Sharing the NASA Experience with Students

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NASA Goddard Space Flight Center

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Outline

- About NASA
- Presentation References and Acknowledgement
- NASA Space Missions Overview
- Space Communications and Navigation (SCaN)
- Research Collaboration with Academia

About NASA?

- http://www.nasa.gov/about/
- http://www.nasa.gov/missions/

Vision

We reach for new heights and reveal the unknown for the benefit of humankind.

Mission

Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth.

Core Values

- Safety
- Integrity
- Teamwork
- Excellence

http://science.nasa.gov/media/medialibrary/2014/04/18/FY2014_NASA_StrategicPlan_508c.pdf

Overarching Approach

- **Invest** in next-generation technologies and approaches to spur innovation;
- **Inspire** students to be our future scientists, engineers, explorers, and educators through interactions with NASA's people, missions, research, and facilities;
- **Expand** partnerships with international, intergovernmental, academic, industrial, and entrepreneurial communities, recognizing their roles as important contributors of skill and creativity to our missions and for the propagation of our results;
- **Commit** to environmental stewardship through Earth observation and science, and the development and use of green technologies and capabilities in NASA missions and facilities; and
- **Safeguard** the public trust through transparency and accountability in our programmatic and financial management, procurement, and reporting practices.

More Information

» Full Strategic Plan, Performance Plan, and Budget: http://nasa.gov/news/budget/index.htm
» Agency Priority Goals: http://goals.performance.gov/agency/nasa
» Cross-Agency Priority Goals: http://goals.performance.gov/goals_2013

National Aeronautics and Space Administration

Headquarters
300 E Street, SW
Washington, DC 20546
NP-2014-01-964-HQ
www.nasa.gov

National Aeronautics and Space Administration

Strategic Plan 2014

NASA's 2014 Strategic Goals

Strategic Goal 1

Expand the frontiers of knowledge, capability, and opportunity in space

By empowering the NASA community to...

Objective 1.1: Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration.

Objective 1.2: Conduct research on the International Space Station (ISS) to enable future space exploration, facilitate a commercial space economy, and advance the fundamental biological and physical sciences for the benefit of humanity.

Objective 1.3: Facilitate and utilize U.S. commercial capabilities to deliver cargo and crew to space.

Objective 1.4: Understand the Sun and its interactions with Earth and the solar system, including space weather.

Objective 1.5: Ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere.

Objective 1.6: Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars.

Objective 1.7: Transform NASA missions and advance the Nation's capabilities by maturing crosscutting and innovative space technologies.

Strategic Goal 2

Advance understanding of Earth and develop technologies to improve the quality of life on our home planet

By engaging our workforce and partners to...

Objective 2.1: Enable a revolutionary transformation for safe and sustainable U.S. and global aviation by advancing aeronautics research.

Objective 2.2: Advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet.

Objective 2.3: Optimize Agency technology investments, foster open innovation, and facilitate technology infusion, ensuring the greatest national benefit.

Objective 2.4: Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets.

Strategic Goal 3

Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure

By working together to...

Objective 3.1: Attract and advance a highly skilled, competent, and diverse workforce, cultivate an innovative work environment, and provide the facilities, tools, and services needed to conduct NASA's missions.

Objective 3.2: Ensure the availability and continued advancement of strategic, technical, and programmatic capabilities to sustain NASA's Mission.

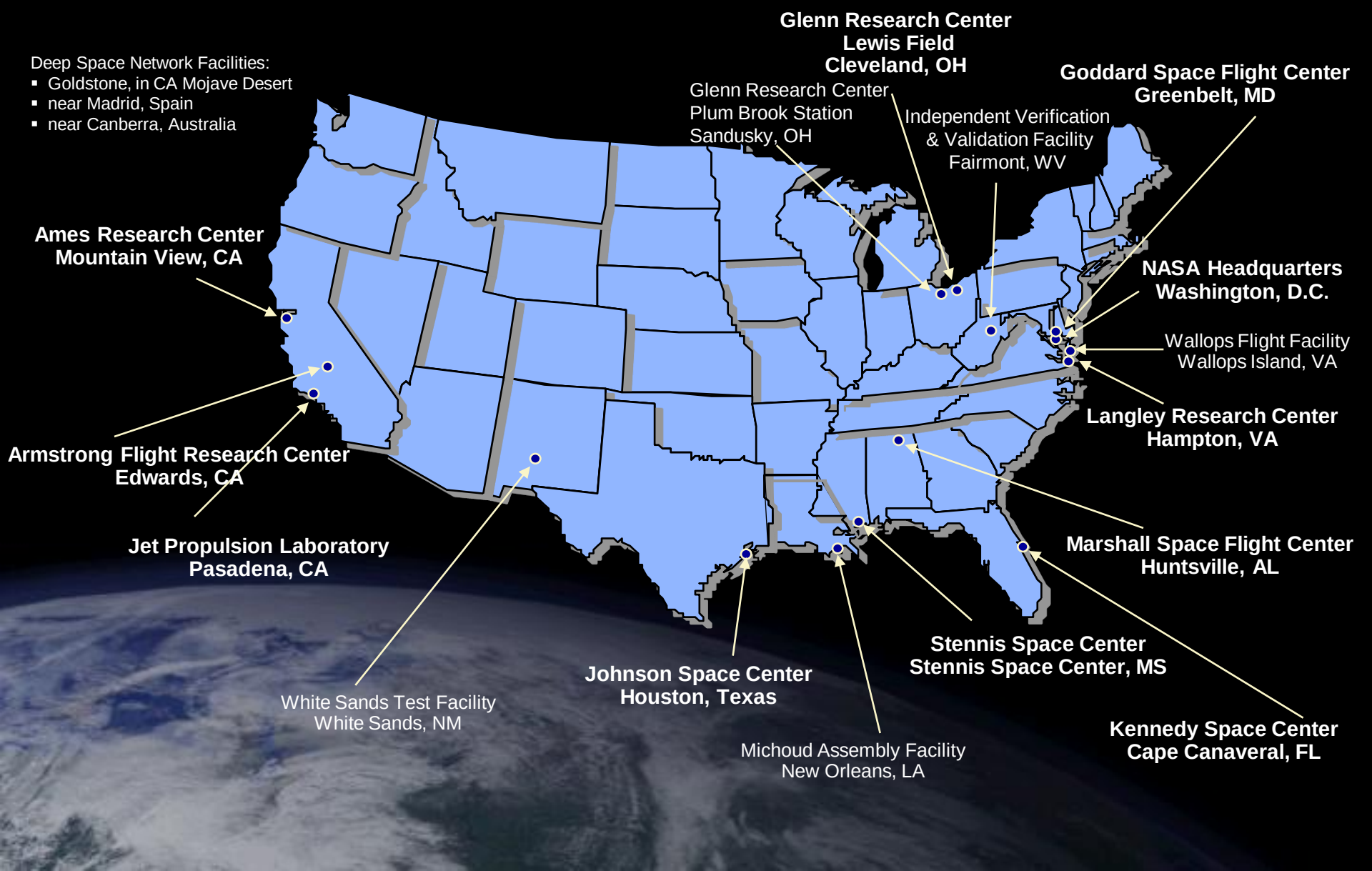
Objective 3.3: Provide secure, effective, and affordable information technologies and services that enable NASA's Mission.

Objective 3.4: Ensure effective management of NASA programs and operations to complete the mission safely and successfully.

http://science.nasa.gov/media/medialibrary/2014/04/18/FY2014_NASA_StrategicPlan_508c.pdf

National Aeronautics and Space Administration

NASA Centers and Facilities



NASA Goddard Space Flight Center (GSFC)

http://www.nasa.gov/centers/goddard/home/installations.html

- NASA GSFC's Facilities include:

Goddard Space Flight Center, main campus located within Greenbelt, Md

Wallops Flight Facility, located on Virginia's Eastern Shore

NASA Goddard Space Flight Center (GSFC) Organizations and Projects

- http://www.nasa.gov/centers/goddard/about/organizations/org2.html

100 - Office of the Director

Office of the Chief Technologist

Government and Community Relations

Diversity and Inclusion

Alternative Dispute Resolution Program

Ombudsman Program

Anti-Harassment Program

Office of the Chief Knowledge Officer

- 100.1 - Business Management Office
- 101 - New Opportunities Office
- 120 - Equal Opportunity Programs Office
- 130 - Office of Communications
- 140 - Office of Chief Counsel
  - 140.1 - Office of Patent Counsel
- 160 - Office of Education
- 180 - NASA IV&V Facility
- 190 - Office of Inspector General

110 - Office of Human Capital Management

- 110.1 - Business, Planning and Strategic Alignment

500 - Applied Engineering and Technology Directorat (AETD)

