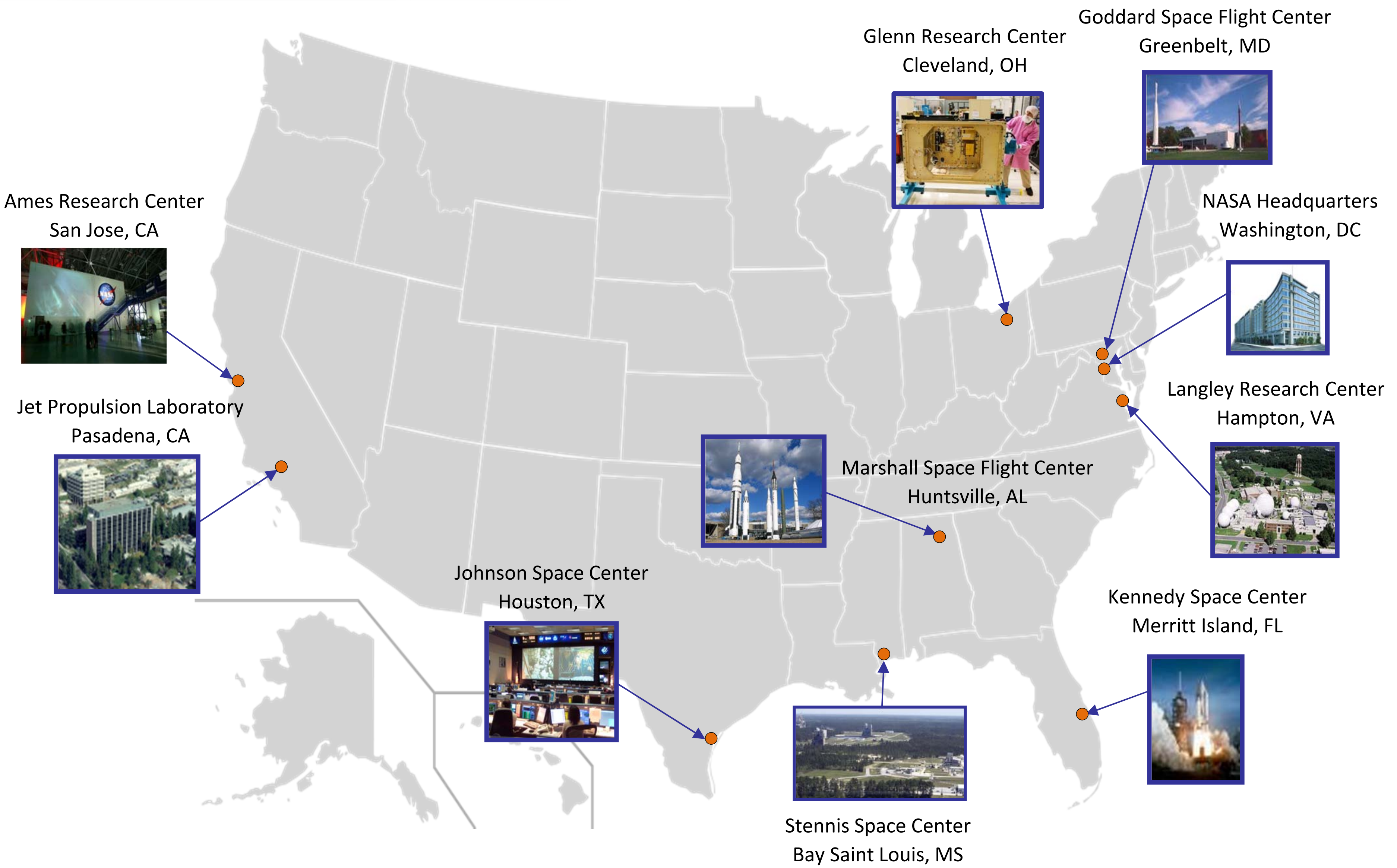
SCaN Organization



SCaN's Vision

To build and maintain a scalable integrated mission support infrastructure that can readily evolve to accommodate new and changing technologies, while providing comprehensive, robust, cost effective, and exponentially higher data rate space communications services to enable NASA's science, space operations, and exploration missions.

NASA Centers Supporting SCaN Activities



NASA Requirements for SCaN

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

SCaN Functions

- **Delineated in memorandum from NASA Associate Administrator (Sept. 24, 2007).**
- SCaN serves as the **Program Office** for all of the Agency's space communications activities.
- SCaN manages and directs:
  - The ground-based facilities and user services provided by the Near Earth Network (Ground Network) and Deep Space Network;
  - The ground- and space-based facilities and user services provided by the geosynchronous Space Network and by a future Lunar Network and Mars Network.
- Activities include those that:
  - Integrate all existing NASA SCaN assets and build a single NASA-wide space communications and navigation architecture;
  - Represent NASA before associated national and international programs of spectrum management and space data systems standardization;
  - Represent and negotiate on behalf of NASA on all matters related to Space Telecommunications in coordination with the appropriate offices and flight mission directorates.

Program Goal and Challenges

Goal

To implement the SCaN integrated network , its elements, architectural options, and future capabilities as an evolutionary process in response to NASA's key driving requirements and missions. The architectural approach provides for a **framework** for SCaN system evolution and will guide the development of requirements and designs.

Challenges

Forming an **integrated** network from three pre-existing individual aging networks that have been operated and maintained independently one from the others

Uncertainty in timing and nature of future communications mission **requirements**

Addressing **requirement**-driven, **capability**-driven, **technology-driven, and affordable** approaches **simultaneously, while providing operational support to existing customers and honoring existing commitments**

Interoperability with U.S. and foreign spacecraft and networks

SCAN NETWORK

SCaN Network

Overview of the SCaN Network

Space Network

Near Earth Network

Deep Space Network

DESCRIPTION

Space Network

Global orbital satellite communications fleet

Optimized for continuous, high data rate communications

Critical for human spaceflight safety and critical event coverage

Near Earth Network

World-wide network of stations

Evolved from fully NASA-owned to portfolio of owned assets and procured commercial services (greater than 50%)

Surge capability through partnerships (e.g., NOAA)

Optimized for cost-effective, high data rate services

Deep Space Network

Three station global network of large-scale antennas

Focused on detecting and differentiating faint signals from stellar noise

Optimized for data capture from deep space distances orders of magnitude above near Earth

SAMPLE MISSIONS

Space Network

International Space Station

ISS Resupply: NASA CoTS, ESA ATV, JAXA HTV

Hubble Space Telescope

Terra, Fermi Gamma-ray Space Telescope

Near Earth Network

Aqua, Aura,

Lunar Reconnaissance Orbiter,

Landsat, Radiation Belt Storm Probes

Deep Space Network

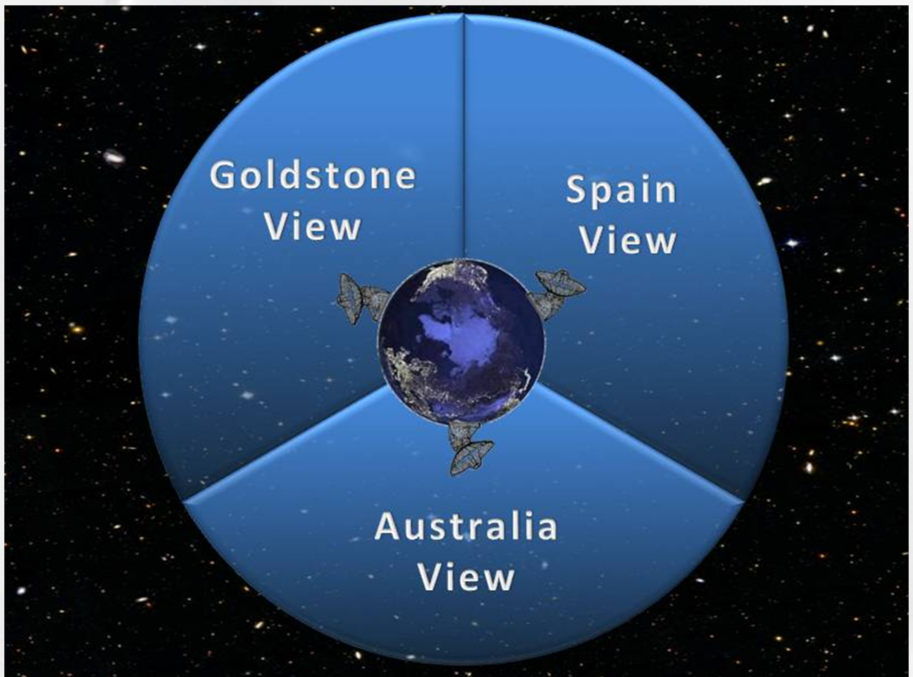
Kepler, Cassini

Mars Rovers and Orbiters ,

Mars Science Laboratory (Curiosity)

Voyagers 1 and 2, Spitzer Space Telescope

Deep Space Network



- The Deep Space Network has three tracking stations located approximately 120 degrees apart on the Earth (120 + 120 + 120 = 360).
- As the Earth rotates, at least one station is in view of the satellites in deep space.

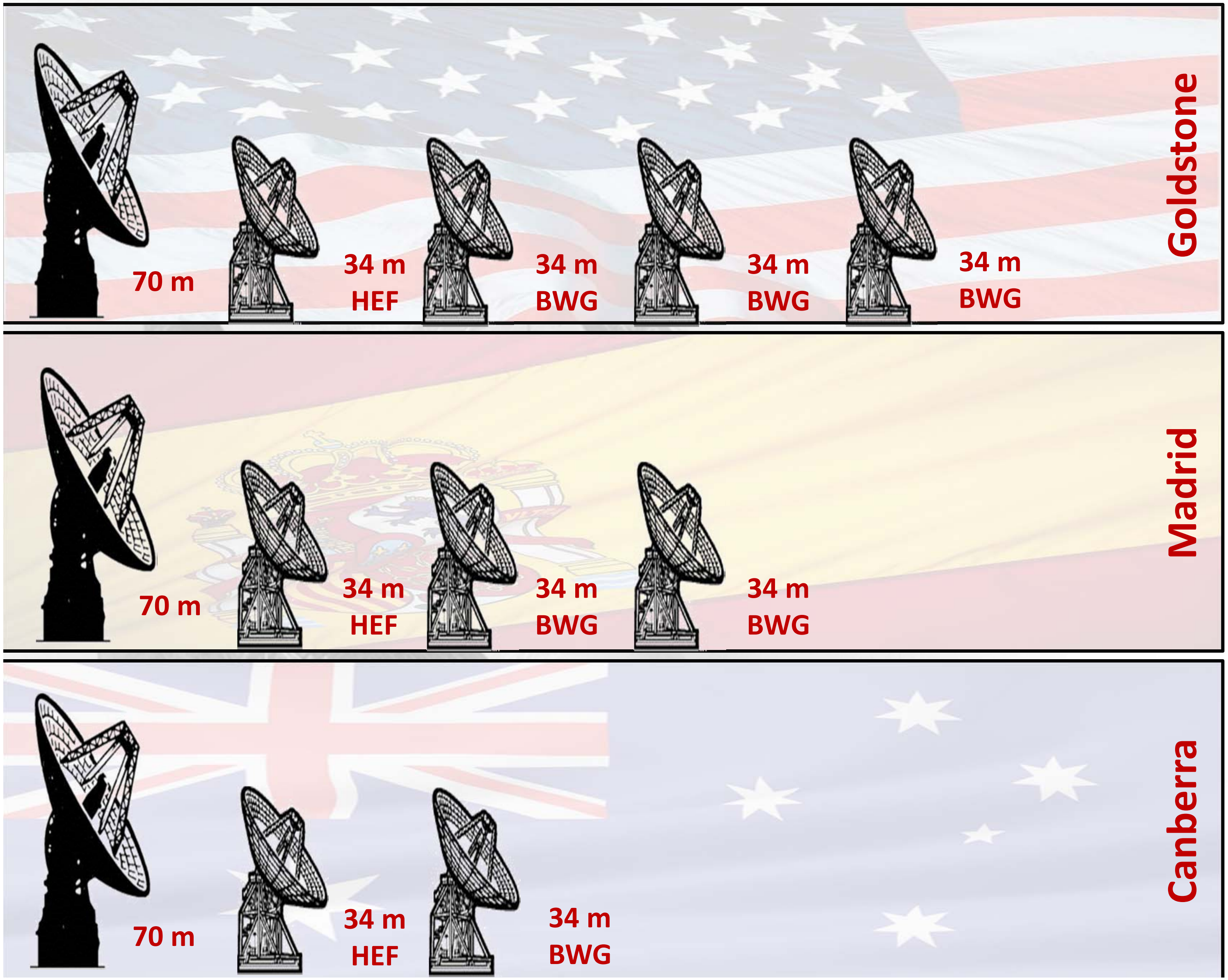
Deep Space Network (DSN)

