Communications Technology Division

Electron and Optical Device Technology

Antenna, Microwave, And Optical Systems

Digital Communications Technology

Satellite Networks & Architectures

Communications System Integration

Aerospace Communications at the NASA Glenn Research Center

Félix A. Miranda, Ph.D.

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Polytechnic University of Puerto Rico
San Juan, Puerto Rico
September 22, 2005


Asteroid Vesta
HST · WFPC2
NO COMMUNICATIONS
No Data
No Commands
No Pictures
No Video
No Voice
No Safety
NO SCIENCE
NO EXPLORATION

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Abstract

The Communications Division at the NASA Glenn Research Center in Cleveland Ohio has as its charter to provide NASA and the Nation with our expertise and services in innovative communications technologies that address future missions in Aerospace Technology, Spaceflight, Space Science, Earth Science, Life Science and Exploration.

Our world class research includes: satellite networks and architectures; electron and optical devices; antennas and microwave systems; digital communications components, and systems-level integration.

Our products encompass technology, expertise, and research laboratories to evaluate, develop and supply our stakeholders' products that are value-added, affordable and sustainable.

To achieve this, we work in partnership with Industry, Academia and other Government Agencies to boost technological innovation and commercial competitiveness to further realize the potential of NASA technology, and address national priorities.

This presentation will provide an overview of our current activities in the aforementioned areas.

Communications Technology Division

- Electron and Optical Device Technology
- Antenna, Microwave, And Optical Systems
- Digital Communications Technology
- Satellite Networks & Architectures
- Communications System Integration

5600 MS 54-1

COMMUNICATIONS DIVISION

W. Daniel Williams, Chief

(Gene Fujikawa, Acting Chief)

J. Van Horn, Secretary

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5620 54-5

Electron and Optical Device Technology Branch

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- TWTA Development
- MMIC Development
- Electron Device Charac. and Testing
- Electron Emission/ Suppression Devices Development
- Computer Aided Design and Analysis of SS Devices
- Electronic Materials Characterization
- Solid State Power Amplifier
- RF MEMS Devices

5640 54-8

Antenna, Microwave, And Optical Systems Branch

F. A. Miranda Chief

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- Phased Array Antennas
- Advanced Antenna Concepts
- Comm Terminal Systems
- Spacecraft Components and Subsystems
- Smart/Reconfigurable Antennas
- MEMS Based Antennas
- Optical Phased Arrays and Communications Systems
- Electro-Optical Technology
- Cryogenic Microwave Tech.
- Atmospheric Propagation Studies
- Antenna Metrology and Characterization

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Digital Communications Technology Branch

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- Digital and Wireless Subsystems
- Low Power Transceivers
- Onboard Network Interface Controllers, Hubs
- Software Defined Radios
- Aeronautical Digital Avionics
- FPGA, ASIC Development
- Digital Modulation and Coding
- Routers, Packet Switching
- Computer Aided Design, Analysis, and System Simulation

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Satellite Networks & Architectures Branch

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- Network Simulation & Management
- Internet Protocols & Standards Development
- Interoperability Testbeds & Experiments
- Next Generation Space-Based Networking
- Network Applications Development (Internet-Based) for NASA Missions

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Communications System Integration Branch

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- Comm Systems Research
- Link and Network Analysis
- Technology Trades
- Orbital Analysis
- Comm System Design
- Laboratory System Integ.
- System Level Experiments & Demonstrations
- Performance Measurements
- Customer Focus & Outreach