- 501 - Business Management Office
- 504 - Innovative Partnerships Program Office
- 540 - Mechanical Systems Division
  - 541 - Materials Engineering Branch
  - 542 - Mechanical Systems Analysis & Simulation Branch
  - 543 - Mechanical Engineering Branch
  - 544 - Electro-Mechanical Systems Branch
  - 545 - Thermal Engineering Branch
  - 546 - Contamination and Coatings Engineering Branch
  - 547 - Advanced Manufacturing Branch
  - 548 - Mechanical Systems Branch at WFF
  - 549 - Environmental Test Engineering and Integration Branch
- 550 - Instrument Systems & Technology Division
  - 551 - Optics Branch
  - 552 - Cryogenics and Fluids Branch
  - 553 - Detector Systems Branch

Open the link to view GSFC Organizations and Projects

Presentation References and Acknowledgement

Would like to thank and acknowledge the sources below that have provided materials for the following slides focusing on “Space Communications and Navigation (SCaN)”

1. http://www.nasa.gov/content/scan-presentations/

2. Badri Younes, “Future of Space Communications,” *Space Generation Congress, Naples, Italy,* September 2012 http://www.nasa.gov/sites/default/files/696855main_Pres_Future_of_Space_Communications_SGC_2012.pdf

3. Phil Liebrecht, “Communicating with Astronaut and Robotic Explorers across the Solar System,” *Public University of Navarra, Spain,* December 2010 http://www.nasa.gov/sites/default/files/694635main_Pres_Public_University_Navarra_Astronaut_Robotic.pdf

The following slides will focus on Space Communications and Navigation (SCaN)”

– My current work tasks support the SCaN Program

SCaN Current Networks

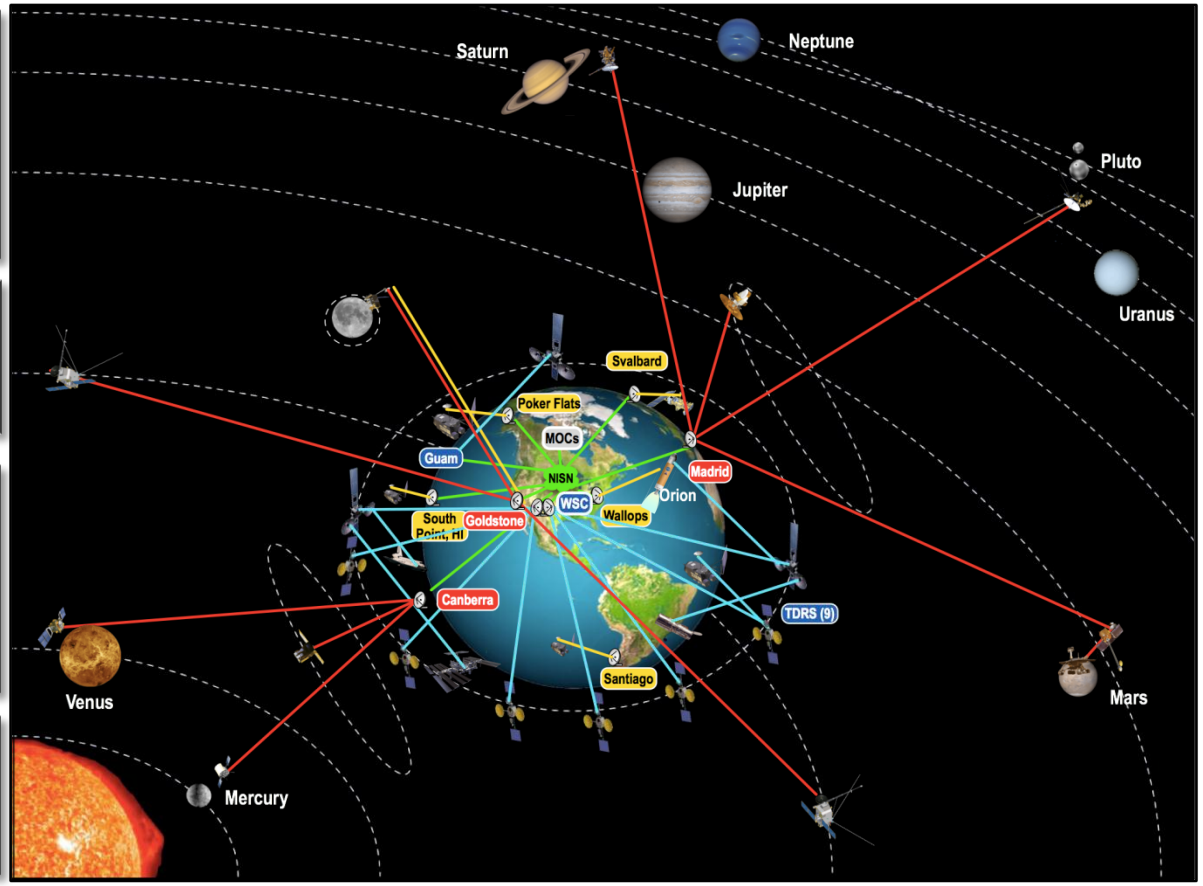
The current NASA space communications architecture embraces three operational networks that collectively provide communications services to supported missions using space-based and ground-based assets

Near Earth Network - 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

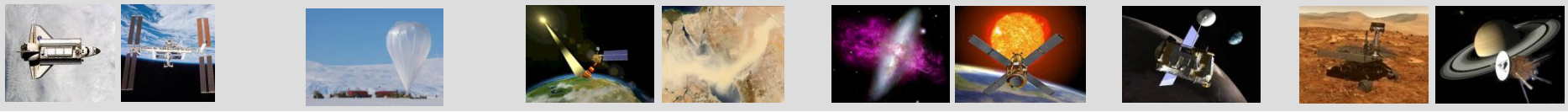
Deep Space Network - ground stations spaced around the world providing continuous coverage of satellites from Earth Orbit (GEO) to the edge of our solar system

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



http://www.nasa.gov/sites/default/files/696855main_Pres_Future_of_Space_Communications_SGC_2012.pdf

SCaN Network



- ***DSN***
- ***NEN/NASA***
- ***NEN/Commercial***
- ***NEN/Partner***
- ***SN***

Alaska Satellite Facility
Fairbanks, Alaska

Partner Station:
Gilmore Creek, Alaska

USN Alaska
Poker Flat & North Pole, Alaska

Madrid Complex
Madrid, Spain

Kongsberg Satellite Services (KSAT)
Svalbard, Norway

Swedish Space Corp. (SSC)
Kiruna, Sweden

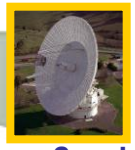
German Space Agency (DLR)
Weilheim, Germany

Guam Remote Ground Terminal
Guam, Marianna Islands

USN Hawaii
South Point, Hawaii

USN Australia
Dongara, Australia

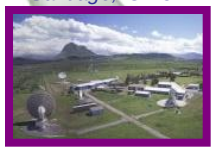
White Sands Ground Station
White Sands, New Mexico



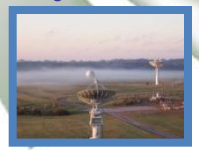
Canberra Complex
Canberra, Australia

White Sands Ground Terminals
White Sands, New Mexico

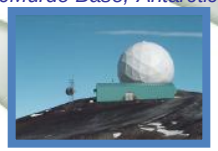
Merritt Island Launch Annex
Merritt Island, Florida