Madrid Deep Space Communications Complex
Operated by ISDEFE

Canberra Deep Space Communications Complex
Operated by CSIRO

Goldstone Deep Space Communications Complex
Operated by ITT Exelis

DSN Aperture Enhancement Project



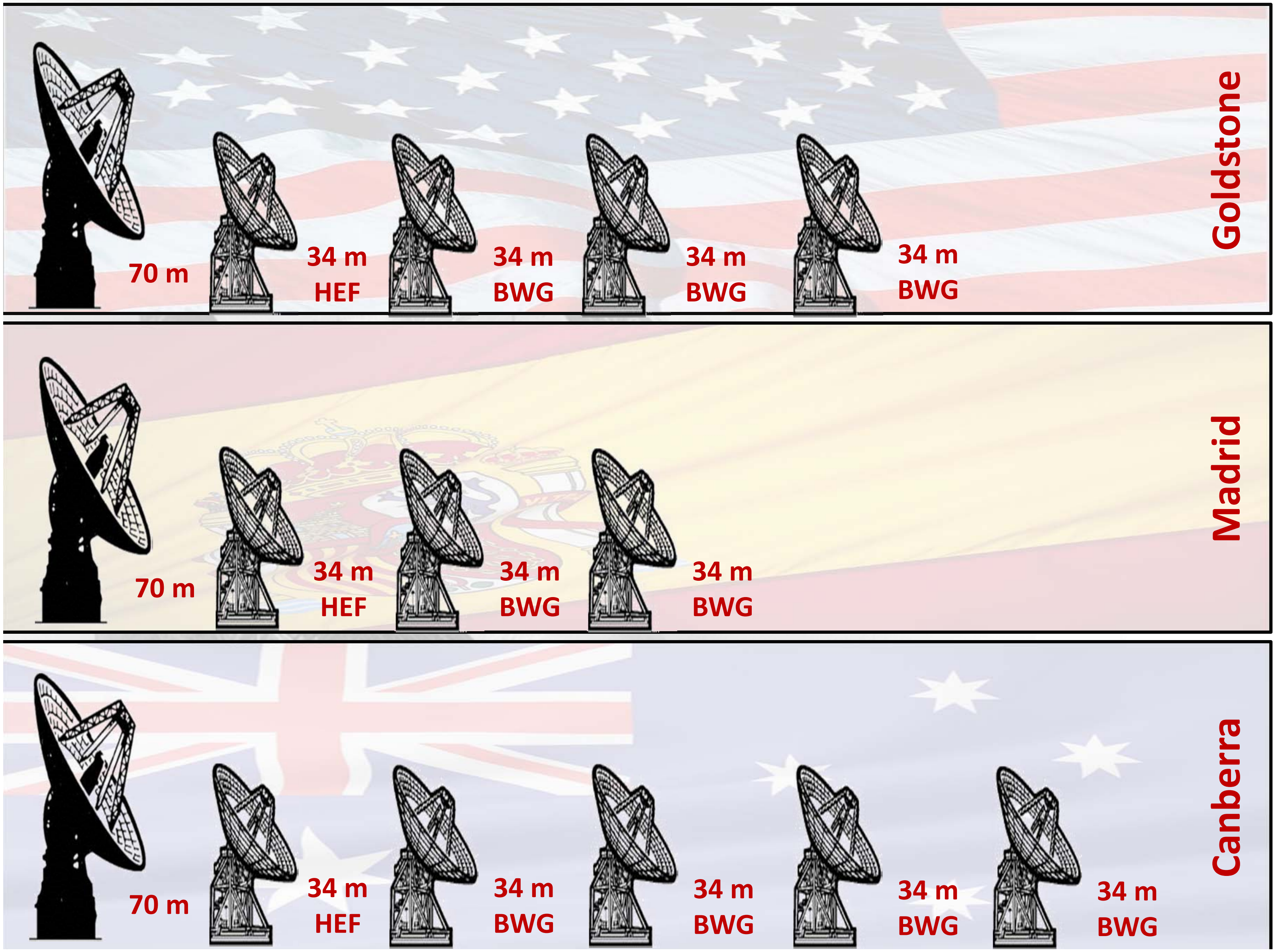
DSN Configuration: Today

Each ground station has:

- one 70m antenna
- one 34m High Efficiency antenna (HEF)
- one or more Beam Wave Guide (BWG) antennas.

- HEF antennas were built in the 1980's and were the first to support X-band uplink.
- BWG antennas were built in the 1990's and route energy between the reflector and a room below ground which allows for many feeds and amplifiers at multiple frequencies to be illuminated selectively by a mirror.

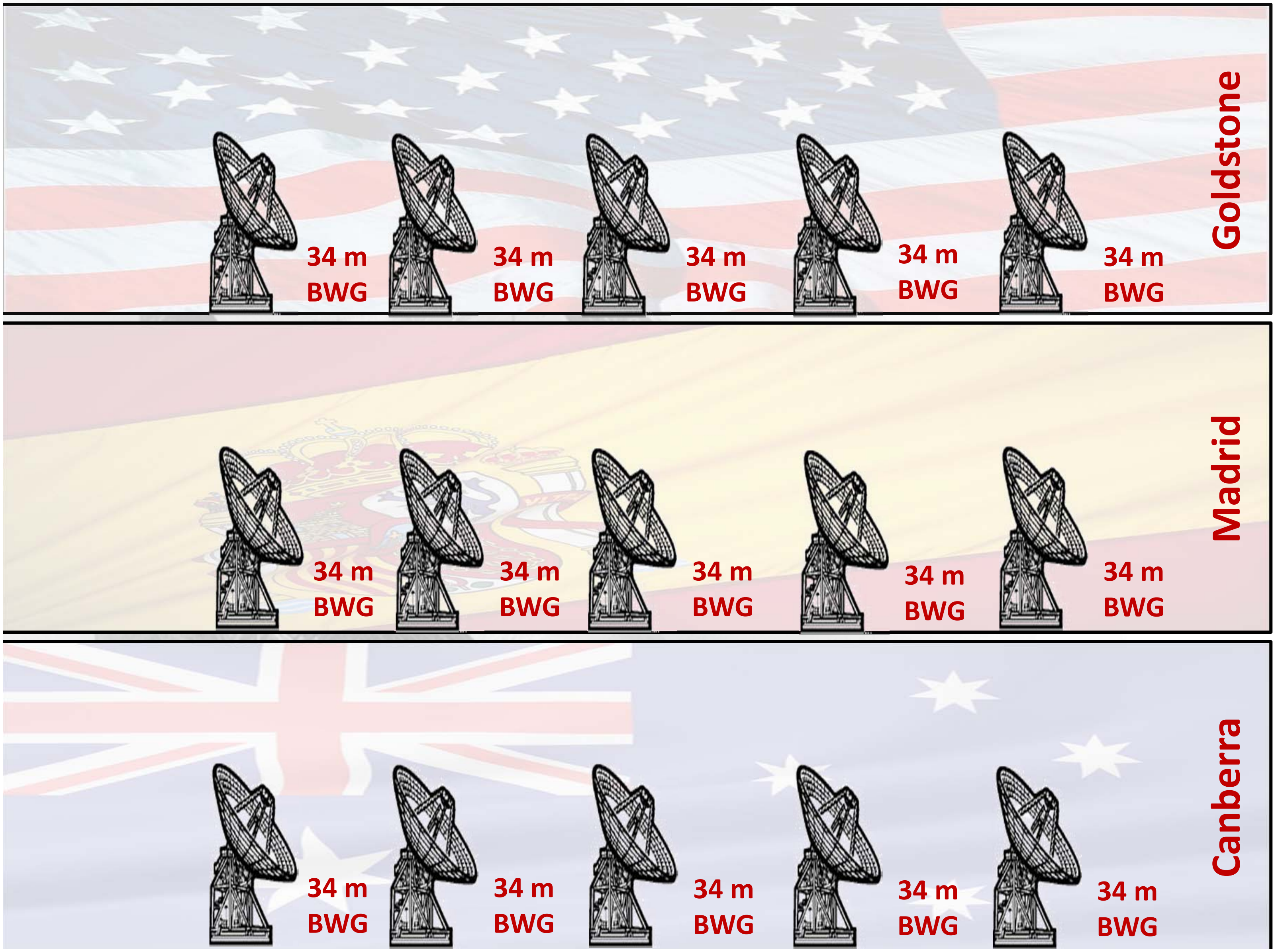
DSN Aperture Enhancement Project



DSN Configuration: 2018

Three more 34 meter BWG antennas are commissioned to be built in Canberra by 2018.

DSN Aperture Enhancement Project

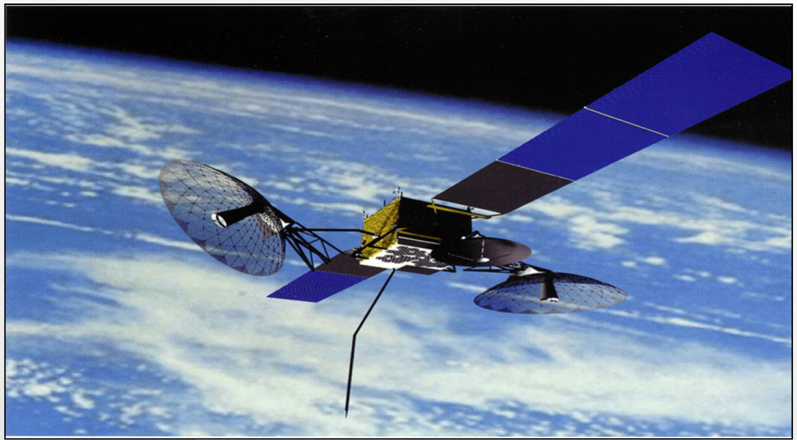


DSN Configuration: 2025

By 2025, the 70 meter antennas at all three locations will be decommissioned and replenished with 34 meter BWG antennas that will be arrayed.

All systems will be upgraded to have X-band uplink capabilities and both X- and Ka-band downlink capabilities.

Space Network (SN)



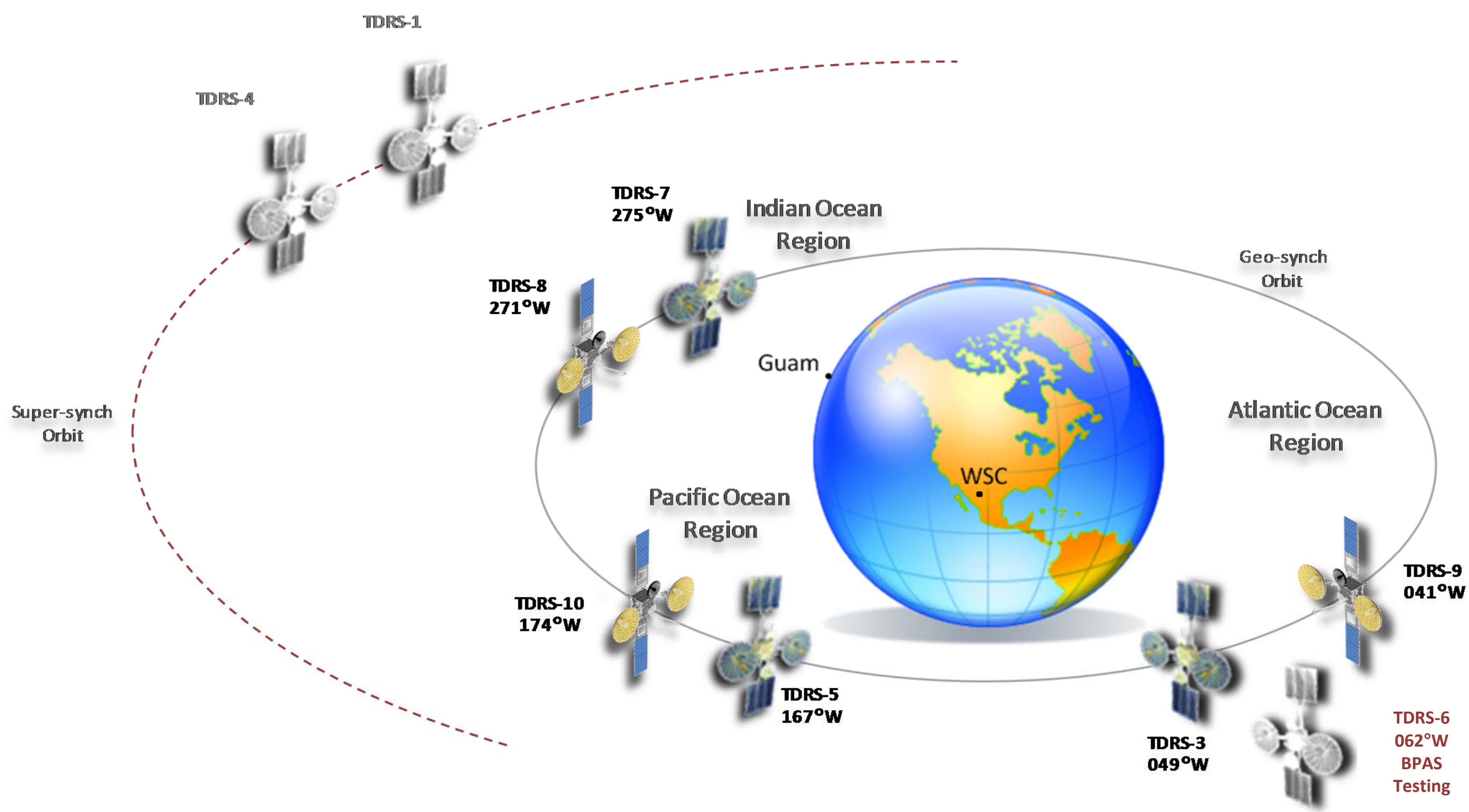
Tracking and Data Relay Satellite (TDRS)
Generation 1 by TRW;
Generation 2 and 3 by Boeing

White Sands Complex (WSC)
Operated by ITT Exelis

Second TDRS Ground Terminal (STGT)
Operated by ITT Exelis

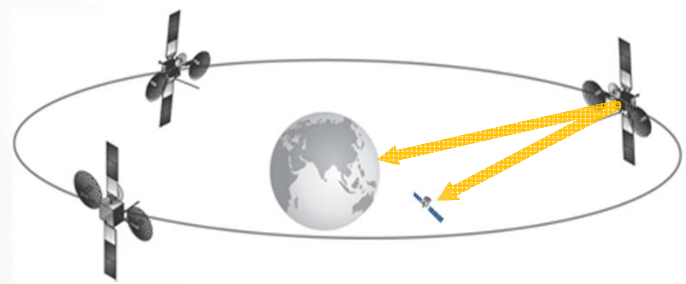
Guam Remote Ground Terminal (GRGT)
Operated by ITT Exelis