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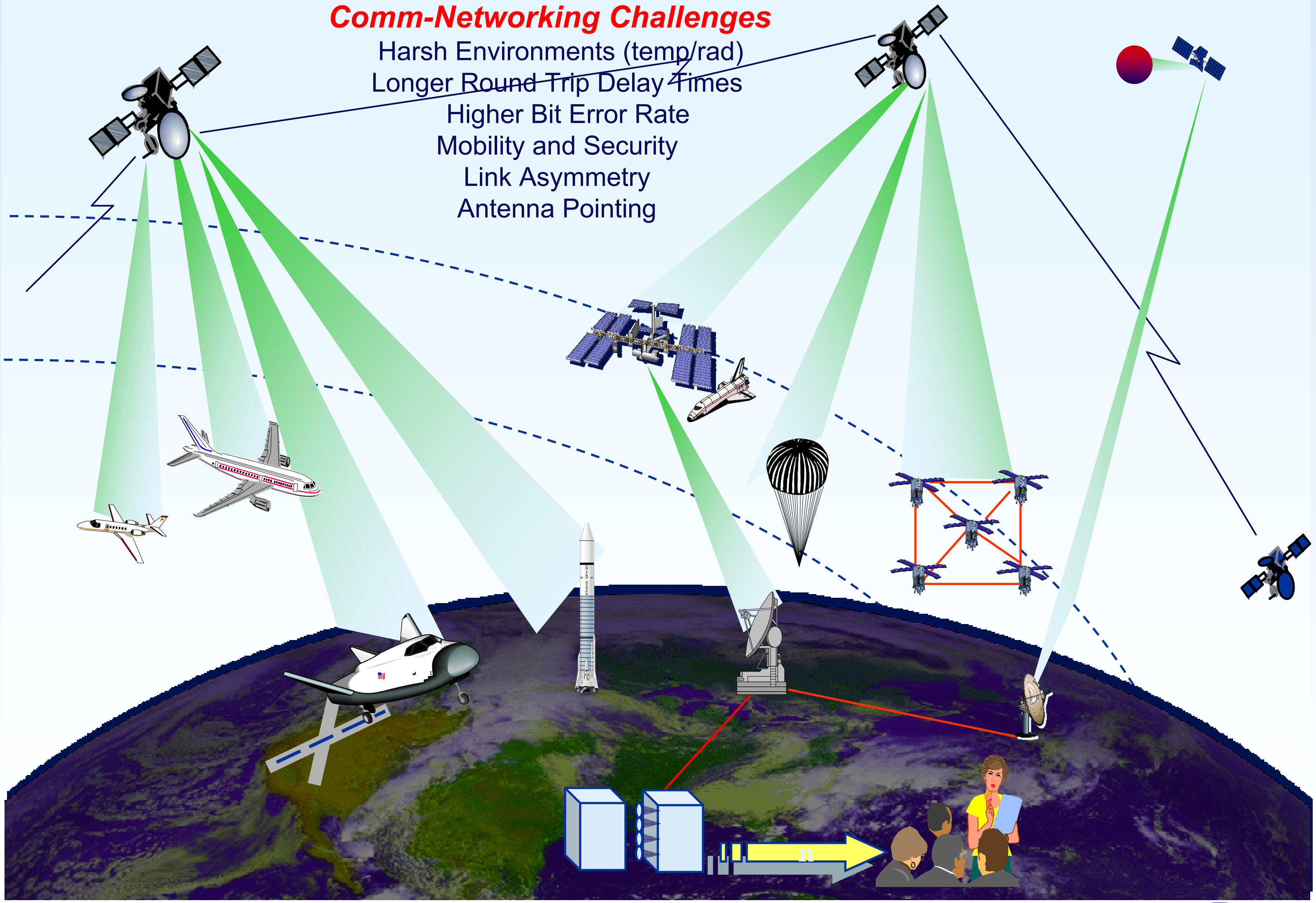
Notional Aero-Space Interconnection Architecture



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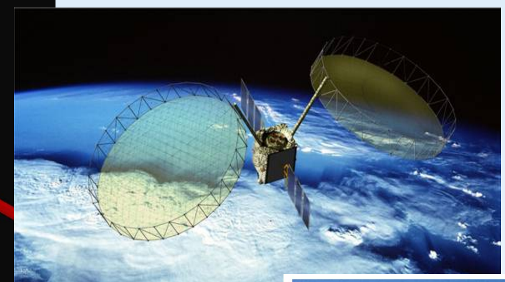
Enabling Technologies