USN Chile
Santiago, Chile



Wallops Ground Station
Wallops, Virginia

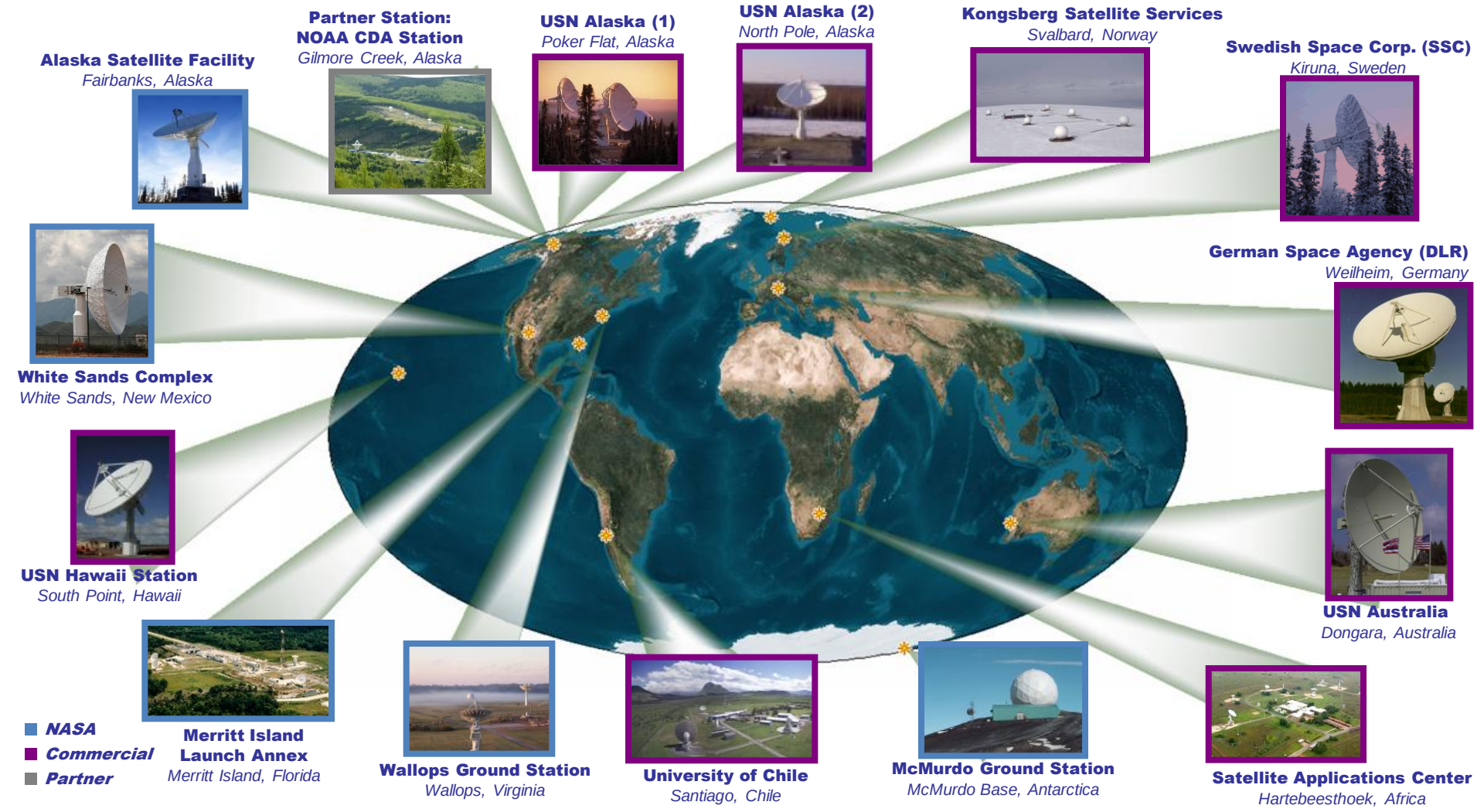


McMurdo Ground Station
McMurdo Base, Antarctica

Satellite Applications Center
Hartebeesthoek, Africa

http://www.nasa.gov/sites/default/files/696855main_Pres_Future_of_Space_Communications_SGC_2012.pdf

Near Earth Network Overview



Space Network
Space Segment

- TDRS F-1 through F-7
  - The most complex communications satellite ever build at that time
  - Single access S-Band and Ku-Band services and Multiple Access system
  - 10 year design life
  - Series launched from 1983 - 1995
    - Original series still in operation
    - TDRS-B lost with the Challenger
    - TDRS 1 retired in 2010

First Generation TDRS F-1 through F-7

- TDRS F-8 through F-10
  - Backwards compatible S-Band and Ku-Band services
  - New Ka-Band Service, up to 1.2 Gbps Capability
  - Enhanced Multiple Access system
  - Increased on-orbit autonomy
  - 15 year design life
  - Series launched from 2000 – 2002

Second Generation TDRS F-8 through F-10

- The 3rd Generation of TDRS spacecraft, known as TDRS K, L, and M: TDRS K launched January 30, 2013, and TDRS L launched January 23, 2014. TDRS M's launch readiness date is scheduled for 2015. http://tdrs.gsfc.nasa.gov/tdrs/136.html

SN Ground Segment

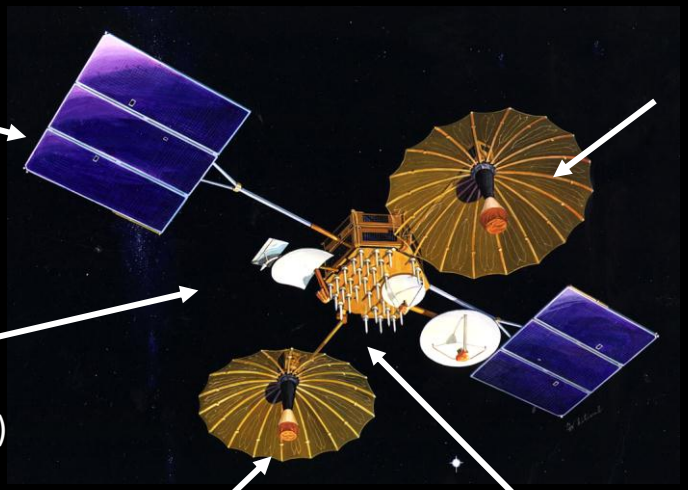
White Sands Ground Terminal (WSGT) and the Second TDRSS Ground Terminal (STGT).

Guam Remote Ground Terminal (GRGT). The GRGT allows for the closure of the the Zone of Exclusion.

http://www.nasa.gov/sites/default/files/696855main_Pres_Future_of_Space_Communications_SGC_2012.pdf

Space Segment:
Tracking and Data Relay Satellite (F1 - F7)

Solar array
Power output is approximately 1800 watts



Omni Antenna (S-band) and Solar Sail

Single Access Antenna
Dual frequency communications and tracking functions:
- S-band TDRSS (SSA)
- Ku-band TDRSS (KuSA)
- Ku-band auto-tracking

4.9 meter shaped reflector assembly
SA equipment compartment mounted behind reflector
Two axis gimballing

Space-to-Ground-Link Antenna
TDRS downlink
2.0 meter parabolic reflector
Dual orthogonal linear polarization TDRS:
- single horn feed
- orthomode transducer

Two axis gimballed

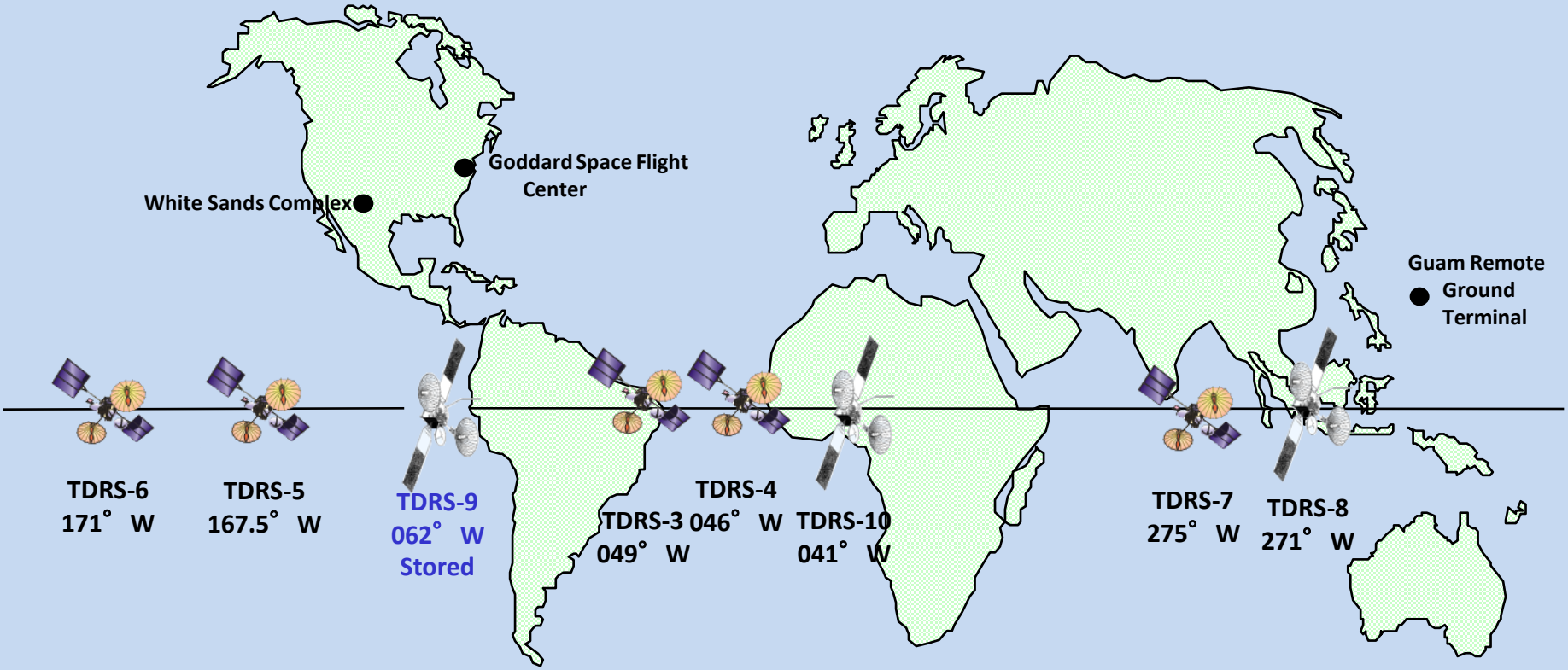
Multiple Access Antenna
30 helices:
- 12 diplexers for transmit
- 30 receive body mounted