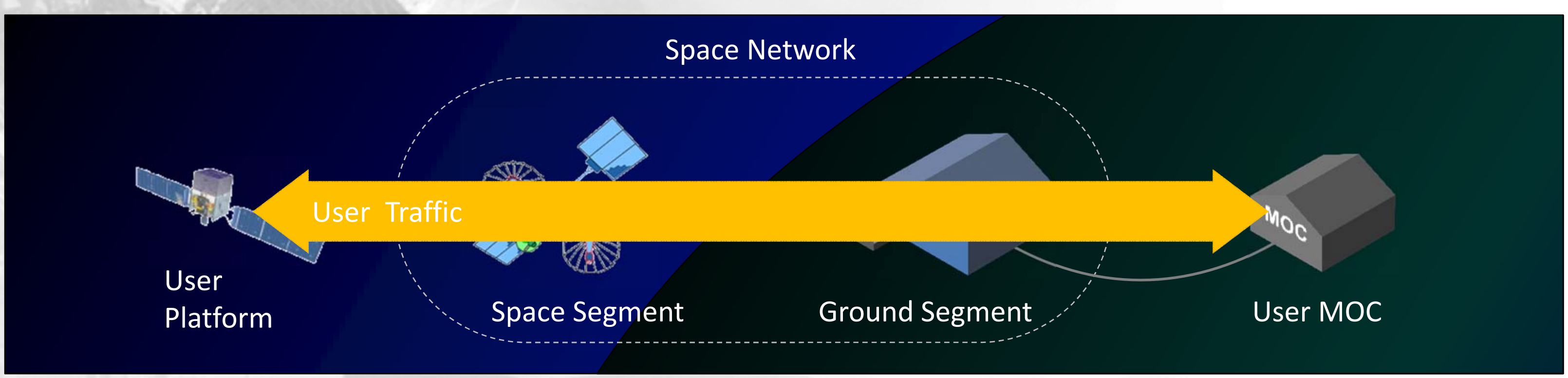
Space Network



Space Network Ground Segment Sustainment Mission

- What is the Space Network?
  - Communications relay system consisting of a Space Segment and a Ground Segment
    - Space segment consists of TDRS Fleet
    - Ground segment includes multiple ground terminals
  - Provides space platform to mission operations center (MOC) connectivity for TT&C, mission data transfer
- The mission of the Space Network Ground Segment Sustainment (SGSS) is to:
  - Implement a flexible and extensible ground segment,
  - Maintain the high level of service in the future,
  - Accommodate new users and capabilities, and
  - Reduce effort required to operate and maintain the system
  - Replace 20-30 yr old equipment with modern architecture





Beyond SGSS

- Frequent periodic refreshes and upgrades
  - SGSS modularity, extensibility, architecture and application isolation support non-disruptive upgrades, enabling a continuous refresh cycle
  - Network architecture and distributed intelligence improves scalability
  - Software modems enable introduction of new capabilities easily
- Phased transition to the SCaN Integrated Network architecture
- Increased customer adoption of the capabilities and standards
  - CCSDS Space Link Extension service management
  - New modulation and coding schemes
- Continued O&M savings

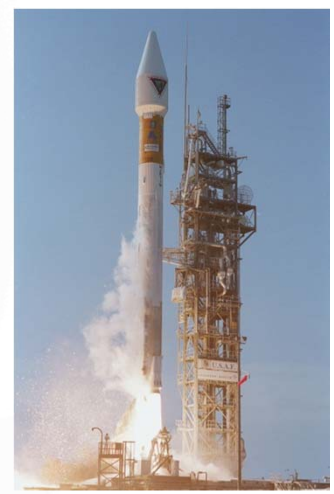
Replenishing the Tracking and Data Relay Satellites (TDRS)

- Three third generation Tracking and Data Relay Satellites (TDRS) are being prepared for launch.
  - TDRS-K Launch Readiness – 2013
  - TDRS-L Launch Readiness – 2014
  - TDRS-M Launch Readiness – 2015
- These satellites will replenish the fleet as original 20+ year old satellites begin to fail
- Third generation satellites are nearly the same as second generation satellites to limit development cost
- Ground terminals at White Sands, Guam, and Blossom Point are being updated to handle them

TDRS Launch History and Plans

TDRS	Launch Date
TDRS-A (TDRS-1)	April 15,1983 *(Retired Fall 2009, Disposal June 2010)*
TDRS-B	Destroyed January 28, 1986 in Challenger explosion
TDRS-C (TDRS-3)	September 29, 1988
TDRS-D (TDRS-4)	March 13, 1989 *(Retired December 2011, Disposal April 2012)*
TDRS-E (TDRS-5)	August 2, 1991
TDRS-F (TDRS-6)	January 13, 1993
TDRS-G (TDRS-7)	July 13, 1995 (replacement for TDRS-B)
TDRS-H (TDRS-8)	June 30, 2000
TDRS-I (TDRS-9)	March 8, 2002
TDRS-J (TDRS-10)	December 4, 2002
TDRS-K (TDRS-11)	Scheduled to launch in January 2013
TDRS-L (TDRS-12)	Scheduled to launch in 2014
TDRS-M (TDRS-13)	Scheduled to launch in 2015

TDRS 1 – 7 were taken up by the Space Shuttle



TDRS 8-12 were/will be launched by Atlas rockets

Near Earth Network (NEN)

Svalbard Ground Station
Operated by KSAT, Norway

Wallops Ground Station (WGS)
Operated by ITT Exelis

McMurdo Ground Station
Operated by ITT Exelis

WS1 Antenna at WSC
Operated by ITT Exelis

SCAN ARCHITECTURE

SCaN Current Network

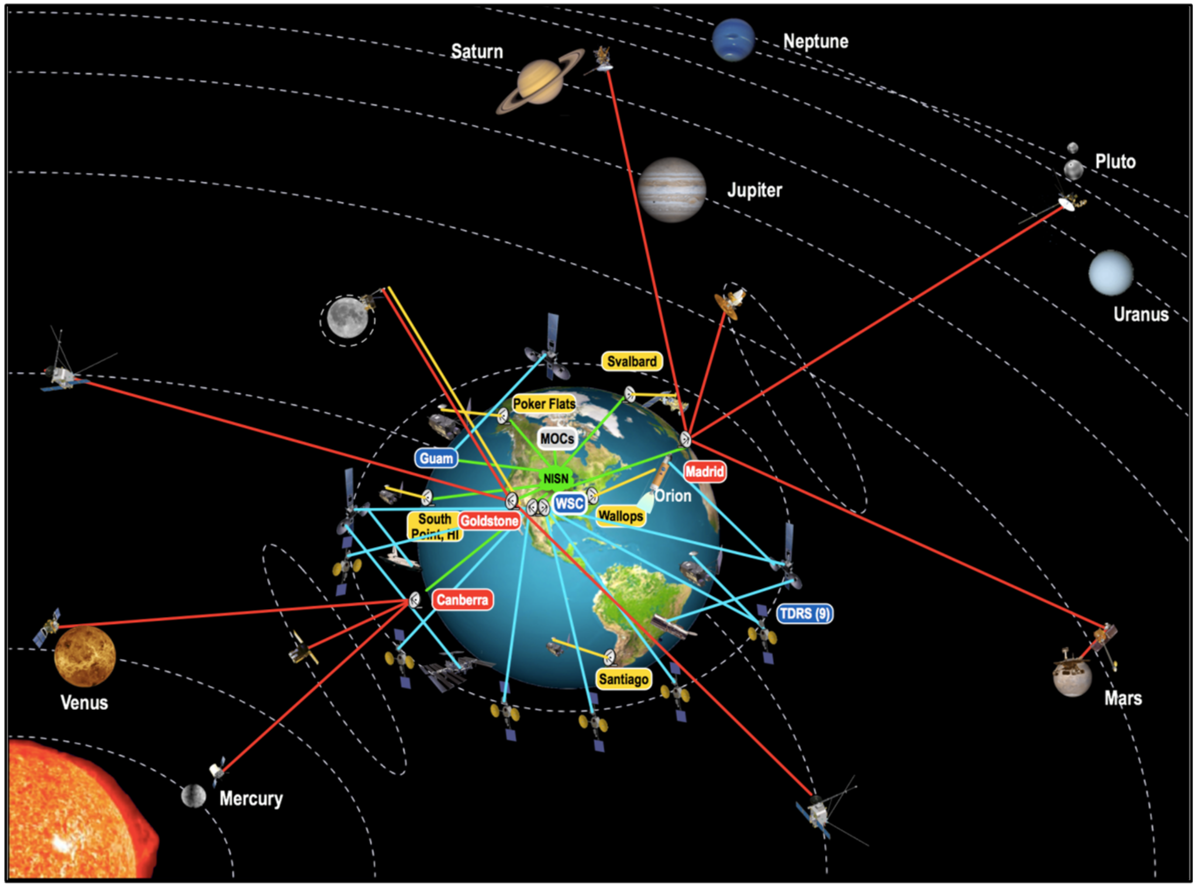
The current NASA space communications architecture embraces three operational networks that collectively provide communications services to supported missions using space-based and ground-based assets

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

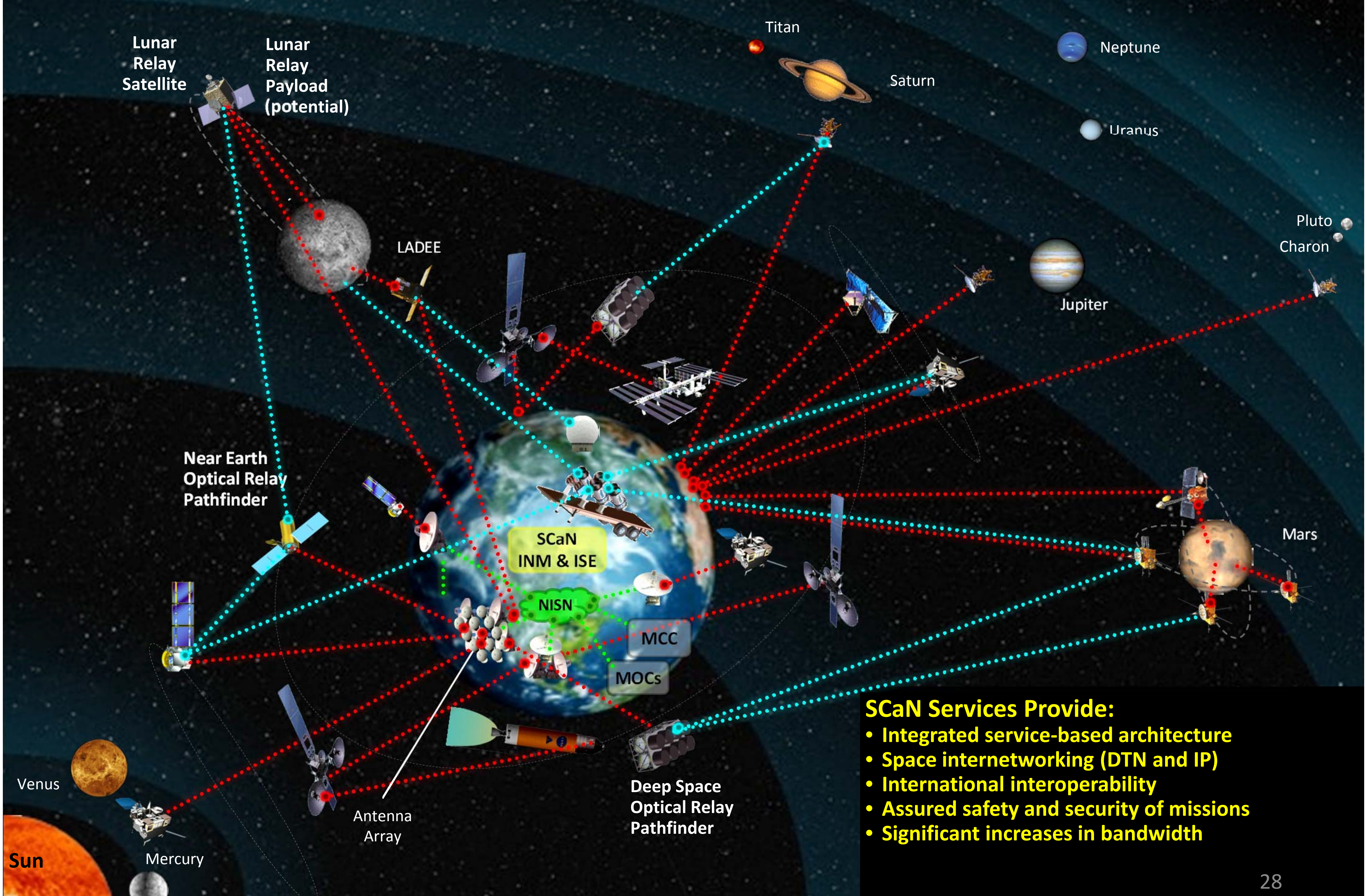
Space Network - constellation of geosynchronous relays (TDRSS) and associated ground systems

Deep Space Network - ground stations 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) – no longer part of SCaN – managed by OCIO; provides terrestrial connectivity



SCaN Notional Integrated Communication Architecture

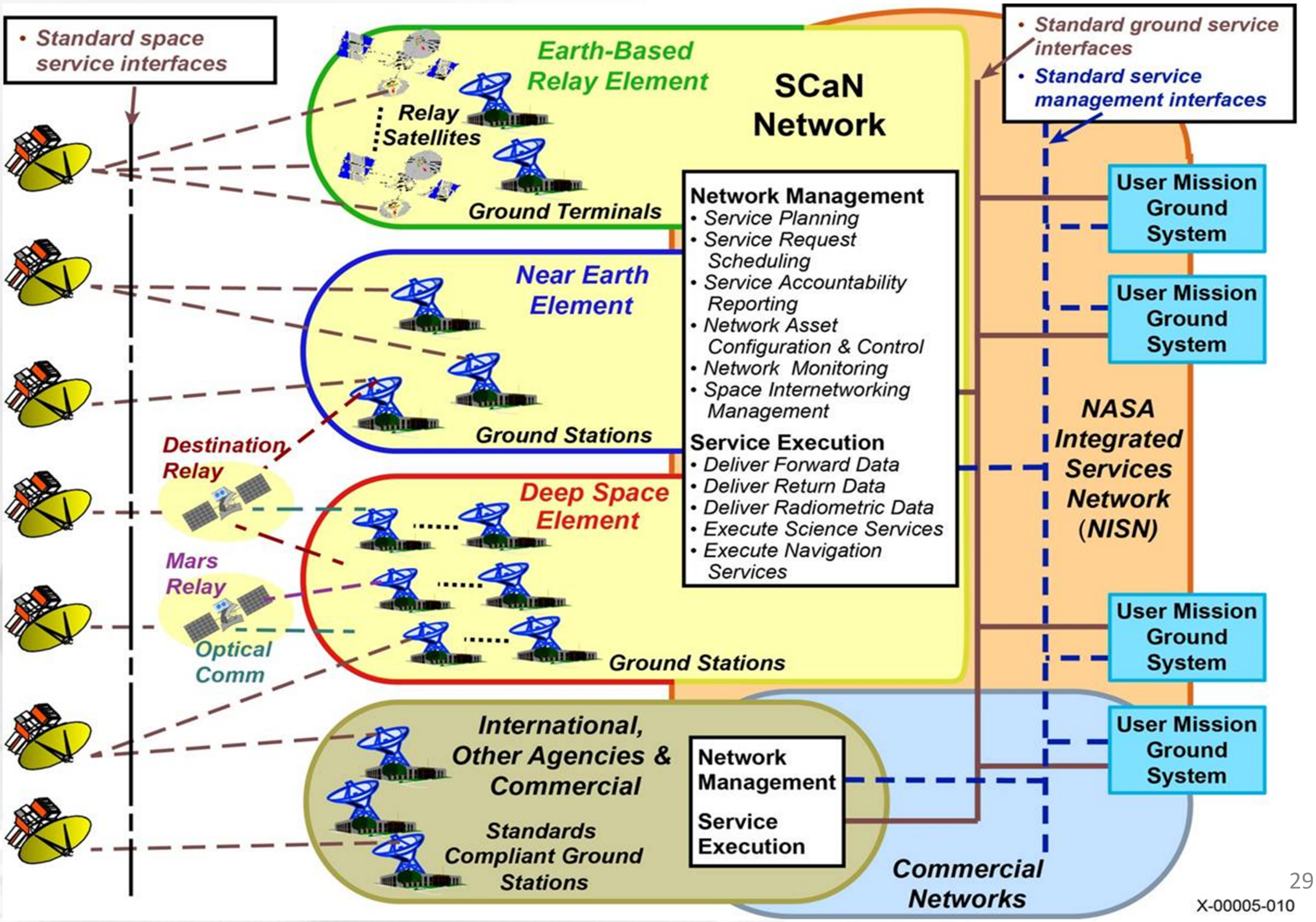


SCaN Services Provide:

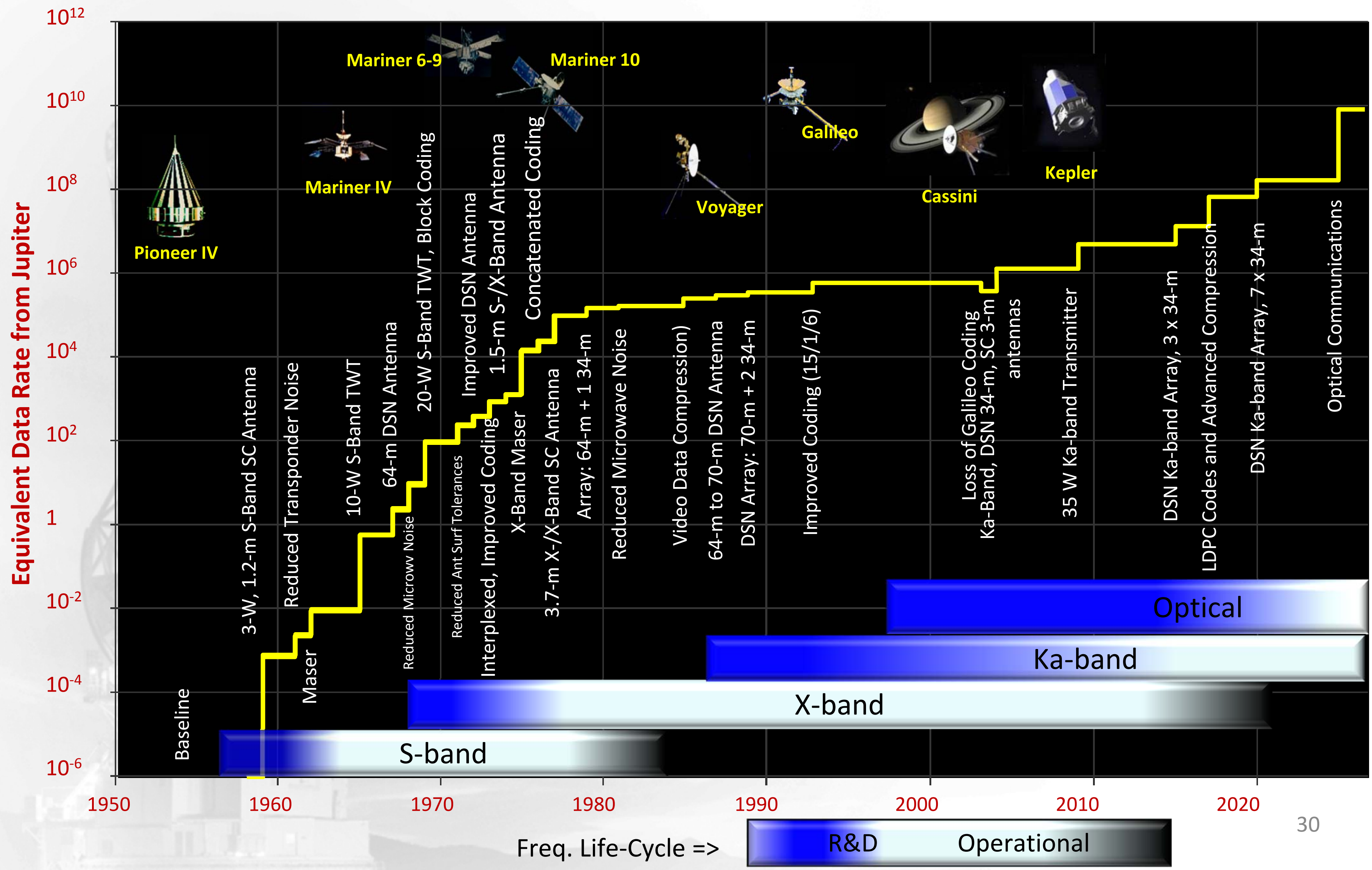
- Integrated service-based architecture
- Space internetworking (DTN and IP)
- International interoperability
- Assured safety and security of missions
- Significant increases in bandwidth

Microwave Links | Optical Links | NISN

SCaN Integrated Network:
Service Architecture

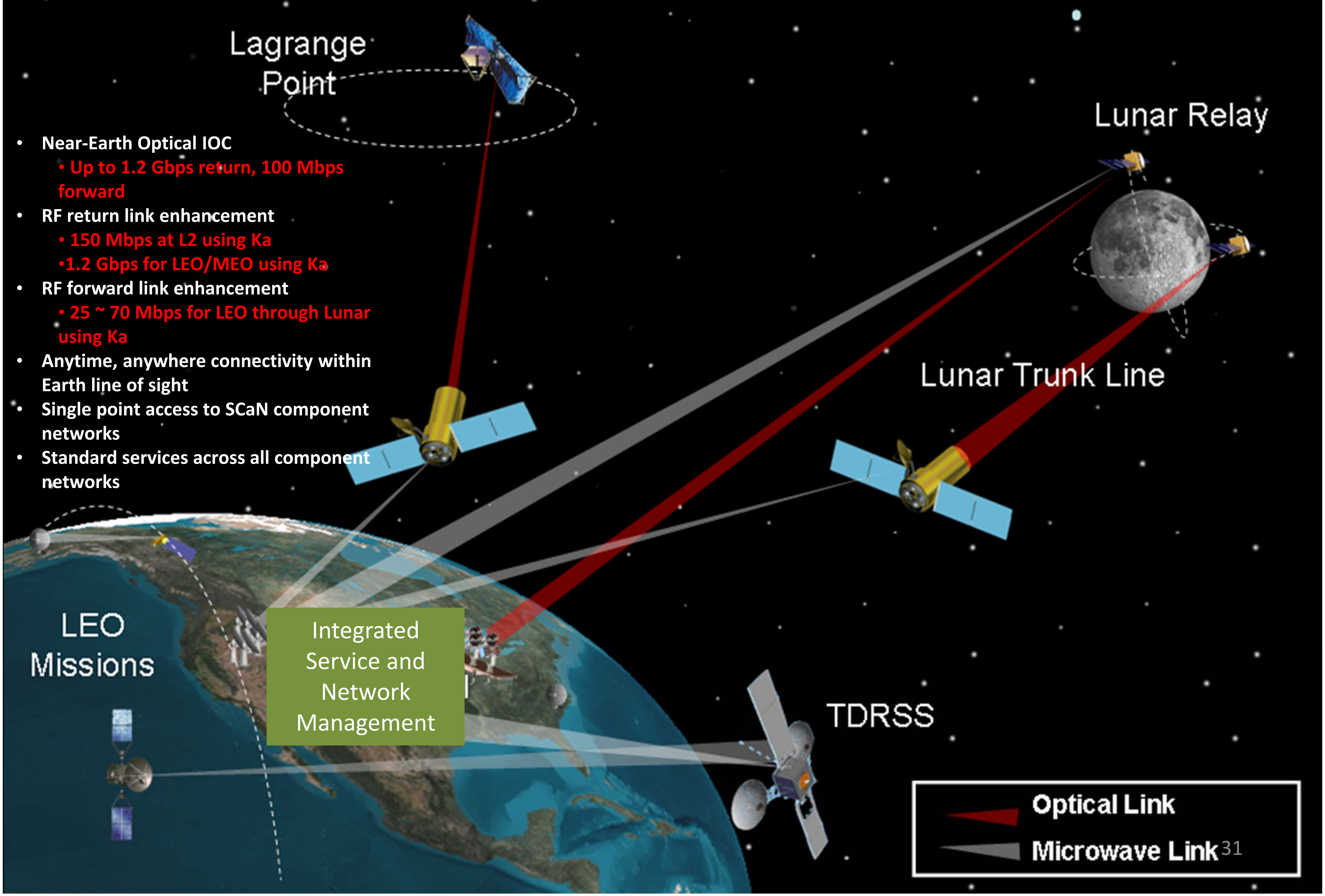


Data Rate Evolution

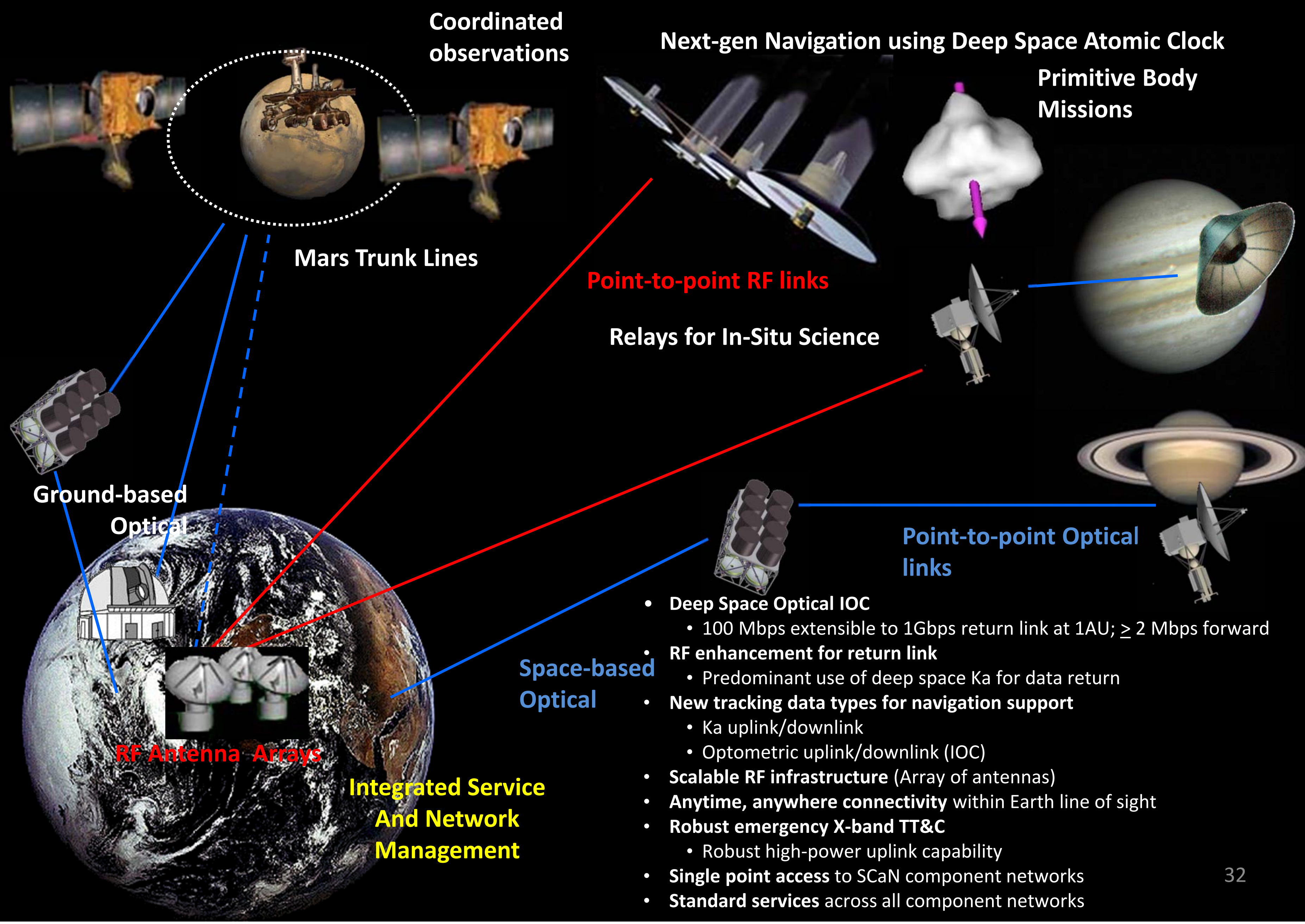


Notional Enhanced Earth Domain Capabilities

- 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



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
  - Optometric uplink/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