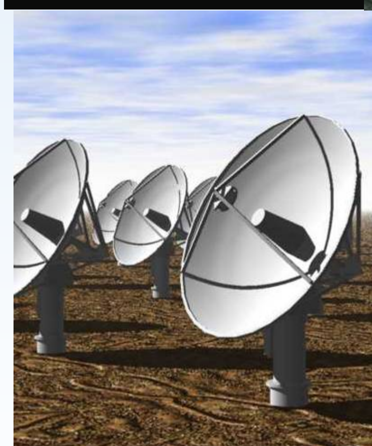
Optical Communications

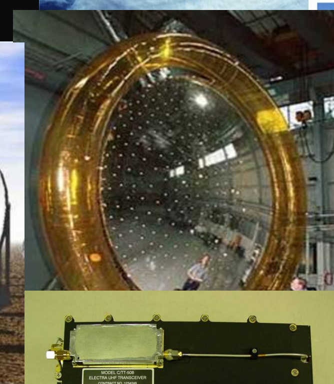
- High capacity comm with low mass/power required
- Significantly increase data rates for deep space

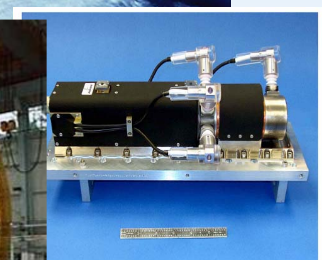
Uplink Arraying

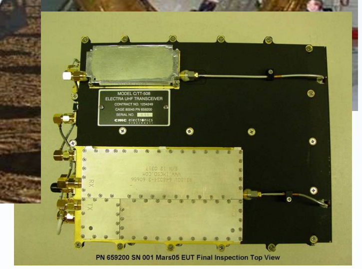
- Reduce reliance on large antennas and high operating costs, single point of failure
- Scalable, evolvable, flexible scheduling
- Enables greater data-rates or greater effective distance











Spacecraft RF Technology

- High power sources, large antennas and using surface receive array can get data rates to 1Gbps from Mars

Software Defined Radio

- Reconfigurable, flexible, interoperable allows for in-flight updates open architecture.
- Reduce mass, power, vol.

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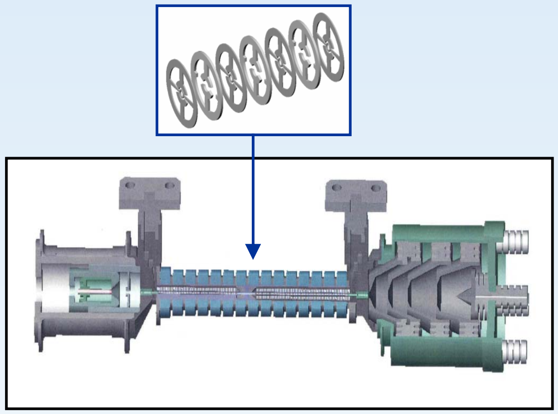
Rainee N. Simons, Ph. D.

Miniature TWT (2004)



Frequency 32 GHz
P_{out} 20 W, PAE 55%
Size & Mass 50 %
less than Cassini TWT,
10X increase in data rate

- **TWTA (Traveling Tube Amplifier) Development**
- **MMIC (Monolithic Microwave Integrated Circuit) Development**
- **Electron Device Characterization and Testing**
- **Electron Emission/Suppression Devices Development**
- **Computer Aided Design and Analysis of Solid State Devices**
- **Electronic Materials Characterization**
- **Solid State Power Amplifier**
- **RF MEMS Devices**

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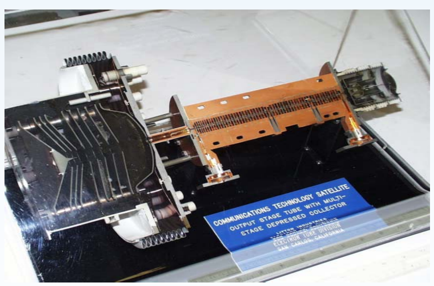
Traveling Wave Tube (TWT) Technology

Capability

Communications Technology Satellite (CTS) TWT (1976)