Single commanded beam, transmit
20 adapted beams for receive
Ground implemented receive function

Forward (FWD): link from TDRSS Ground Station through TDRS to Customer Spacecraft
Return (RTN): link from Customer Spacecraft through TDRS to TDRSS Ground Station

http://www.nasa.gov/sites/default/files/694635main_Pres_Public_University_Navarra_Astronaut_Robotic.pdf

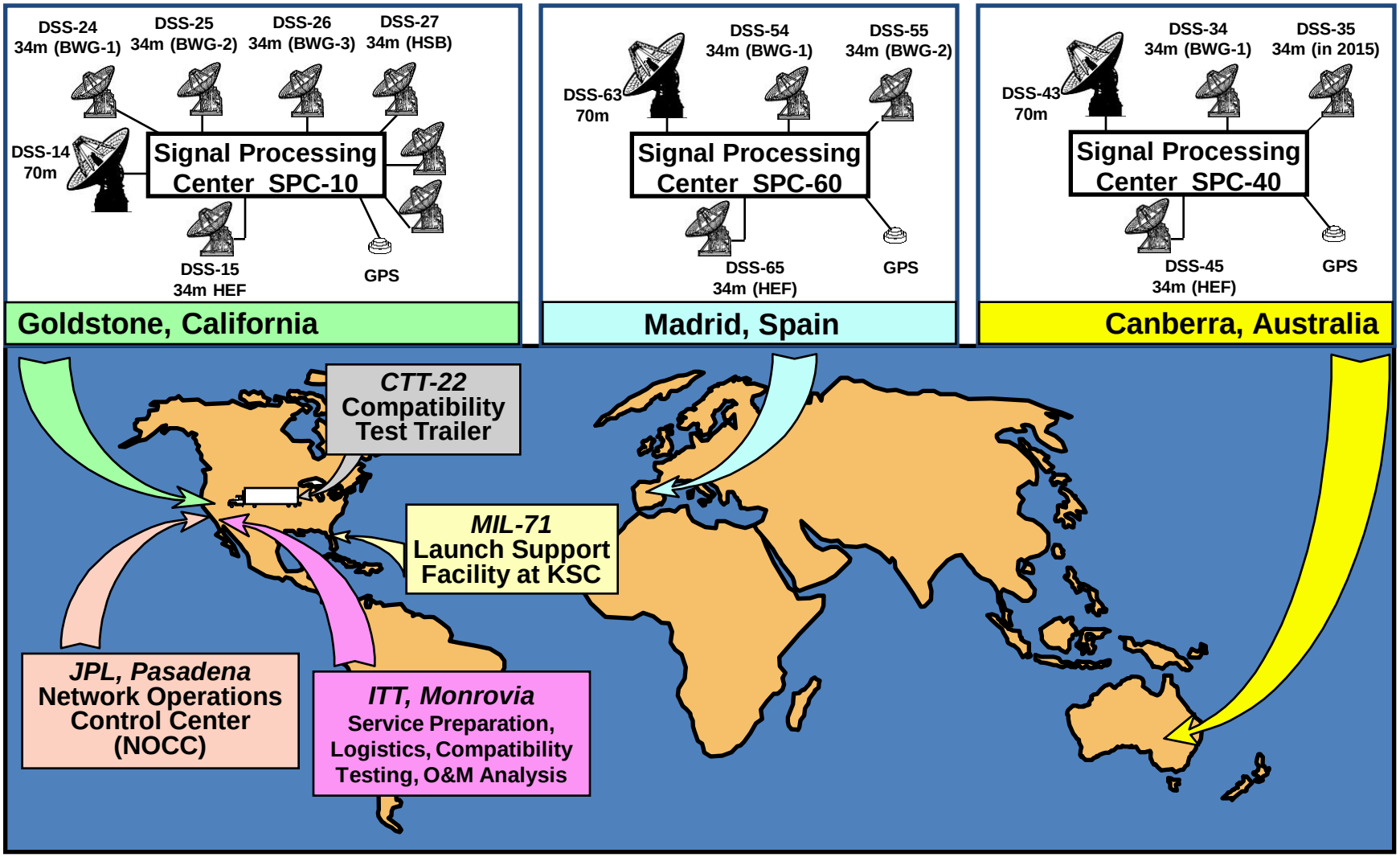
1st and 2nd Generation TDRSS Constellation



In a typical month the SN supports approximately 10,000 scheduled customer service events.

http://www.nasa.gov/sites/default/files/694635main_Pres_Public_University_Navarra_Astronaut_Robotic.pdf

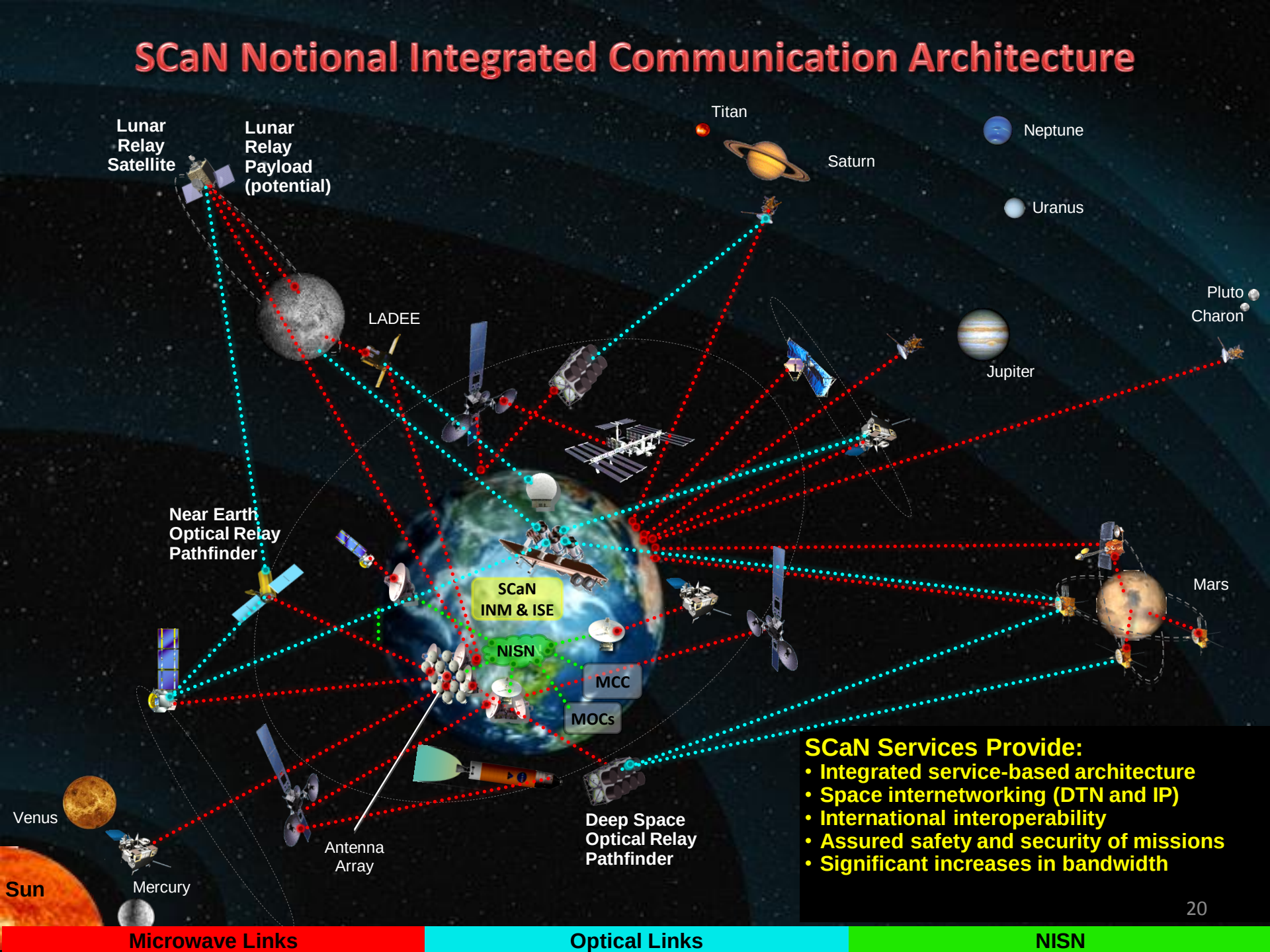
Deep Space Network Facilities



http://www.nasa.gov/sites/default/files/694635main_Pres_Public_University_Navarra_Astronaut_Robotic.pdf