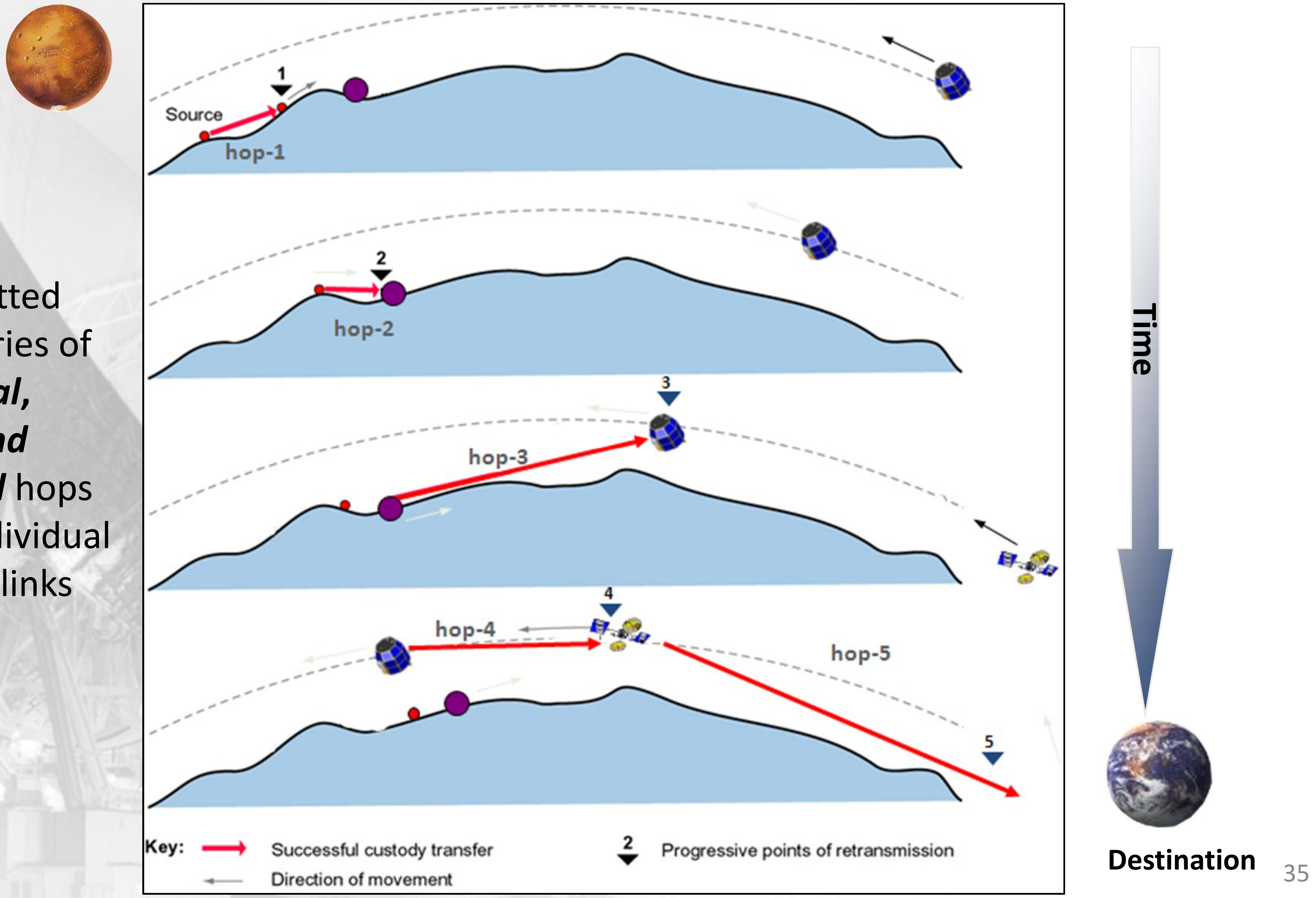
SCaN Funds Push and Pull Technologies

- A **Push Technology** is one that is not directed to or required by a specific space mission, but instead would provide a generic capability which could enable or enhance future space missions
  - E.g., a high sensitivity receiver that could improve link capability by 20 decibels

- 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

Disruption Tolerant Network (DTN)

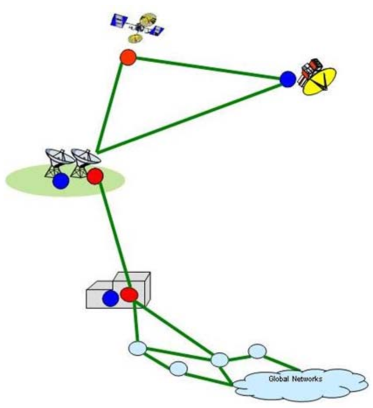
Data is transmitted via a series of ***custodial, store and forward*** hops over individual disjoint links

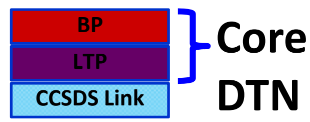


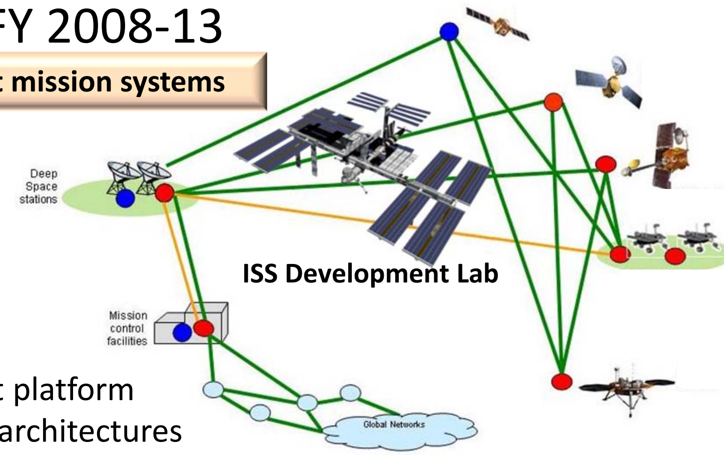
NASA DTN Development Strategy

DTN Phase-1/2: FY 2008-13

Use DTN to automate current mission systems



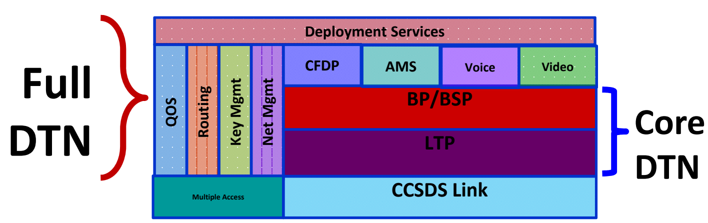


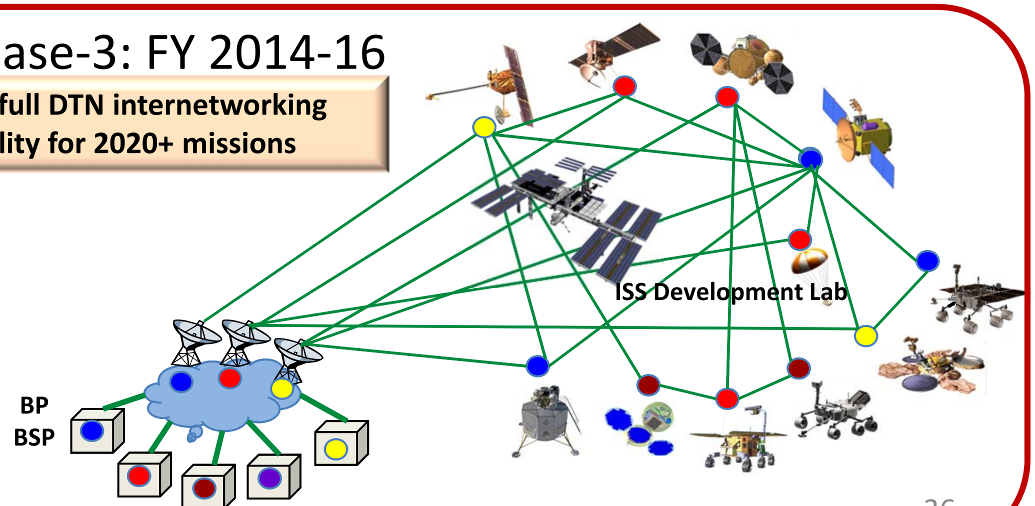


- Develop Core DTN protocols
  - Use ISS as a development platform
  - Apply to current mission architectures

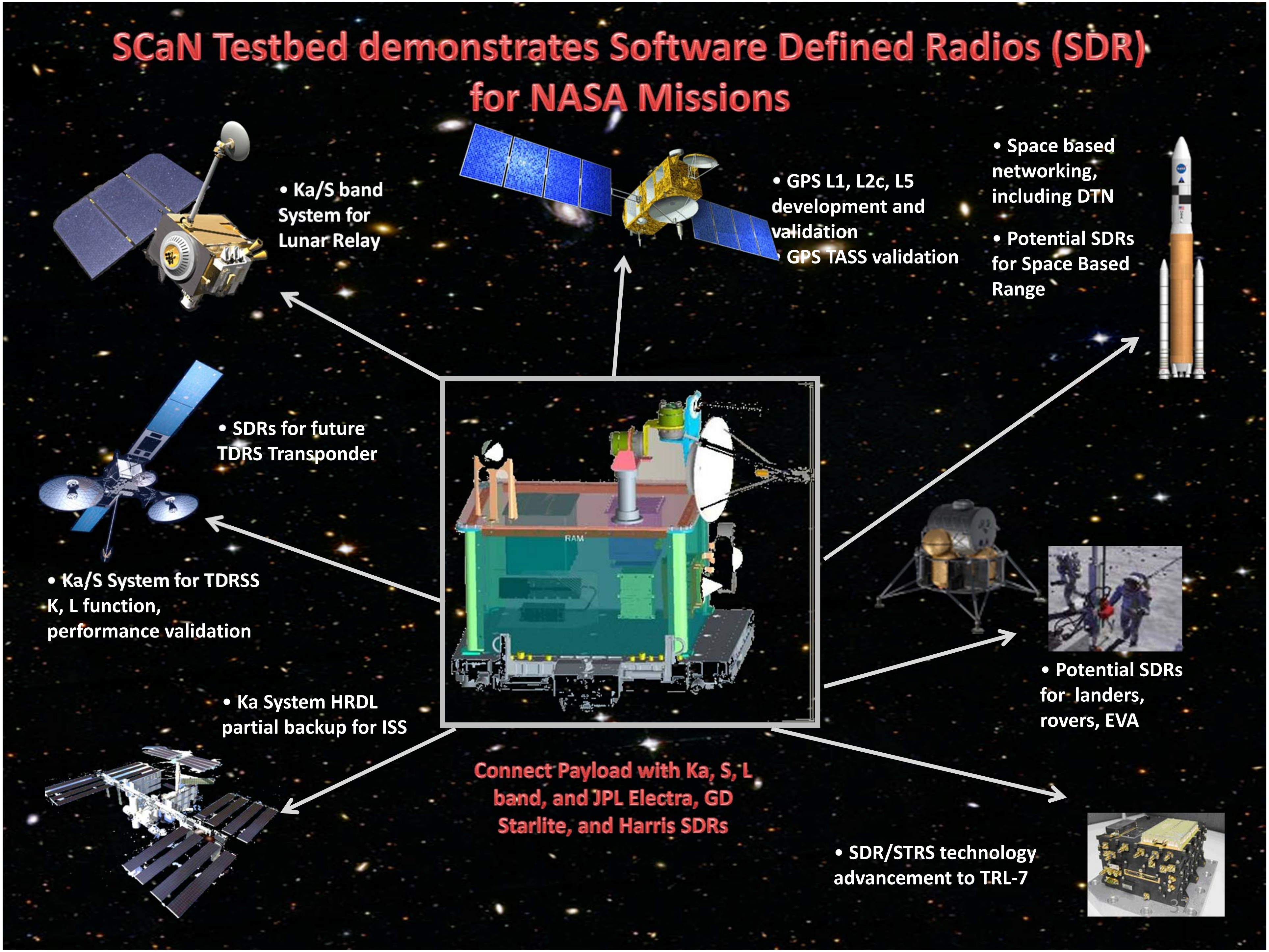
DTN Phase-3: FY 2014-16

Develop full DTN internetworking capability for 2020+ missions





- Develop full DTN protocol suite for internetworking
  - Continue to use ISS as a development platform
  - Seek early Exploration mission infusion


SCaN Testbed demonstrates Software Defined Radios (SDR) for NASA Missions
• Ka/S band System for Lunar Relay
• GPS L1, L2c, L5 development and validation
• GPS TASS validation
• Space based networking, including DTN
• Potential SDRs for Space Based Range
• SDRs for future TDRS Transponder
• Ka/S System for TDRSS K, L function, performance validation
RAM
• Potential SDRs for landers, rovers, EVA
• Ka System HRDL partial backup for ISS
Connect Payload with Ka, S, L band, and JPL Electra, GD Starlite, and Harris SDRs
• SDR/STRS technology advancement to TRL-7
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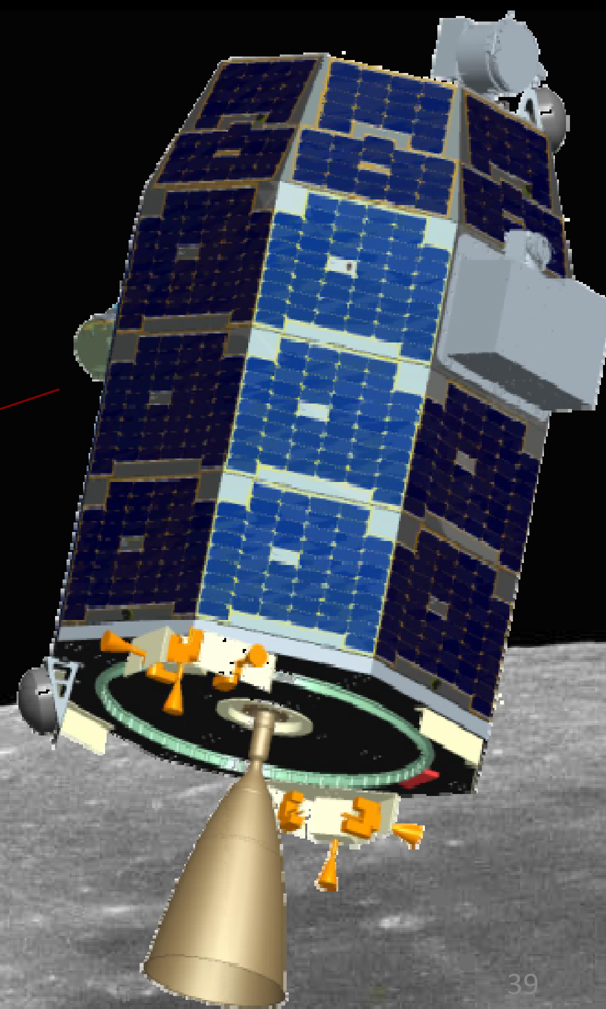
SCaN Testbed Demonstrates Software Defined Radios