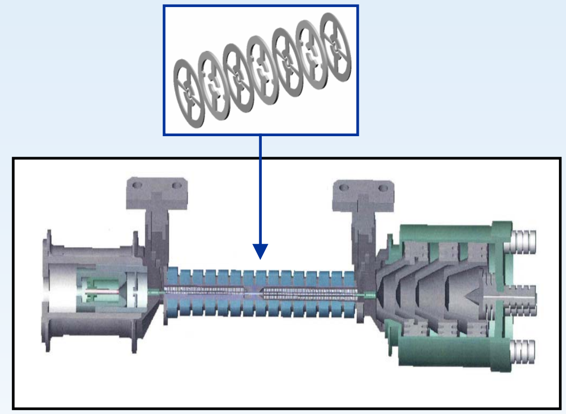


Frequency 12 GHz
Pout 240 W, PAE 35%

Cassini TWT
1990

Frequency 32 GHz
Pout 10 W, PAE 50 %

Miniature TWT
2004



Frequency 32 GHz
Pout 20 W, PAE 55%
Size & Mass 50 %
less than Cassini TWT,
10X increase in data rate

Time

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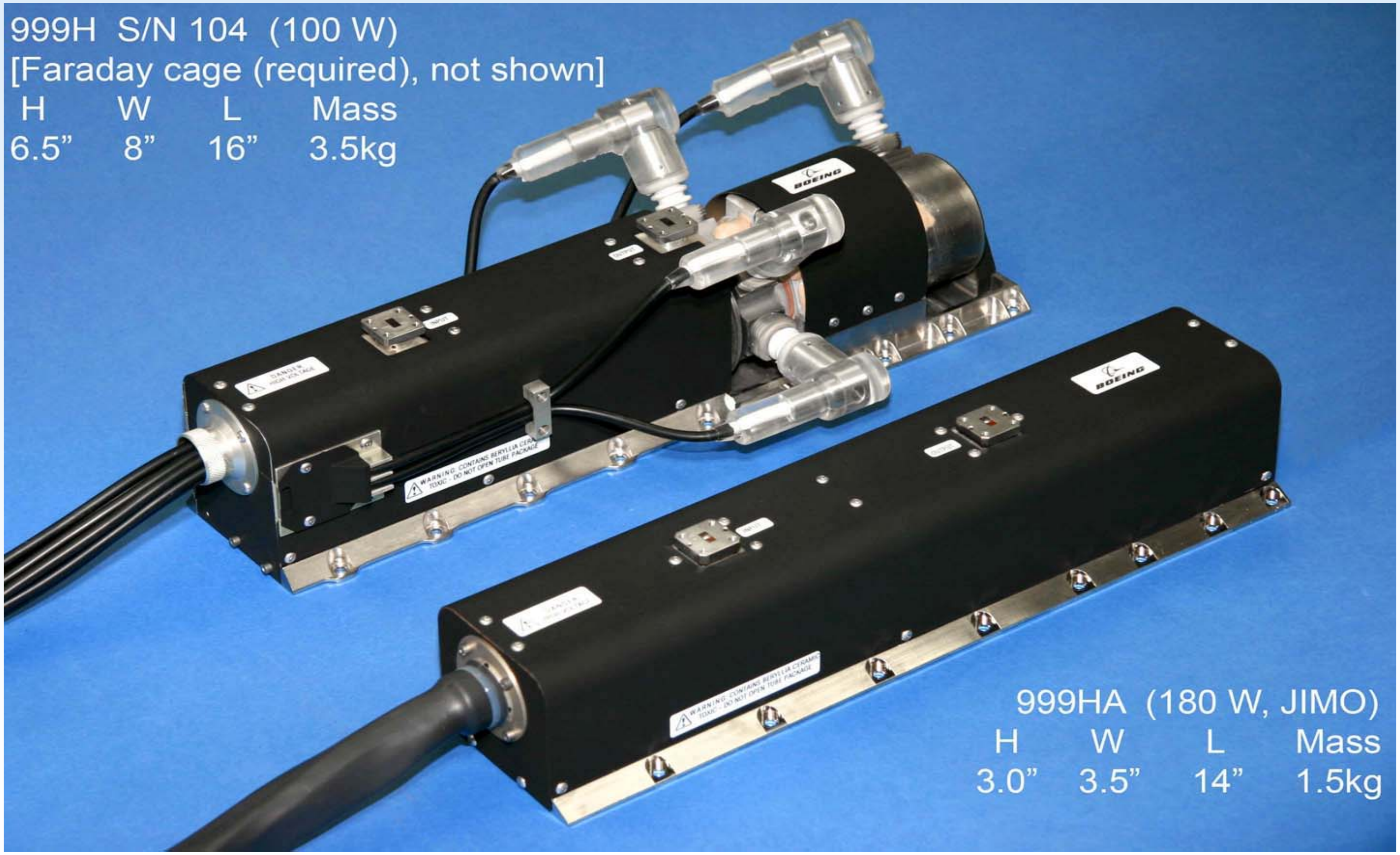
100 W and 180 W Ka-Band TWTs