Deep Space Complexes

SCaN Notional Integrated Communication Architecture

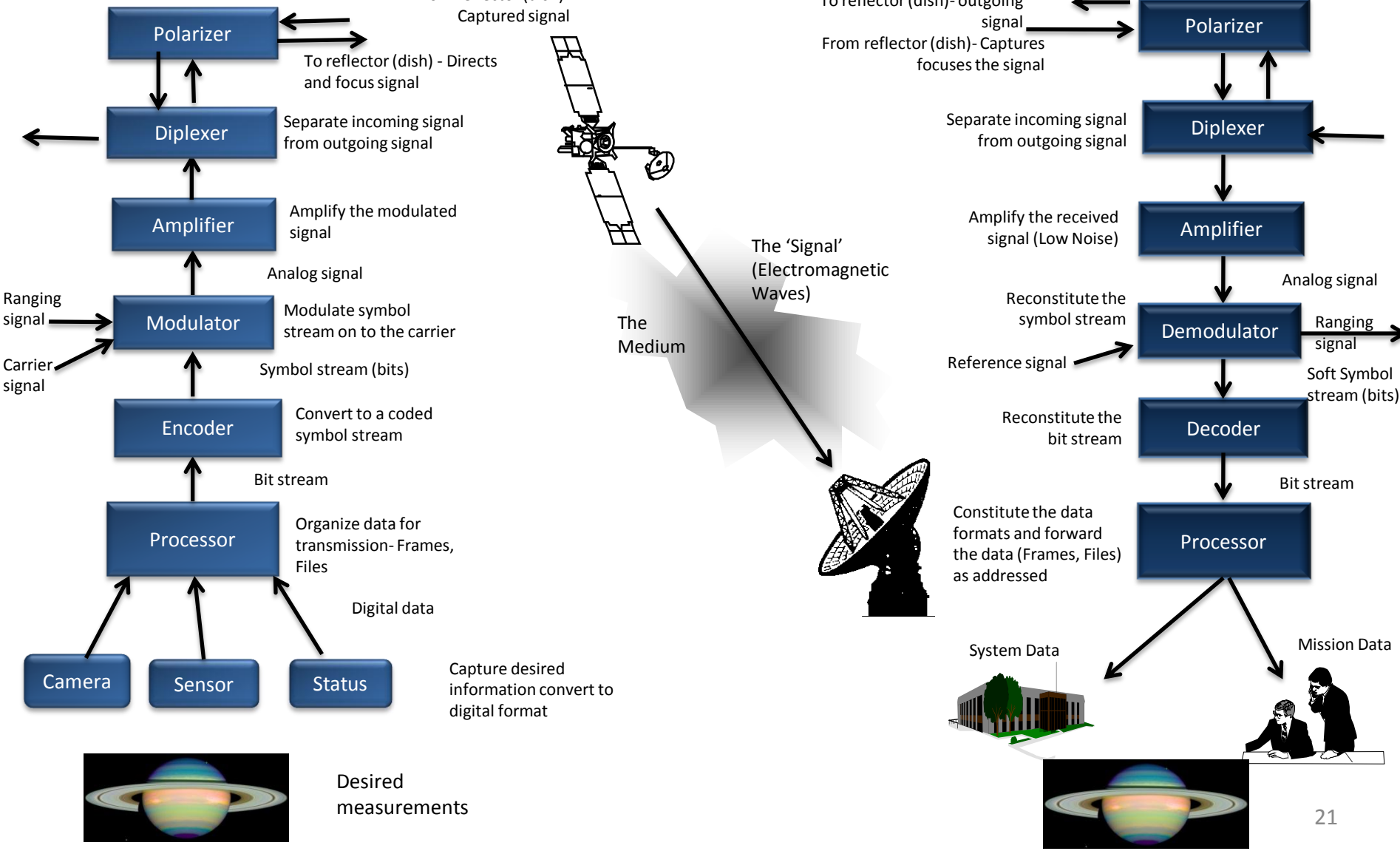


SCaN Services Provide:

- 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

Space Communications
End to End Process



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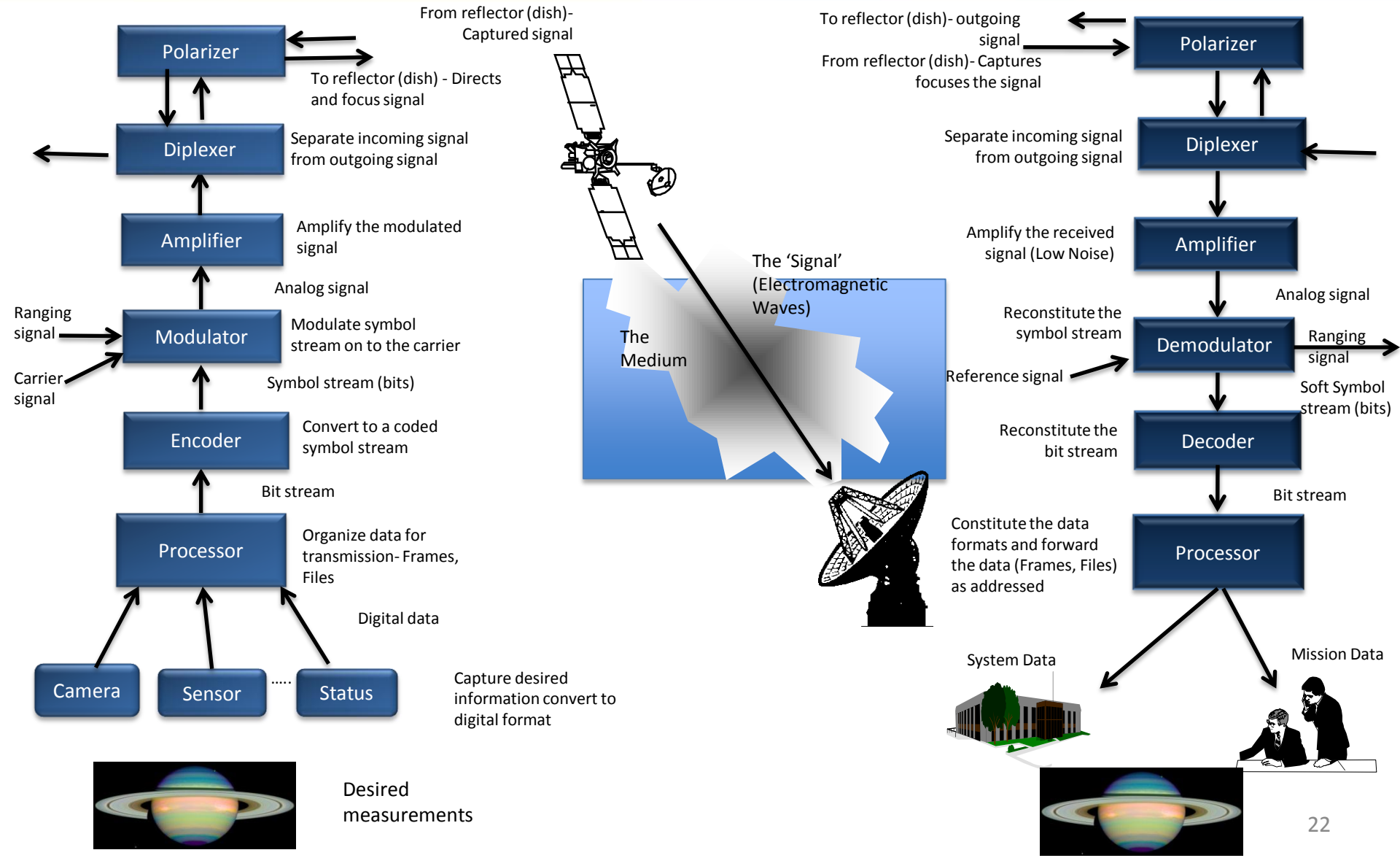
Space Communications
The Medium



http://www.nasa.gov/sites/default/files/694635main_Pres_Public_University_Navarra_Astronaut_Robotic.pdf