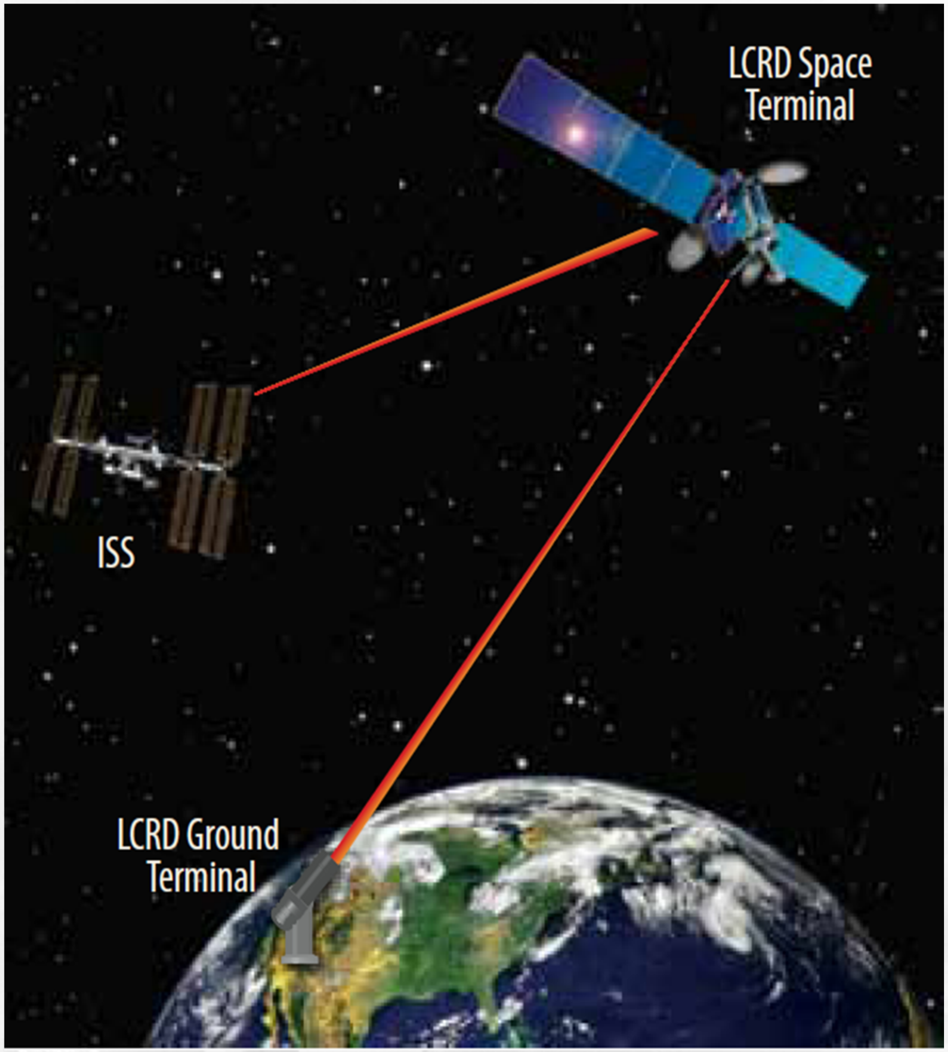
- Software Defined Radios (SDR) provide unprecedented operational flexibility with software functionality that allows communications functions to be updated in flight
  - Functions can be changed within the same SDR across mission phases
    - E.g., Range Safety functions in launch phase, mission ops 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., Mars Reconnaissance Orbiter (MRO) corrected EMI problem with software update in transit to Mars using the Electra SDR
- Small size, weight, and power is achievable for all SDRs, especially mobile units (e.g., Extra Vehicular Activities (EVA), 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

Lunar Laser Communication Demo

- Lunar Laser Communications Demo (LLCD) to fly on Lunar Atmosphere and Dust Environment Explorer (LADEE)
- Launch Readiness Date: August 2013 from Wallops Flight Facility, VA on Minotaur V
  - One month transfer
  - One month commissioning
    - 250 km orbit
    - LLCD operation demonstrating 600 Mbps downlink
    - Spacecraft and science payloads checkout
  - Three months science
    - 50 km orbit
    - Three science payloads
      - Neutral Mass Spectrometer
      - UV Spectrometer
      - Lunar Dust Experiment



Laser Communications Relay Demo (LCRD)



- LCRD will fly in 2017 and demonstrate optical communication for possible inclusion in NASA's Next Generation Tracking and Data Relay Satellite (TDRS).
- LCRD will be a network node with two optical terminals based on the LLCD design.
- Data transfer will be at variable data rates up to 2.8 Gbps.
- Onboard processing will implement DTN protocols to help address atmospheric conditions.

Benefits of Optical Communications

Depending on the mission application, an optical communications solution could achieve…

- **~ 50%** savings in mass
  - Reduced mass enables decreased spacecraft cost and/or increased science through more mass for the instruments
- **~ 65%** savings in power
  - Reduced power enables increased mission life and/or increased science measurements
- Up to **20x** increase in data rate
  - Increased data rates enable increased data collection and reduced mission operations complexity

…over existing RF solutions

Mars Reconnaissance Orbiter (MRO) Example

This image taken by the Mars Reconnaissance Orbiter represents what one could see from a helicopter ride at 1000 feet above the planet. While this mission is collecting some of the highest resolution images of Mars to date and it will collect 10 to 20 times more data than previous Mars missions, bandwidth is still a bottleneck.

Data collection for climate observations must be turned off while not over the poles because we cannot get the data back.

At MRO's maximum data rate of 6 Mbps (the highest of any Mars mission), it takes nearly 7.5 hours to empty its on-board recorder and 1.5 hours to transfer a single HiRISE image to earth.

In contrast, with an optical communications solution at 100 Mbps, the recorder could be emptied in 26 minutes, and an image could be transferred to earth in less than 5 minutes.

SPECTRUM MANAGEMENT

Agency Spectrum Management Objectives

- The overall planning, policy, and administration of the NASA Spectrum Management Program
- Ensure that NASA activities comply with national and international rules and regulations
- Ensure adequate spectrum to support NASA programs
  - Space Communications Architecture
  - Science and aeronautical missions

Spectrum Management

- Responsibility for Agency Spectrum Management vested in SCaN
  - Agency Spectrum Manager is Deputy Associate Administrator/SCaN
  - NASA Policy Directive 2570.5E
  - Director Spectrum Policy and Planning responsible for program execution
- Domestic Spectrum Management a bifurcated mandated process
  - Federal Communications Commission (FCC)
  - National Telecommunications and Information Administration (NTIA)
- International Spectrum Management treaty based driven
  - International Telecommunications Union (ITU)
    - World Radiocommunication Conference (WRC)
  - Space Frequency Coordination Group (SFCG)
  - Regional coordination with Inter-American Telecommunication Commission (CITEL)

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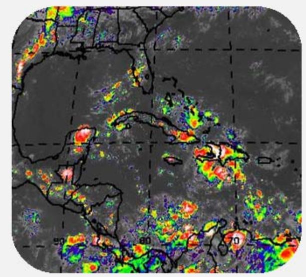
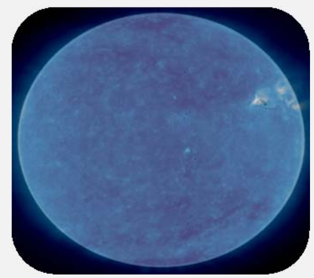


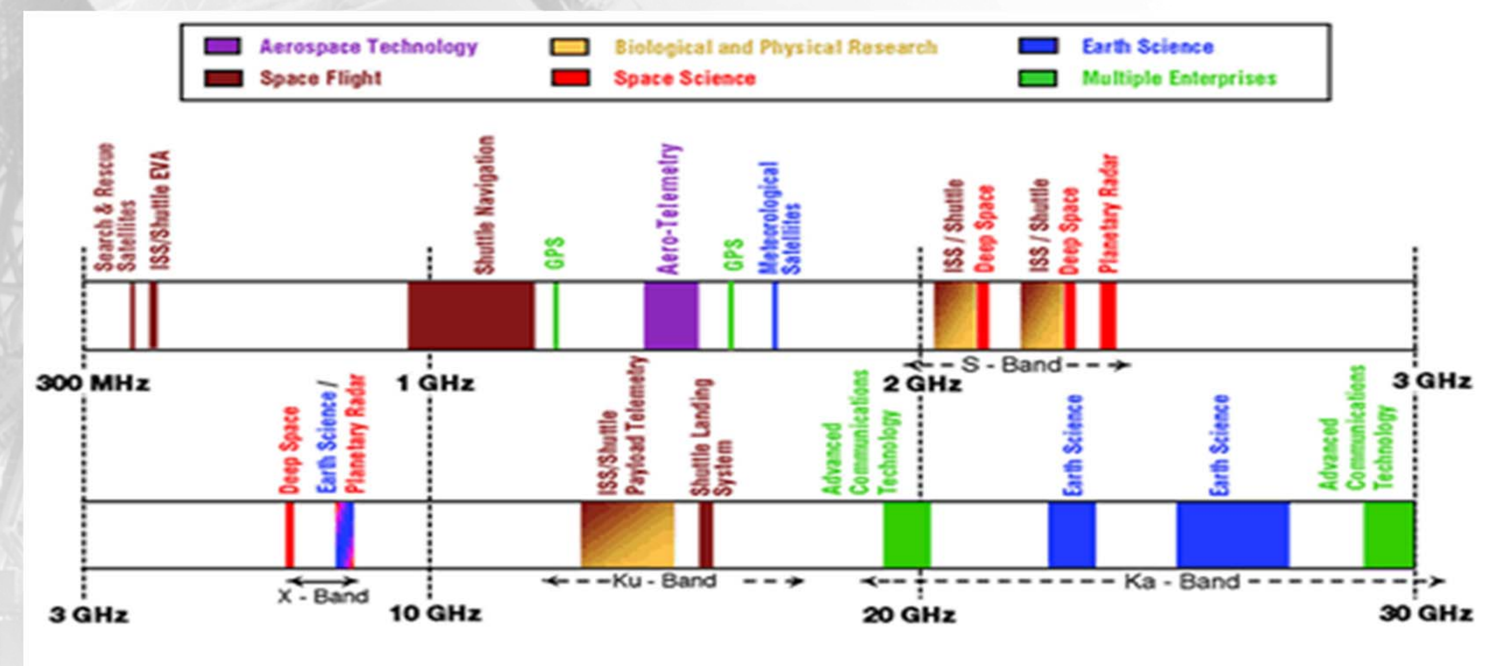
Visible

UV



Spectrum Management

- Spectrum access and use is absolutely vital to scientific and aeronautics communities
- Spectrum is a highly valued regulated resource subject to continuous competition
- NASA fully reliant on spectrum to sustain all flight programs
- Requirement for NASA Spectrum Management codified in Federal law
  - Communication Act of 1934
  - Communications Satellite Act of 1962
  - Commercialization of Space Act of 1983
  - National Space Policy (Classified/Unclassified)

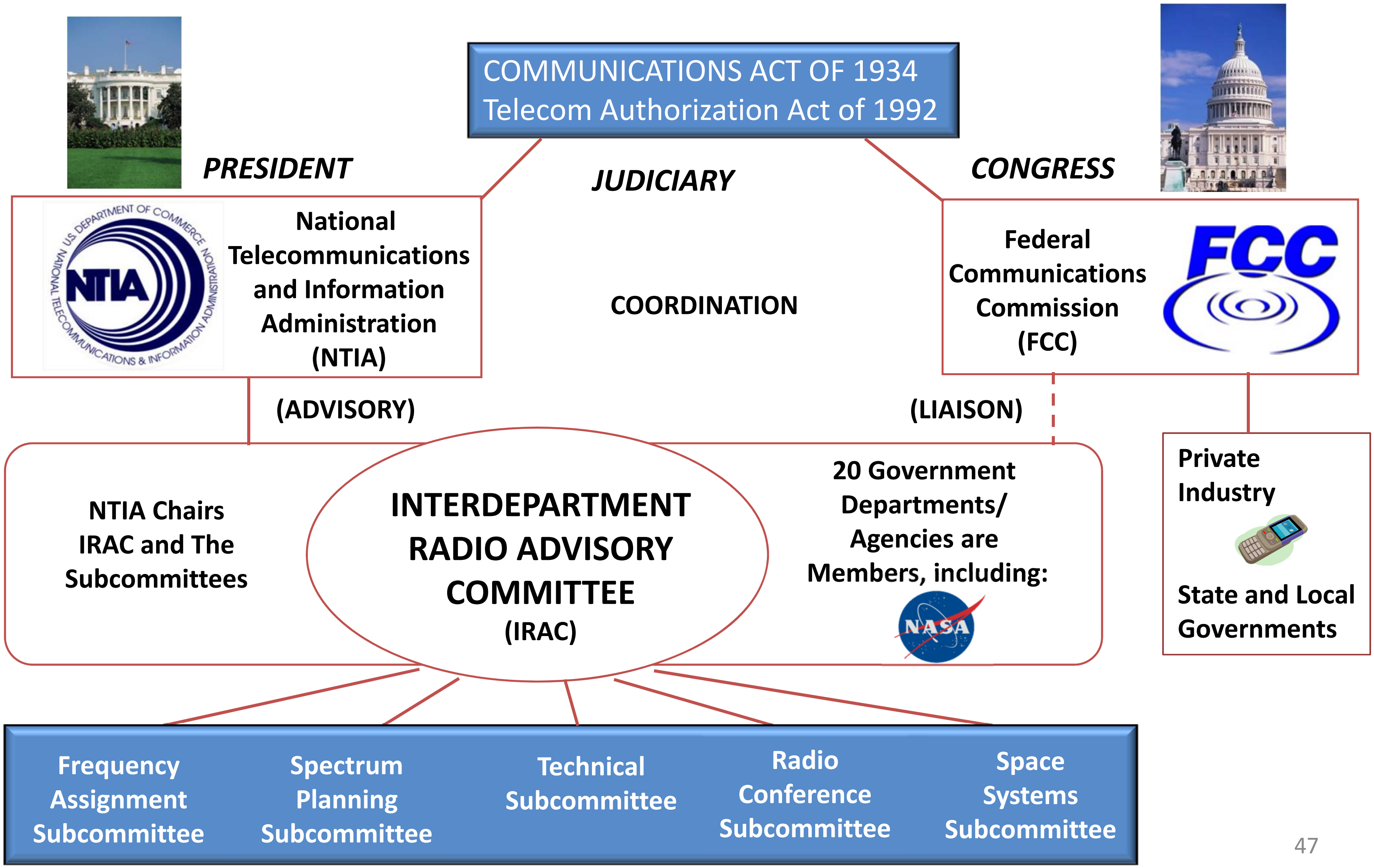


Representative NASA Spectrum Use (300 MHz - 30 GHz)