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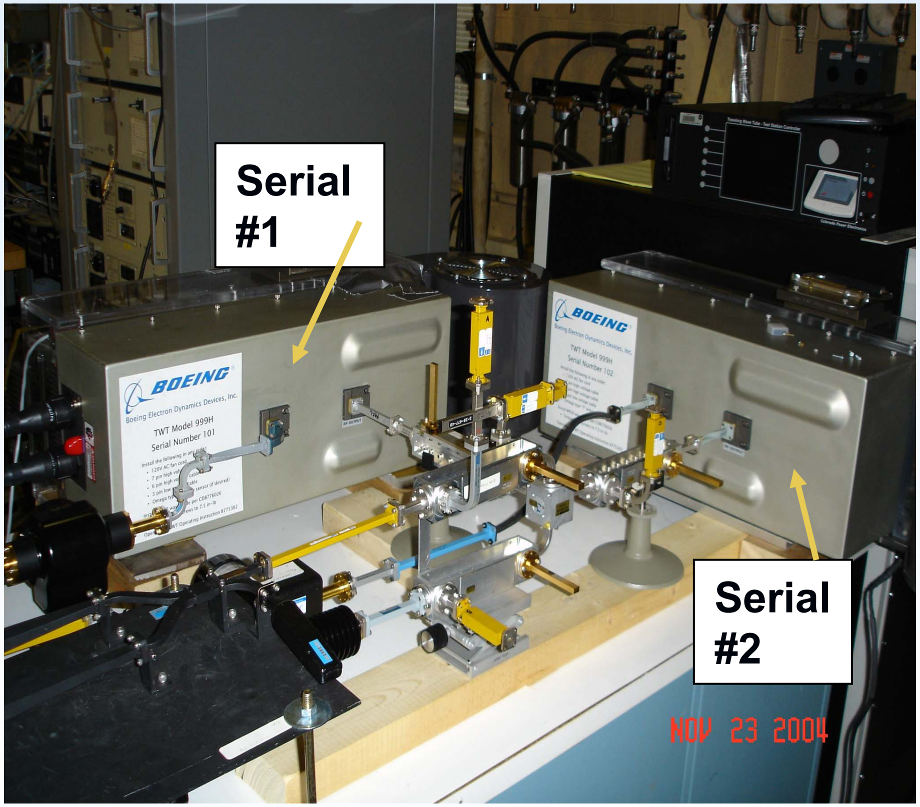
Space Traveling Wave Tube (TWT) Power Combiner Test Bed

Program Goals

- Demonstrate a high power high-efficiency space TWT Power Combiner for NASA Space Science missions (31.8 – 32.3 GHz) such as Project Prometheus (JIMO)
- Achieve >90% overall efficiency with about 200 Watt combined RF Power
- Demonstrate 622 Mbps QPSK data through put through the combiner

Combiner Test Bed

Boeing TWT Model 999H



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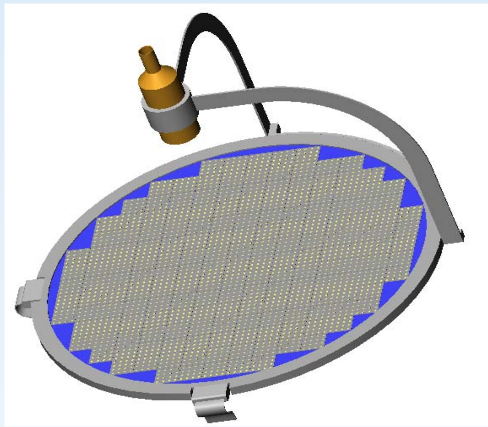