Research Areas

- Get more information from our “Space Technology Roadmaps”
  - http://www.nasa.gov/offices/oct/home/roadmaps/index.html
  - http://www.nasa.gov/sites/default/files/501627main_STR-Int-Foldout_rev11-NRCupdated.pdf
  - http://www.nasa.gov/externalflash/OCT_Interactive_Roadmaps/OCT_Interactive_Roadmaps.html

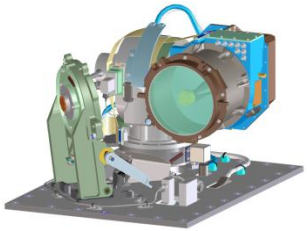
SCaN Communications and Navigation
Technology Themes

- 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

http://www.nasa.gov/sites/default/files/694635main_Pres_Public_University_Navarra_Astronaut_Robotic.pdf

SCaN Technologies Trying to Take the TRL 7 Leap

- Optical Communication

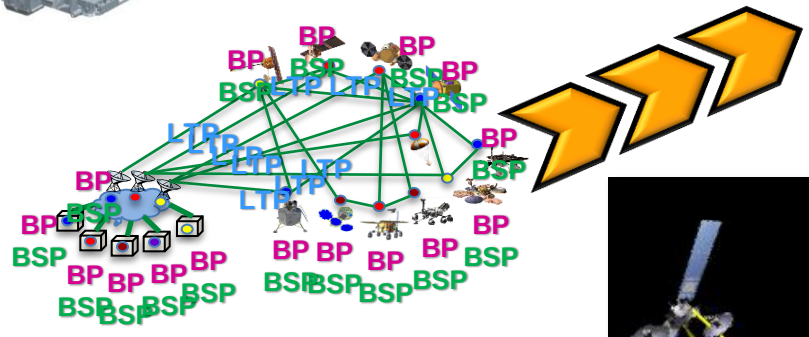


LADEE

- Software Defined Radios

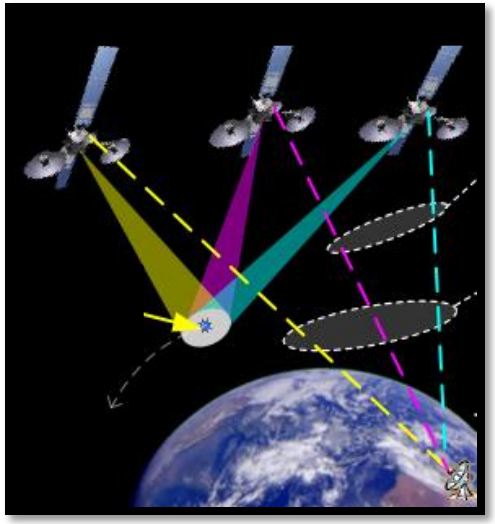
ISS

- Disruptive Tolerant Networking



- TDRSS Antenna Combining

TDRSS



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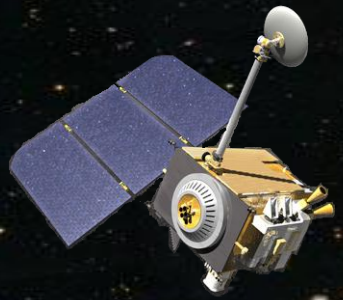
Benefits of SCaN Testbed to NASA Programs and Missions



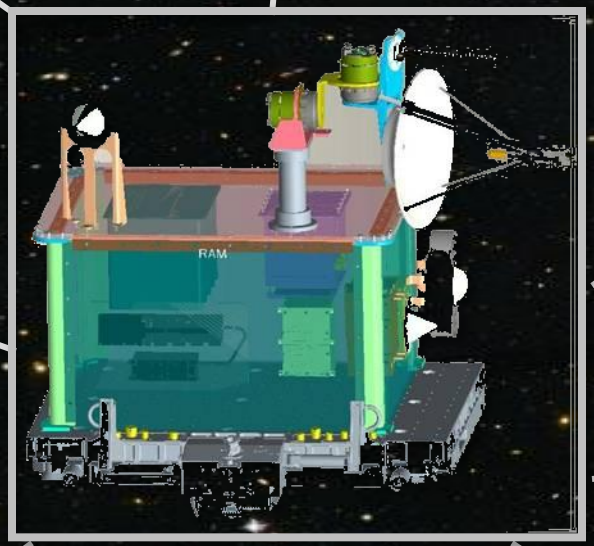
• Ka/S band System for Lunar Relay

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

• Space based networking, including DTN

• Potential SDRs for Space Based Range

• SDRs for future TDRSS Transponder



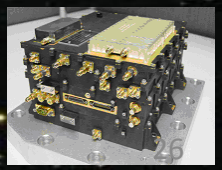
• Ka/S System for TDRSS K, L function, performance validation

• Ka System HRDL partial backup for ISS

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

• Potential SDRs for lunar landers, rovers, EVA

• SDR/STRS technology advancement to TRL-7



http://www.nasa.gov/sites/default/files/696855main_Pres_Future_of_Space_Communications_SGC_2012.pdf

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

http://www.nasa.gov/sites/default/files/696855main_Pres_Future_of_Space_Communications_SGC_2012.pdf

NASA's Pathways / Student Intern Program

-
- https://intern.nasa.gov/

- http://www.usajobs.gov/
  - NASA's Pathways Student Intern Program
  - Create Resume on USAJOBS Website, specify keywords, i.e. NASA, Internship, Engineering, Aerospace, Electrical, Computer, Physics, etc.

Back Up Slides

NASA Missions

Example - Browse Missions by Topic

- **Earth**

http://www.nasa.gov/content/earth-missions-list

- **Solar System**

http://www.nasa.gov/content/solar-missions-list

- **Humans in Space**

http://www.nasa.gov/content/human-missions-list

- **Universe**

http://www.nasa.gov/content/universe-missions-list

Earth Missions 1/5

Atmosphere	
AIM Aqua ARCTAS ATTREX Aura CALIPSO CHAMP CINDI Cloudsat Glory GOES-N ICEsat	NOAA-N NOAA-N Prime NPP Operation Ice Bridge POES QuikSCAT Radiation Belt Storm Probes (RBSP) TDRS Terra Tropical Rainfall Measuring Mission Upper Atmosphere Radiation Satellite (UARS)

Climate	
Aquarius ARCTAS ATTREX Aura CALIPSO Cloudsat Global Precipitation Measurement (GPM) Glory GOES-N GOES-O GOES-P GOES-R Jason Landsat	LDCM NOAA-N NOAA-N Prime NPP Ocean Surface Topography Mission Orbiting Carbon Observatory POES Radiation Belt Storm Probes (RBSP) SERVIR Solar Radiation and Climate Experiment TDRS Terra Tropical Rainfall Measuring Mission Upper Atmosphere Radiation Satellite (UARS)

Earth Missions 2/5

Continental Drift and Geodynamics	Gravity
LAGEOS 1 and 2 Radiation Belt Storm Probes (RBSP) TDRS	Gravity Probe-B Gravity Recovery and Climate Experiment Radiation Belt Storm Probes (RBSP)

Hurricanes	Ice
GOES-N Hurricanes NPP Polar Radiation Belt Storm Probes (RBSP) TDRS Terra Tropical Rainfall Measuring Mission	ICEsat Landsat LDCM Operation Ice Bridge Radiation Belt Storm Probes (Van Allen Probes) TDRS (Tracking and Data Relay Satellite)

Land and Vegetation	Land and Vegetation
Aqua ICEsat Landsat LDCM NPP Operation Ice Bridge	Orbiting Carbon Observatory Radiation Belt Storm Probes (RBSP) Shuttle Radar Topography Mission TDRS Terra

Earth Missions 3/5

Oceans	Ozone
Aqua Aquarius Jason NOAA-N Prime Ocean Surface Topography Mission QuikSCAT Radiation Belt Storm Probes (RBSP) TDRS Terra TOPEX/Poseidon	Aura NOAA-N Prime Radiation Belt Storm Probes (RBSP) TDRS TOMS-EP Upper Atmosphere Radiation Satellite (UARS)

Earth Missions 4/5

Sun and its Influence on Earth	
CHAMP Earth Radiation Budget Satellite Explorer FAST Geotail Hinode (Solar-b) IMAGE IRIS: Interface Region Imaging Spectrograph Polar Radiation Belt Storm Probes (RBSP) RHESSI	SDO SOHO Solar Anomalous and Magnetospherice Particle Explorer (SAMPEX) SORCE STEREO TDRS Terra THEMIS TIMED TRACE Ulysses WIND