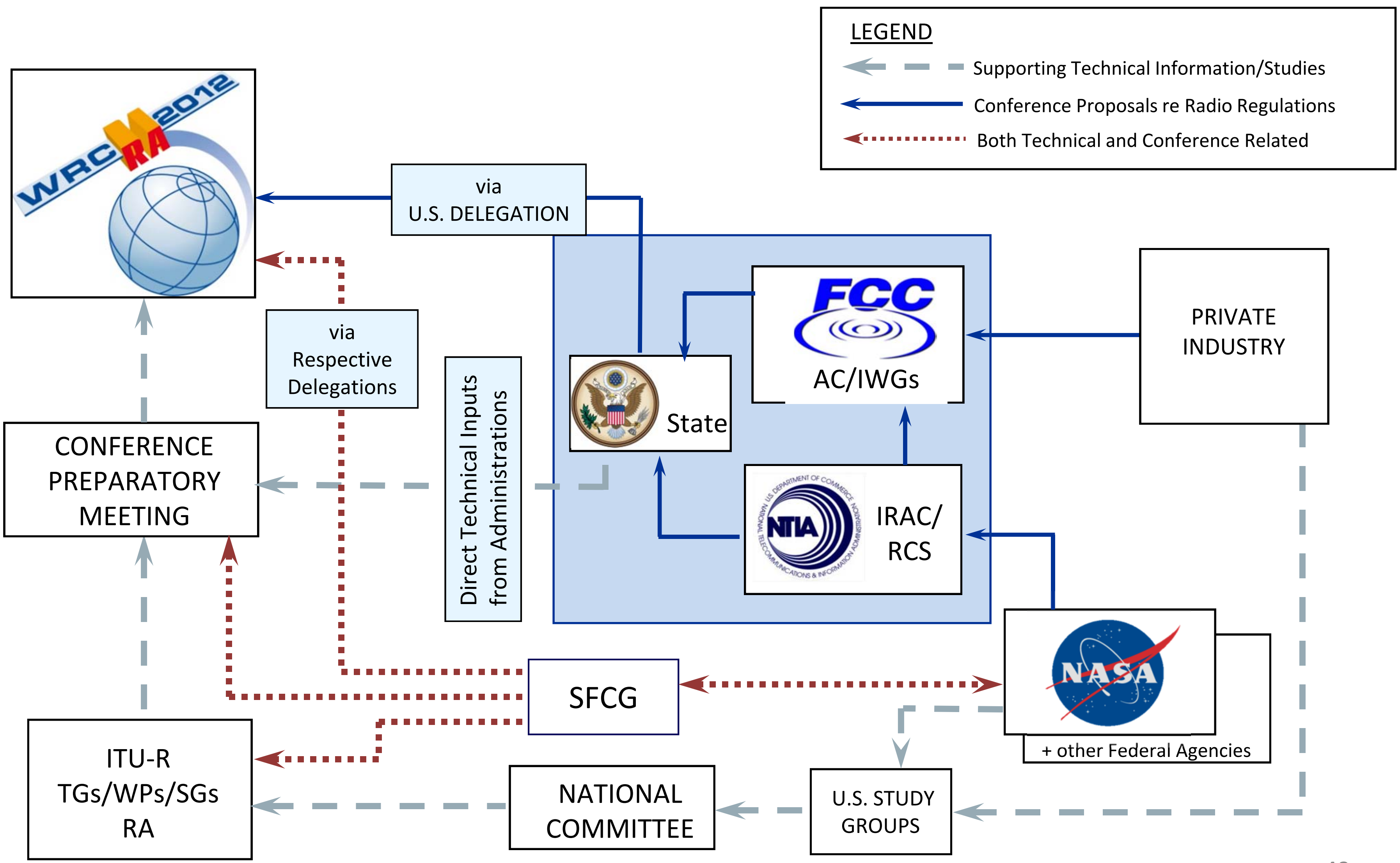
Key Focus Areas

- National Broadband Initiative
  - Several bands identified for consideration
  - Including key NASA S-band down/return links (2200-2290 MHz)
  - Adjacent band compatibility analyses (DISH Network)
  - FCC has several on-going or planned rulemakings associated with the broadband initiative that could affect NASA spectrum equities.
  - GPS Protection – LightSquared compatibility
- Commercial launch policy support
  - Commercial Orbital Transportation Services (COTS), Commercial Resupply Services (CRS) (SpaceX, Orbital Sciences)
- Agency spectrum management database development
- Satellite filings and mission certifications
- Spectrum efficiency policy
  - Response to OMB Circular A-11 revision
- CubeSat Awareness

Domestic Spectrum Management



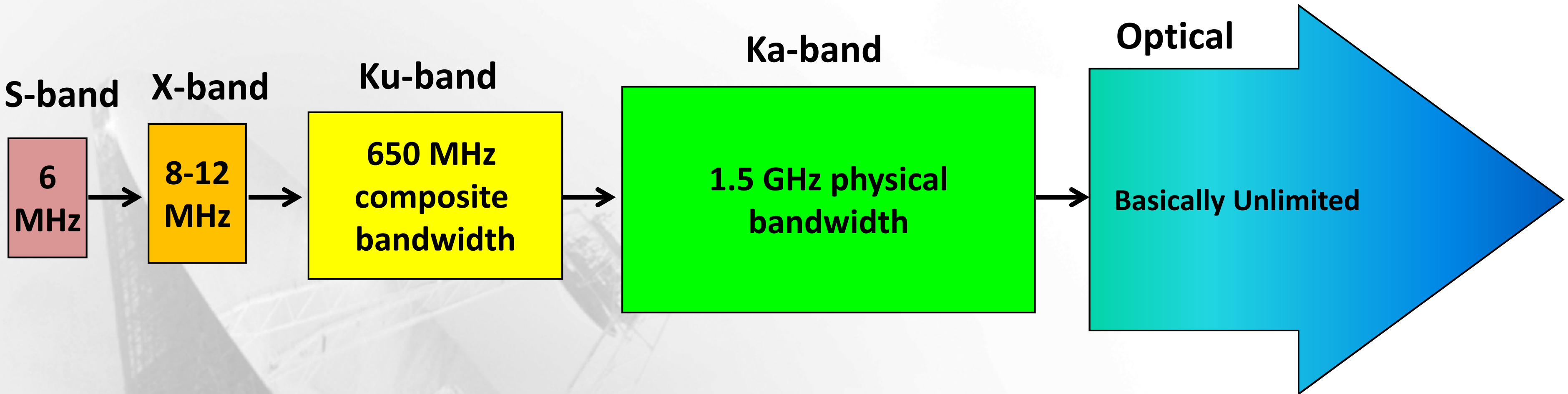
International Spectrum Management Process



Frequency Band Capabilities and Limitations

	S-band	X-band	Ku-Band	Ka-Band and above	Optical
Regulatory Limitations	• Limited to 6 MHz channels by SFCG • PFD limits	• 10 MHz - near-Earth • 8-12 MHz - deep space • PFD limits	• 650 MHz Composite • Secondary • Return link will support up to 300 Mbps	• 26/23 GHz - near Earth • 32/34 GHz - deep space • 37-38/40-40.5 GHz • PFD limits	Currently none
Sharing Conditions	• Heavily used • Shared with ENG • 2110-2120 E-s not allowed in Spain due to cell phones	• Heavily used by EESS and deep space missions • Workhorse of foreign space agencies (e.g., CNES) • No space-space	• Continued increase in "mobile" VSAT and commercial FSS use • RFI threats from FSS use to uplinks, downlinks and space-to space links	• 26 GHz band - SRS and EESS secondary to fixed and mobile • 23 GHz allocation approved at WRC-12 • About 1 GHz is available in Spain and Australia • 37-38 GHz segmented by SFCG agreement – also sharing with HDFS.	Essentially open
Risks	• Broadband (Cell phones)	• FSS target • Broadband (Backhaul)	• Ku-band allocations remain secondary • NTIA and DOD have urged NASA to vacate Ku-band	• MSS target	Atmospheric propagation

Downlink Bandwidth Capability



- Lower bands (S-band, X-band) provide limited bandwidth, low data rates (downlink limited by NTIA regulations and SFCG recommendations)
- Spectrum below 10 GHz is heavily used /shared and under increasing pressure for re-allocation to commercial wireless
- Ku-band allocation is secondary and faces increasing risk from “mobile” VSAT satellite uses
- Way Forward:
  - Increase usage of Ka-band, both deep space and near Earth
  - Ultimate use of optical technology

POLICY AND STRATEGIC COMMUNICATIONS

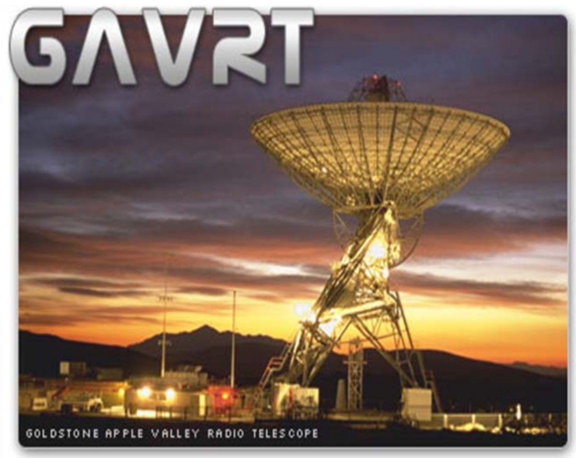
Overview

- **Overview**
  - **Education:**
    - Supports NASA's goal of promoting Science, Technology, Engineering, and Math (STEM) education.
    - Educates students on the value of space communications and navigation (SCaN) and future exciting career opportunities.
  - **Public Outreach**
    - Conducts public outreach activities to the general public and public sub-communities such as through the Speakers Bureau, attending conferences and maintaining SCaN's public website.
- **Objectives and Strategies**
  - Inform customer base and the general public about the role of SCaN in space missions
    - Conduct internal workshops/forums, exhibit at relevant conferences individually and as part of NASA/Human Exploration and Operations Mission Directorate (HEOMD), develop online demos and games as stand-alone and jointly with others.
    - Develop content for the public website to engage the general public, especially students
    - Develop SCaN Speakers Bureau and participate as part of Agency's Speakers Bureau
  - Maintain and develop GAVRT program
    - Educate teachers and students in the US and internationally through GAVRT/PARTNeR in close cooperation with DSN sites
  - Engage younger generation in space-related activities to encourage pursuit of careers in space field
    - Partnering with the Space Generation Advisory Council to build an international outreach plan

Educational Activities

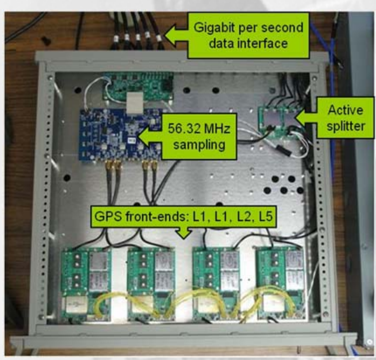
- **Goldstone Apple Valley Radio Telescope (GAVRT)**
  - GAVRT is a public (10%) – private (90%) partnership involving NASA, JPL, and the Lewis Center for Educational Research in Apple Valley, California.
  - GAVRT teaches students science, engineering, and mathematics to make measurements using large de-activated DSN Goldstone antennas in support of NASA missions.
  - GAVRT trains teachers, provides curriculum, and supports classroom implementation. The teachers take this training back to their classrooms for their students.
  - GAVRT uses the Internet to connect students to Operations Control Center at the Lewis Center and the antenna.
  - The GAVRT curriculum meets National Science Education Standards

  and is adapted to meet individual State Education Standards.



- **Proyecto Academico con el Radio Telescopio de NASA en Robledo (PARTNeR)**
  - PARTNeR is a similar program to GAVRT, located at the DSN's Madrid Deep Space Communication Complex.
  - PARTNER provides radio astronomy learning opportunities for schools in Spain.

Grants



SPACE GENERATION ADVISORY COUNCIL

- **University of Alaska Fairbanks**
  - SCaN established a three year grant with the University of Alaska Fairbanks (UAF) for community and secondary education outreach using the Alaska Satellite Facility's (ASF) Ground Station, one of SCaN's Near Earth Network (NEN) antennas.
- **NASA Summer Wings Grant at Southern Illinois University Carbondale**
  - NASA Wings is a week-long camp designed to give interested high school students an opportunity to learn more about how space communication and navigation systems impact and benefit aviation. NASA Wings offers students the chance to explore careers in aviation and aerospace by providing ground and flight training at SIUC's facilities.
- **Ohio University Global Positioning System**
  - This grant's research focused on signal monitoring and GPS capabilities for science missions and space operations from low earth orbit (LEO) to the maximum distance at which GPS signals can be received. This research will help to develop new applications, signal structures, and standards, as well as advanced receiver concepts for correction and monitoring networks to ensure the fidelity of the signals.
- **Space Generation Advisory Council (SGAC)**
  - Since 2008, SCaN has supported the SGAC activities, an international non-profit organization that resulted out of United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) recommendations in 1999. The organization focuses on providing the younger generation, a global volunteer network between the ages of 18-35, a voice in space policy. SCaN support includes providing resources to SGAC's annual Space Generation Congress (SGC) and the Youth for Global Navigation Satellite Systems (YGNSS) project.

Internship

- Summer Intern Project at NASA Glenn Research Center
  - The ten to twelve week Summer Intern Project (SIP) exposes undergraduate students from various fields, hands-on training with real mission scenarios, exposure to powerful communication systems and network software tools, and skills to design and analyze space communications systems and networks.

International Collaboration

- SCaN represents NASA's interests at all national and international organizations related to space communications and navigation requirements and missions.
  - Interoperability Plenary (IOP)
  - Interagency Operations Advisory Group (IOAG)
  - Consultative Committee for Space Data Systems (CCSDS)
  - Space Frequency Coordination Group (SFCG)
  - International Telecommunications Union/World Radiocommunications Conference (ITU/WRC)
  - International Committee on Global Navigation Satellite Systems (ICG)
  - ICG Providers Forum (PF)
- SCaN engages in bilateral and multilateral meetings with other agencies to discuss various matters of common interest and potential areas of collaboration. This may involve Space Act Agreements in support of various missions.