Inflatable/Deployable Antennas

- Phased Array Antennas
- Advanced Antenna Concepts
- Comm. Terminal Systems
- Spacecraft Components and Subsystems
- Smart/Reconfigurable Antennas
- MEMS Based Antennas
- Optical Phased Arrays and Communications Systems
- Electro-Optical Technology
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- Atmospheric Propagation Studies
- Antenna Metrology and Characterization

GRC Antenna Research Heritage

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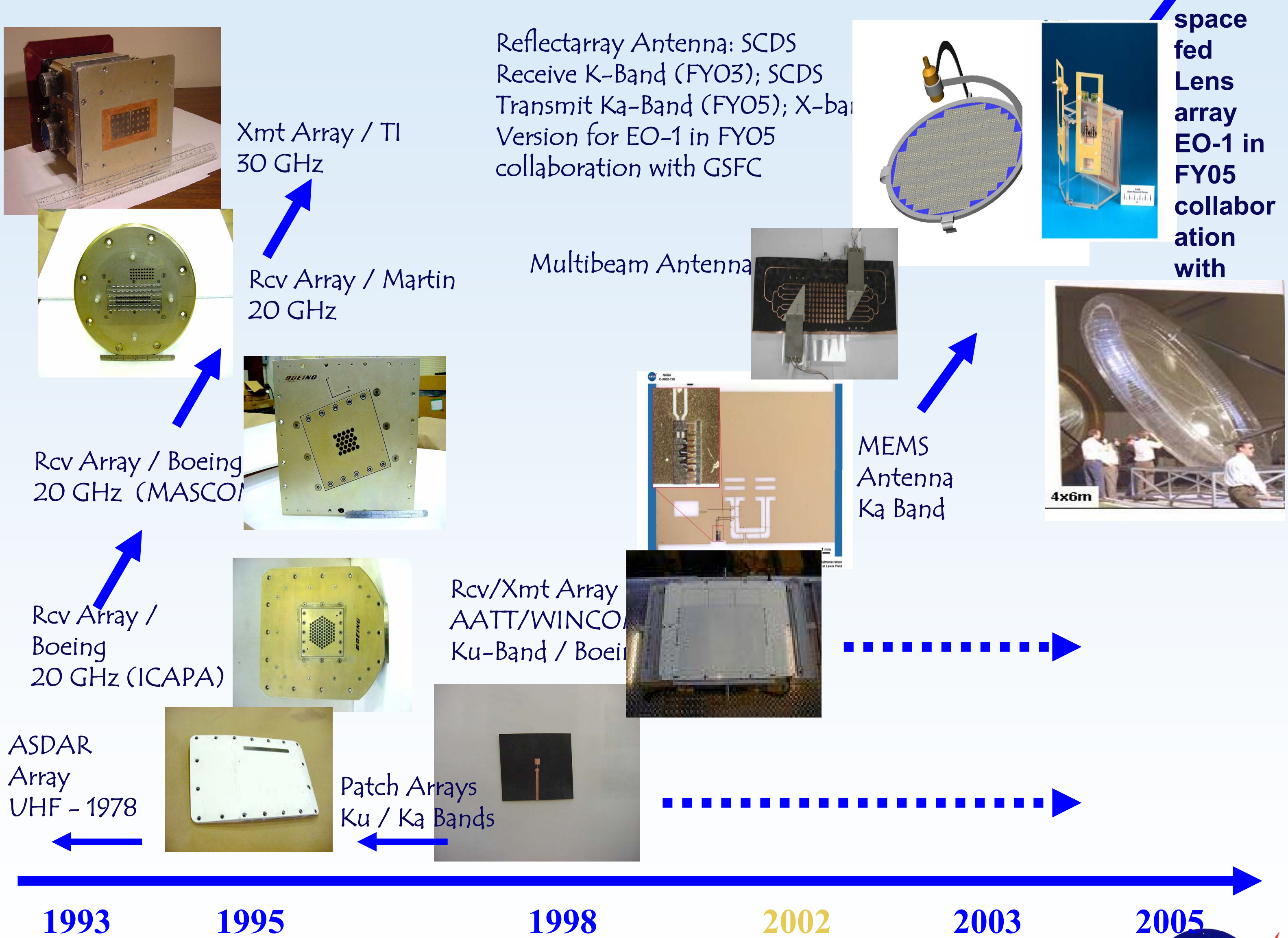