Water Cycle	Wildfires
Aqua ATTREX GOES-N NPP POES Radiation Belt Storm Probes (RBSP) TDRS Tropical Rainfall Measuring Mission	Fire and Smoke GOES-N Landsat LDCM NMP EO-1 Radiation Belt Storm Probes (RBSP) TDRS Terra

Earth Missions 5/5

Weather	
ATTREX GOES-N GOES-O GOES-P NOAA-N NOAA-N Prime	NPP POES Radiation Belt Storm Probes (RBSP) SERVIR TDRS Tropical Rainfall Measuring Mission

Humans in Space Missions

Current Missions	
International Space Station Commercial Resupply	

Past Missions	Future Exploration Plans
Apollo Apollo-Soyuz Gemini Mercury Skylab Space Shuttle	Asteroid Redirect Initiative Commercial Space Orion Crew Vehicle Space Launch System

Solar System Missions 1/3

Asteroids	Comets
Asteroid Redirect Initiative Dawn Near Earth Asteroid Rendezvous (NEAR) Osiris-REX	Deep Impact EPOXI Stardust-NExT

Jupiter	Saturn
Galileo Hubble Juno Pioneer Voyager	Cassini Hubble Pioneer Voyager

Neptune	Pluto
Hubble Voyager **Mercury** MESSENGER	Hubble New Horizons

Solar System Missions 2/3

Uranus	Venus
Hubble Voyager	Magellan Pioneer

Sun and its Influence on Earth	
CHAMP Earth Radiation Budget Satellite Explorer FAST Geotail Hinode (Solar-b) IMAGE IRIS: Interface Region Imaging Spectrograph Magnetospheric MultiScale (MMS) Polar Radiation Belt Storm Probes (RBSP) RHESSI SDO	SOHO Solar Anomalous and Magnetospherice Particle Explorer (SAMPEX) SORCE STEREO TDRS Terra THEMIS TIMED TRACE Ulysses WIND

Solar System Missions 3/3

Mars	Moon
Hubble InSight Mars Exploration Rover Mars Global Surveyor Mars Odyssey Mars Pathfinder Mars Reconnaissance Orbiter Mars Science Laboratory, Curiosity MAVEN Phoenix Viking	Apollo Clementine GRAIL LADEE LCROSS LRO (Lunar Reconnaissance Orbiter) Mini-RF Moon Mineralogy Mapper Ranger Surveyor

Planets	
Hubble James Webb Space Telescope Kepler Roentgen Satellite (ROSAT) SWIFT WISE	

Universe Missions 1/3

Big Bang and Cosmology	Galaxies
ASTRO-1 ASTRO-2 Chandra Compton Gamma-Ray Observatory Cosmic Background Explorer (COBE) Extreme Ultraviolet Explorer Fermi Gamma-ray Space Telescope FUSE GLAST Gravity Probe-B Herschel Hubble Solar Anomalous and Magnetospherice Particle Explorer (SAMPEX) Wide-Field Infrared Explorer	Chandra FUSE GALEX Herschel Hubble James Webb Space Telescope SOFIA Spitzer SWIFT Wide-Field Infrared Explorer

Black Holes	Interstellar Medium
Chandra Fermi Gamma-ray Space Telescope GLAST Herschel Hubble NuSTAR RXTE	Chandra FUSE IBEX Pioneer Spitzer Submillimeter Wave Astronomy Satellite (SWAS) Voyager

Universe Missions 2/3

Planets Beyond the Solar System	Stars
Hubble James Webb Space Telescope Kepler Roentgen Satellite (ROSAT) SWIFT WISE	Chandra GALEX Herschel Hubble SOFIA WISE
Gamma-Ray Bursts	**Gravity**
Chandra Compton Gamma-Ray Observatory HETE-2 SWIFT	Gravity Probe-B Gravity Recovery and Climate Experiment Radiation Belt Storm Probes (Van Allen Probes) TDRS
Nebulae	**Life in the Universe**
Herschel Hubble	Genesis

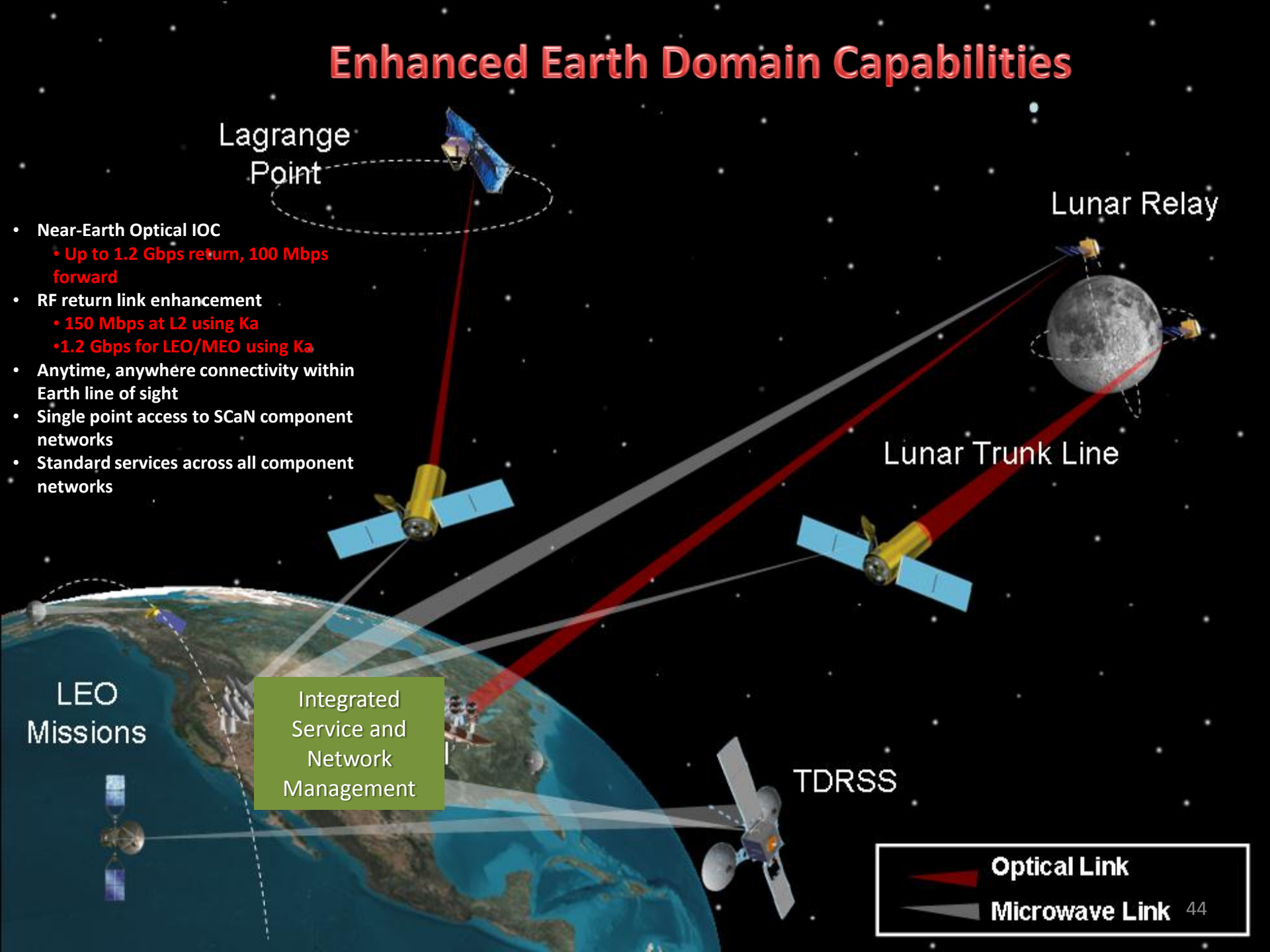
Universe Missions 3/3

Supernovae	
Chandra Herschel Hubble Solar Anomalous and Magnetospherice Particle Explorer (SAMPEX) SWIFT	