GPS and NASA

Positioning, Navigation, and Timing (PNT) are the Global Positioning System (GPS) "services" that enable:

- Real-time On-Board Autonomous Navigation: Use of GPS as a source for position and time allows NASA to maximize the "autonomy" of spacecraft and reduces the burden and costs of network operations. It also enables new precise methods of spaceflight such as formation flying.

- Attitude Determination: Use of GPS enables some missions to meet their attitude determination requirements, such as the International Space Station (ISS).

- Earth Science: GPS used as a remote sensing tool supports atmospheric and ionospheric sciences, geodesy, and geodynamics -- from monitoring sea level heights and climate change to understanding the gravity field.

Positioning, Navigation and Timing (PNT)

National Space-Based PNT Executive Committee

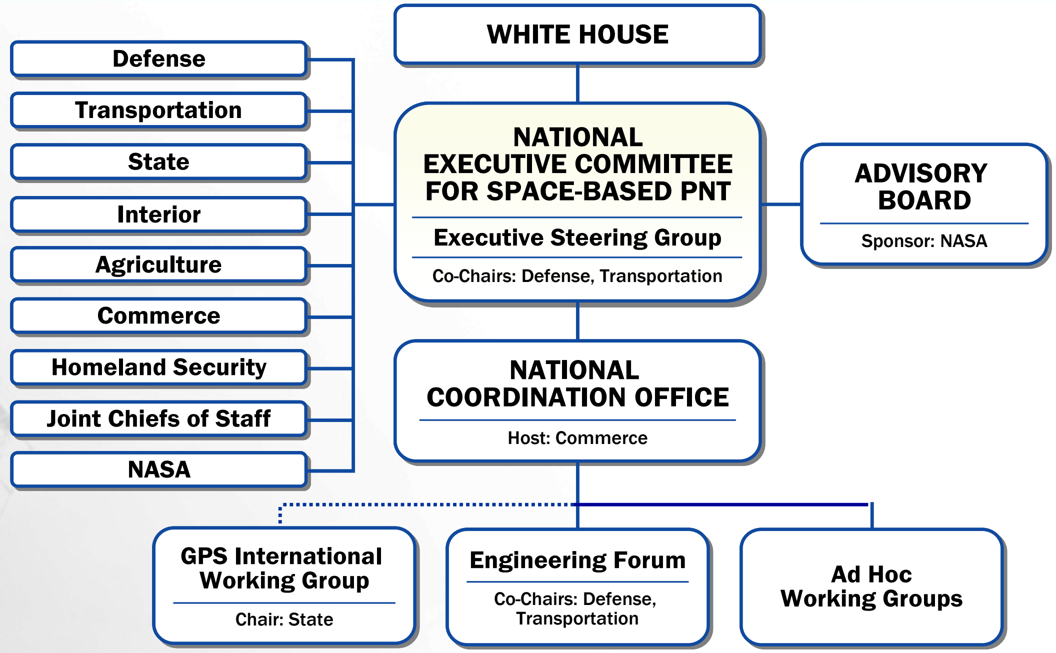
- 2004 U.S. Space-Based PNT Policy strengthens previous policy
- Created a National Executive Committee for Space-Based PNT to advise and coordinate federal departments/agencies on matters concerning GPS and related systems
- Created a National Coordination Office to provide day-to-day staff support to the National Executive Committee and a point of contact for inquiries regarding PNT policy
- Created a PNT Advisory Board from private sector constituency (including international membership) to provide independent advice to the National Executive Committee through its sponsor agency, NASA.

Bilateral Agreements

- U.S.- EU: four working groups were set up under the agreement; agreement to develop interoperable GPS and Galileo navigation signal (Galileo Open Service and GPS L1C).
- U.S.-Japan: Japan's Quasi Zenith Satellite System (QZSS) designed to be fully compatible and highly interoperable with GPS; 2009 NASA/JAXA agreement to set up QZSS monitoring stations in Hawaii and Guam in exchange for data access.
- U.S.- Russia: Negotiations for a U.S.-Russia Agreement on satellite navigation cooperation underway since late 2005 held; Russia considering adopting two new civil CDMA signals at L1, L5 to be interoperable with GPS.
- U.S.-India: Technical meeting focused on GPS-IRNSS compatibility and interoperability.

PNT Policy and NASA's Role

- 2004 U.S. Space-Based Positioning, Navigation, and Timing (PNT) Policy strengthened previous policy created:
- National Executive Committee for Space-Based PNT
  - Advises and coordinates federal departments and agencies on matters concerning the Global Positioning System (GPS) and related systems
- National Coordination Office
  - Provides day-to-day staff support to the National Executive Committee and a point of contact for inquiries regarding PNT policy
- PNT Advisory Board from private sector constituency
  - Provides independent advice to the National Executive Committee through its sponsor agency, NASA
- Enables new ways to fund future GPS modernization for civil applications



<u>NASA's Role</u>:
The NASA Administrator is tasked, in cooperation with the Secretary of Commerce, to develop and provide to the Secretary of Transportation requirements for the use of GPS and its augmentations to support civil space systems.

<u>SCaN's Role</u>:
To advocate for NASA's equities at the National Coordination Office, coordinate National Space-Based PNT activities with the NASA centers, represent NASA at the ESG level, and support the Office of the Administrator at the EXCOM level.

Positioning, Navigation and Timing

International GNSS Service (IGS)

- Voluntary federation of more than 200 worldwide agencies in more than 90 countries pool resources and permanent Global Navigation Satellite System (GNSS) station data to generate precise GNSS products
- Monitors GPS, GLONASS, Galileo; NASA funds the IGS Central Bureau

International Laser Ranging Service (ILRS)

- The primary mission of the ILRS is to support, through satellite and lunar laser tracking data and related products, geodetic and geophysical research activities.
- Laser Ranging to GNSS will assist in developing improved models and reference frames necessary to support civilian and scientific requirements for higher PNT accuracy.

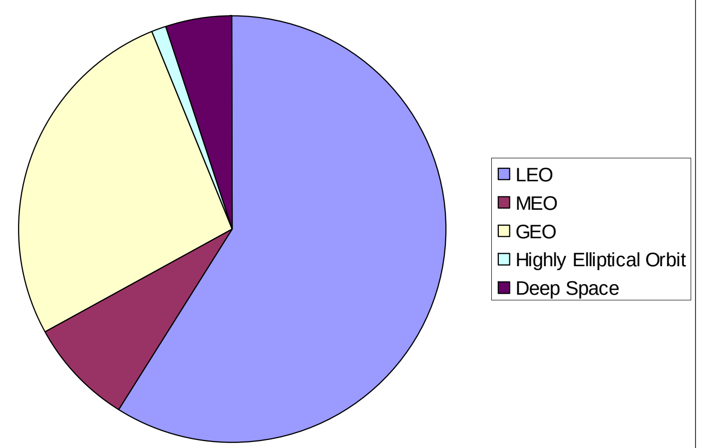
International Committee on GNSS (ICG)

- Established by the United Nations to promotes GNSS use and integration into infrastructures, particularly in developing countries, and to encourage system compatibility, interoperability.
- Membership: GNSS providers, international user organizations and associations
- Providers Forum includes United States, Europe, Russia, China, India, Japan; focused discussions on compatibility, interoperability

GPS Critical to Space Operations

- Nearly 60% of projected worldwide space missions 2008-2027 will operate in LEO (inside the Terrestrial Service Volume)
- An additional 35% of these space missions that will operate at higher altitudes will remain at or below GEO (inside the Space Service Volume)
- Approximately 95% of projected worldwide space missions over the next 20 years will operate within the GPS service envelope
- GPS Application Areas in Space:
  - Navigation, Attitude Determination, Science, etc.

2008-2027 Worldwide Missions by Type



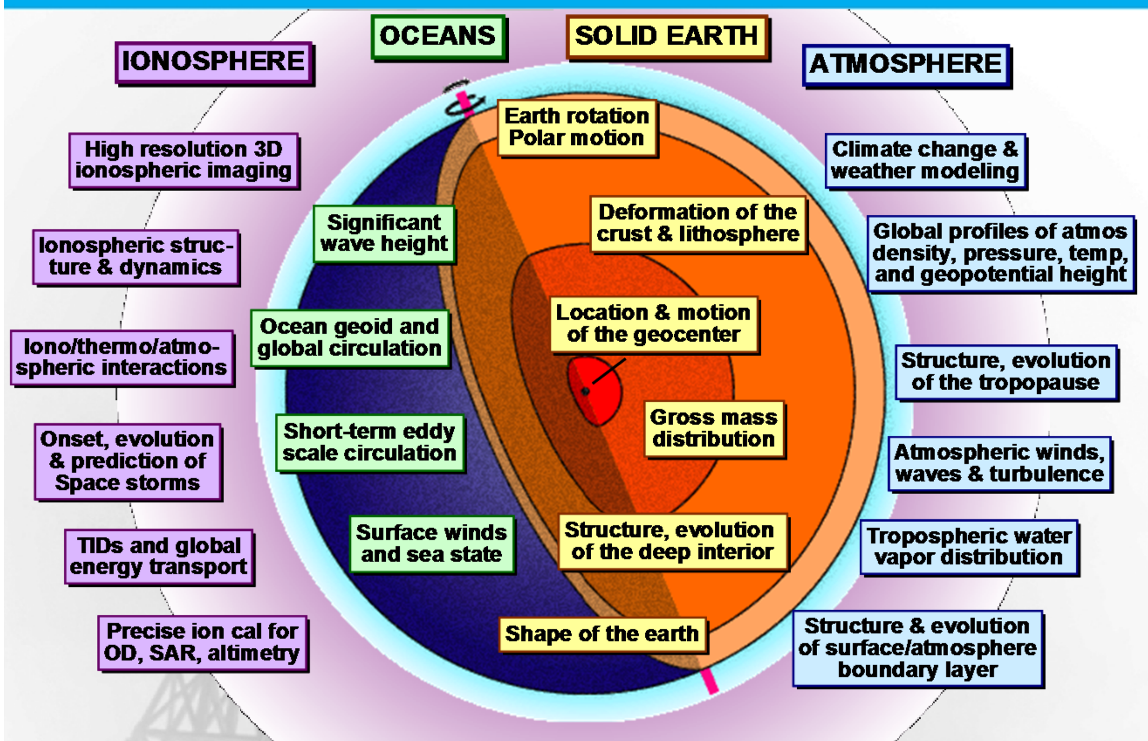
(*) Source: Aerospace America, Dec. 2007

Space Shuttle
(Application: Navigation)

International Space Station
(Application: Attitude Determination)

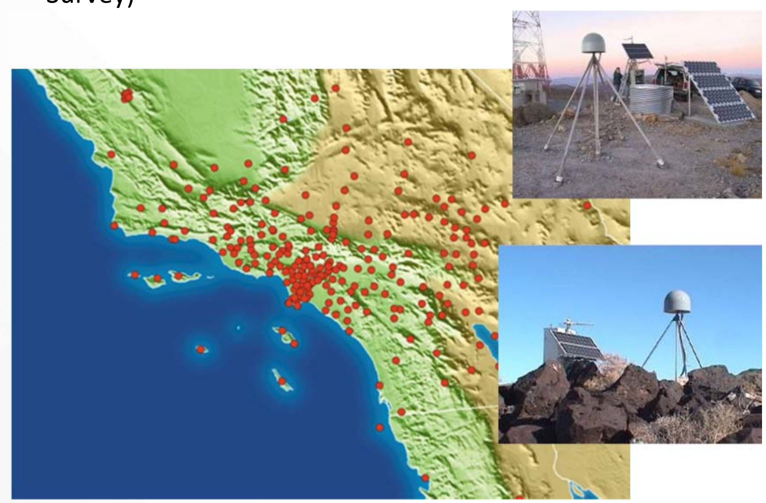
Earth Observing Satellites
(Application: Science)

Earth Science Applications of GPS

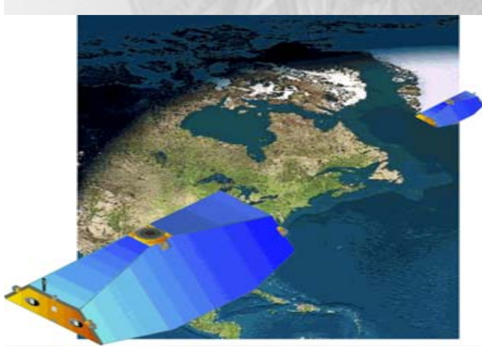


Southern California Integrated GPS Network

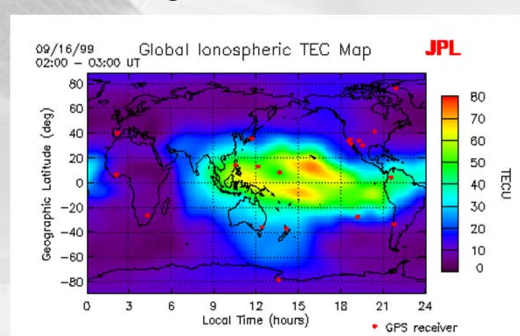
Operated and maintained by NASA, SOPAC (Scripps Orbit And Permanent Array Center) , and USGS (U.S. Geological Survey)



Gravity Field Measurements (GRACE Mission)

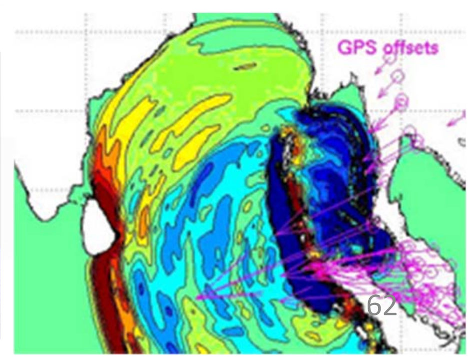


Ionospheric Remote Sensing using GPS Occultation



Ocean Topography

2004 Tsunami with GPS offsets



For more information visit NASA:

www.nasa.gov

or

Space Communications and Navigation (SCaN):

www.spacecomm.nasa.gov