Glenn Research Center

at Lewis Field

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Large Aperture Inflatable Antennas Heritage and Timeline

- NASA GRC has been a leader in large inflatable aperture structures for Solar Concentrators (SC) for the last decade (Thermo-Mechanical Systems Branch, Power and On-Board Propulsion Technology Division).

- 2001: Investigators from the Applied RF Technology Branch of the Communications Technology Division (CTD) at GRC demonstrated feasibility of using SC inflatable base-material (CP-1) for large aperture RF antennas.

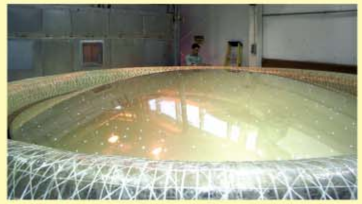
- 2002-2004: Code M's Space Operations Management Office (SOMO) funds GRC's CTD efforts to develop large aperture, extremely lightweight (<1 kg/m^2) inflatable antenna leading to Ka-Band applications.

Current Activities on Inflatable Antenna Program at GRC

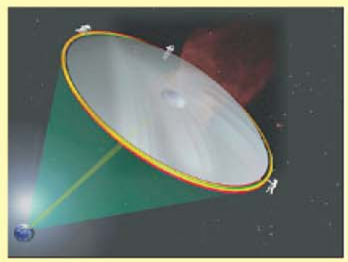
Large Aperture Inflatable Antennas

Space Applications

4- by 6-m inflatable offset parabolic membrane antenna test in GRC near-field facility

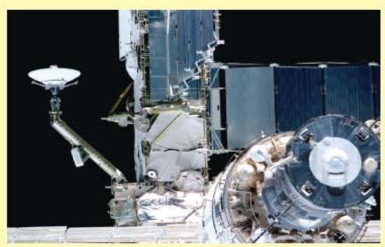


4- by 6-m inflatable offset parabolic membrane antenna inflation test (human in the background)



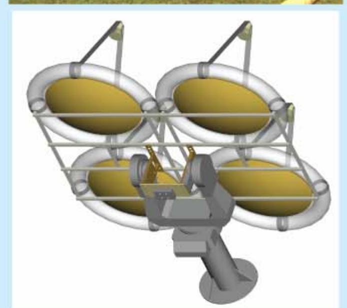
Deep-space relay station concept

Overhead photograph of 4- by 6-m inflatable reflector in GRC near field facility



Backup 2-m inflatable Cassegrain reflector for ISS Ku-band system

Surface Applications



Low-cost tracking ground station experiment in collaboration with Goddard Space Flight Center planned for May 2005

2.5-m inflatable membrane antenna in inflatable radome for ground applications

Goals:

- Develop large, lightweight reflector antennas with areal densities <0.75 kg/m^2, for Lunar, Mars, and deep-space relay exploration applications.
- Develop rigidization techniques (e.g., ultraviolet curing) to eliminate the need for makeup inflation gas.
- Demonstrate a ratio package to deploy volume greater than 1:75.
- Demonstrate quick deployment of large apertures for ground-based and planetary surface applications.