Future of Space Communications

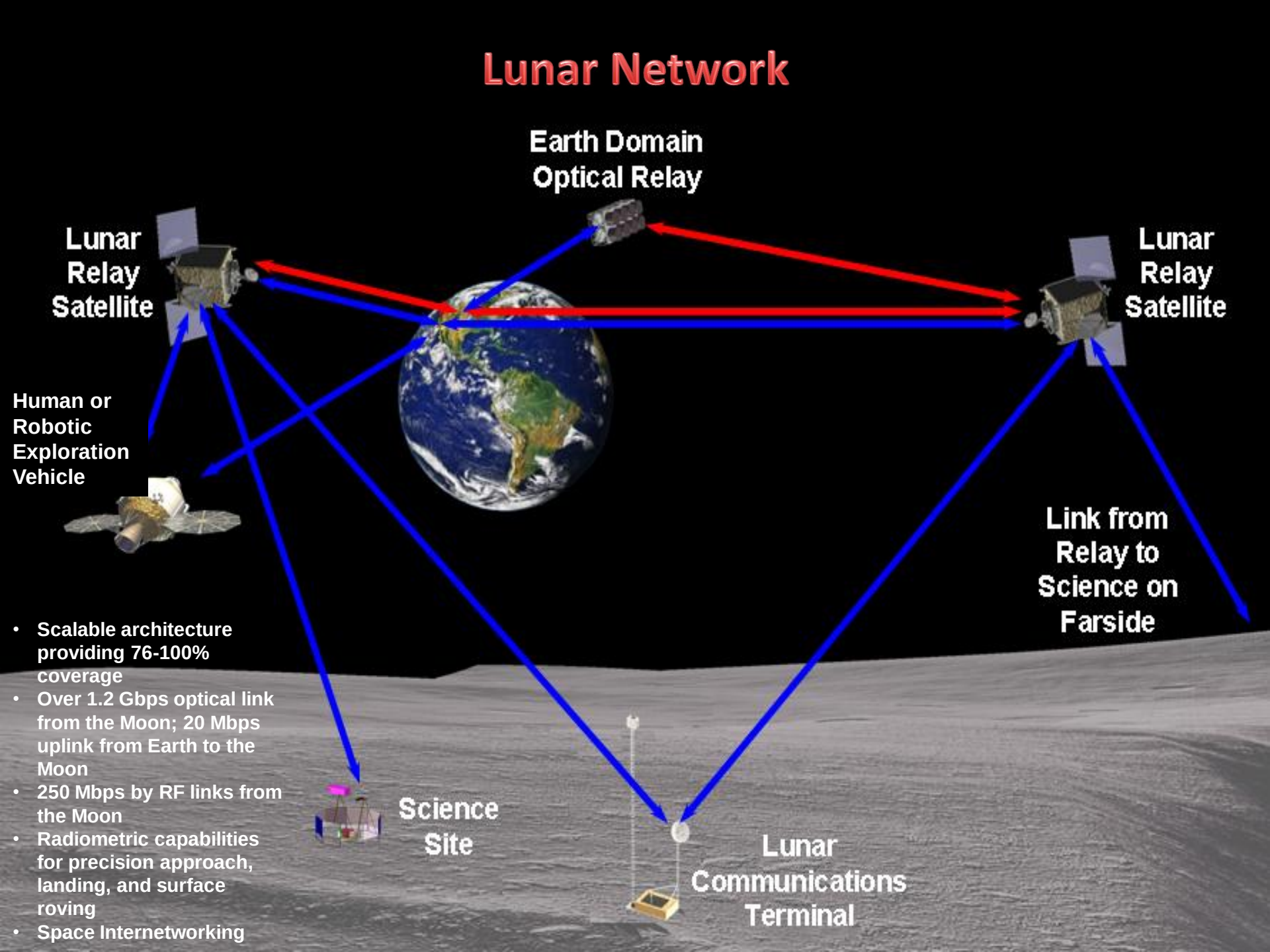
http://www.nasa.gov/sites/default/files/696855main_Pres_Future_of_Space_Communications_SGC_2012.pdf

Enhanced Earth Domain Capabilities



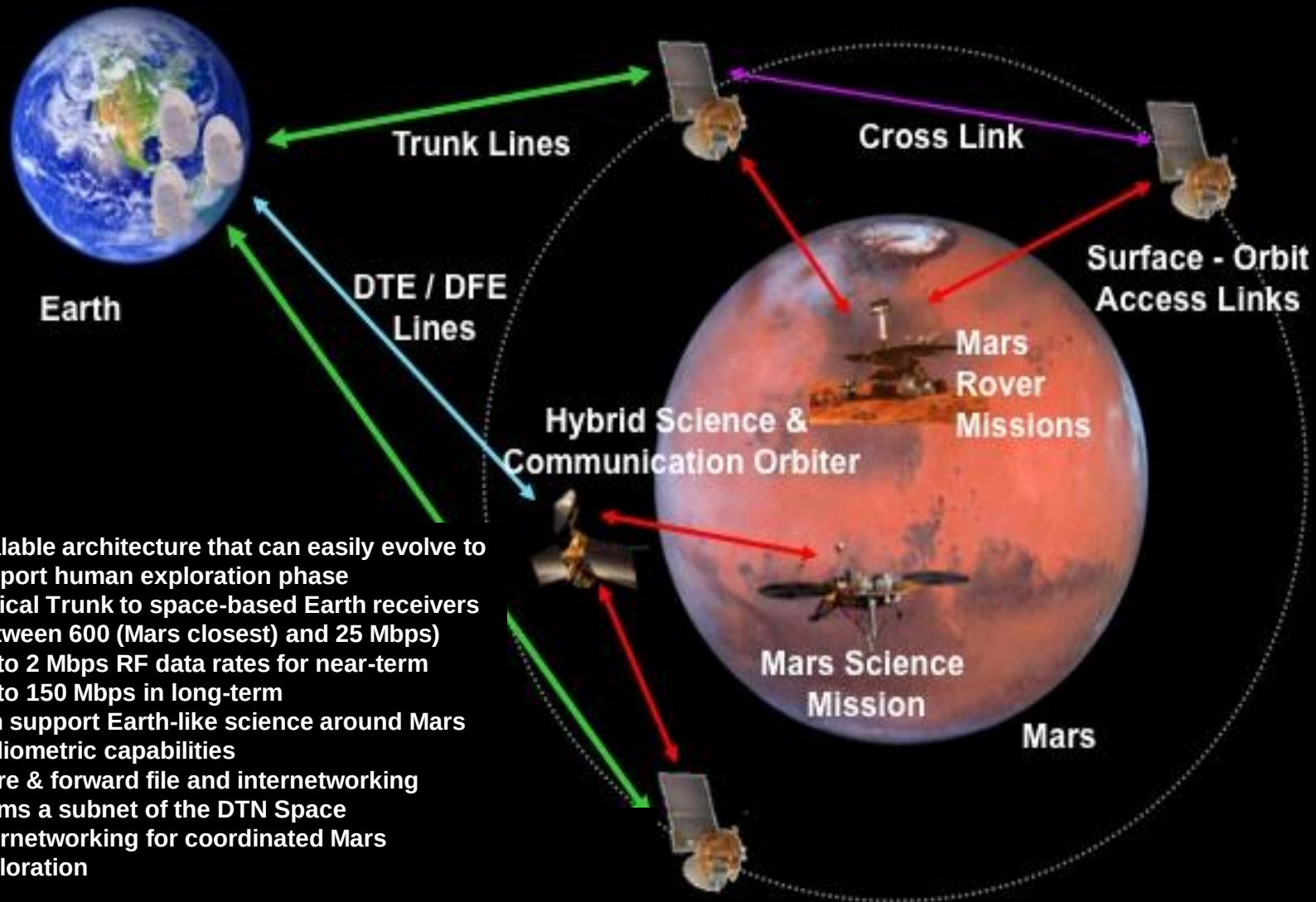
- Near-Earth Optical IOC
  - Up to 1.2 Gbps return, 100 Mbps forward
- RF return link enhancement
  - 150 Mbps at L2 using Ka
  - 1.2 Gbps for LEO/MEO using Ka
- Anytime, anywhere connectivity within Earth line of sight
- Single point access to SCaN component networks
- Standard services across all component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

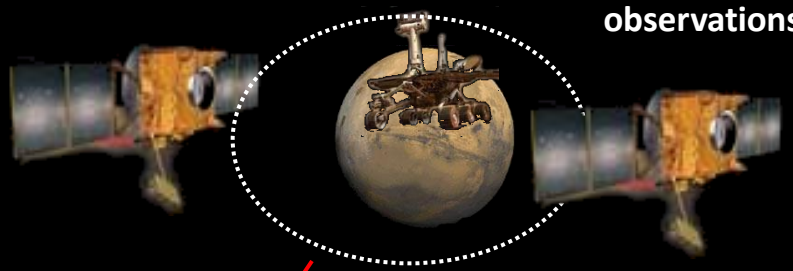
Mars Network



- 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



Coordinated observations

Next-gen Navigation

Primitive Body Missions

Mars Trunk Lines

Point-to-point RF links

Relays for In-Situ Science

Ground-based Optical

Point-to-point Optical links

Space-based Optical

RF Antenna Arrays

Integrated Service And Network Management

- **Deep Space Optical IOC**
  - 100 Mbps extensible to 1Gbps return link at 1AU; ≥ 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