GRC CHARACTERIZATION ANTENNA FACILITIES

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Digital Communications Technology

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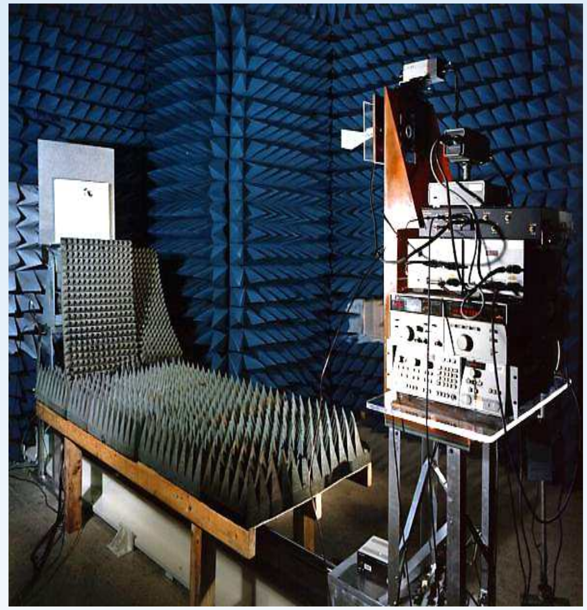
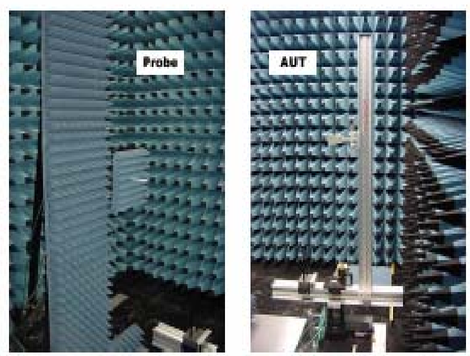
http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?2002/TM-2002-211883.html

Compact Range



Far-Field



Cylindrical Near- Field Range

Near- Field Range

Miniaturized Reconfigurable Antenna For Planetary Surface Communications

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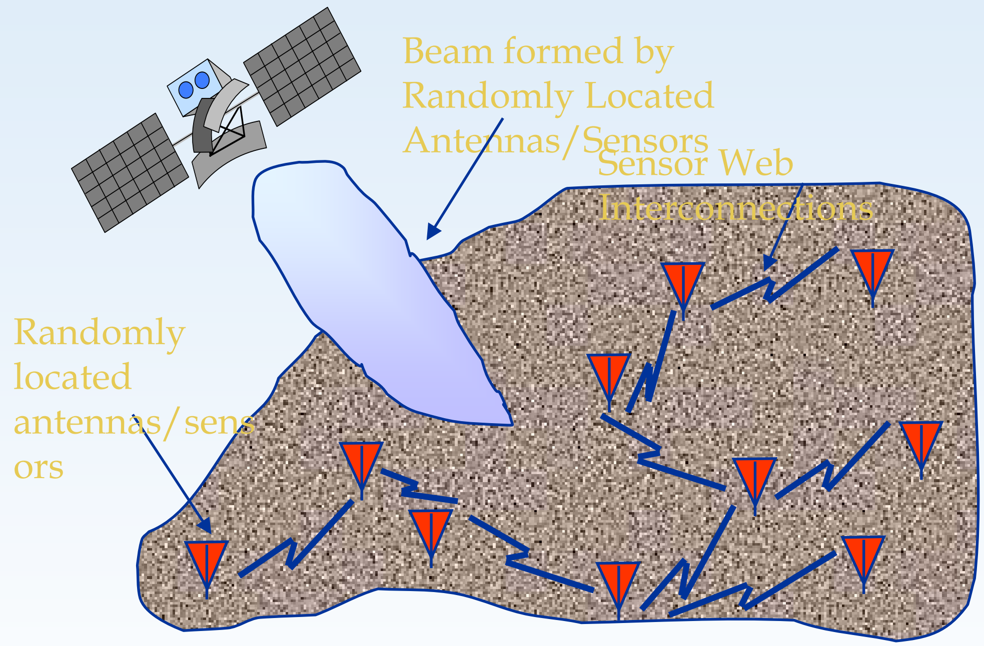
Program Goals

- Develop electrically small (miniaturized) antennas with moderate bandwidths for planetary surface communications between remote sites sensors or orbiters.
- The technology is intended to enable low-risk sensing and monitoring missions in hostile planetary and/or atmospheric environments.
- These antennas are needed for Planetary and Moon Exploration and Monitoring Missions



Collaboration with University of Illinois

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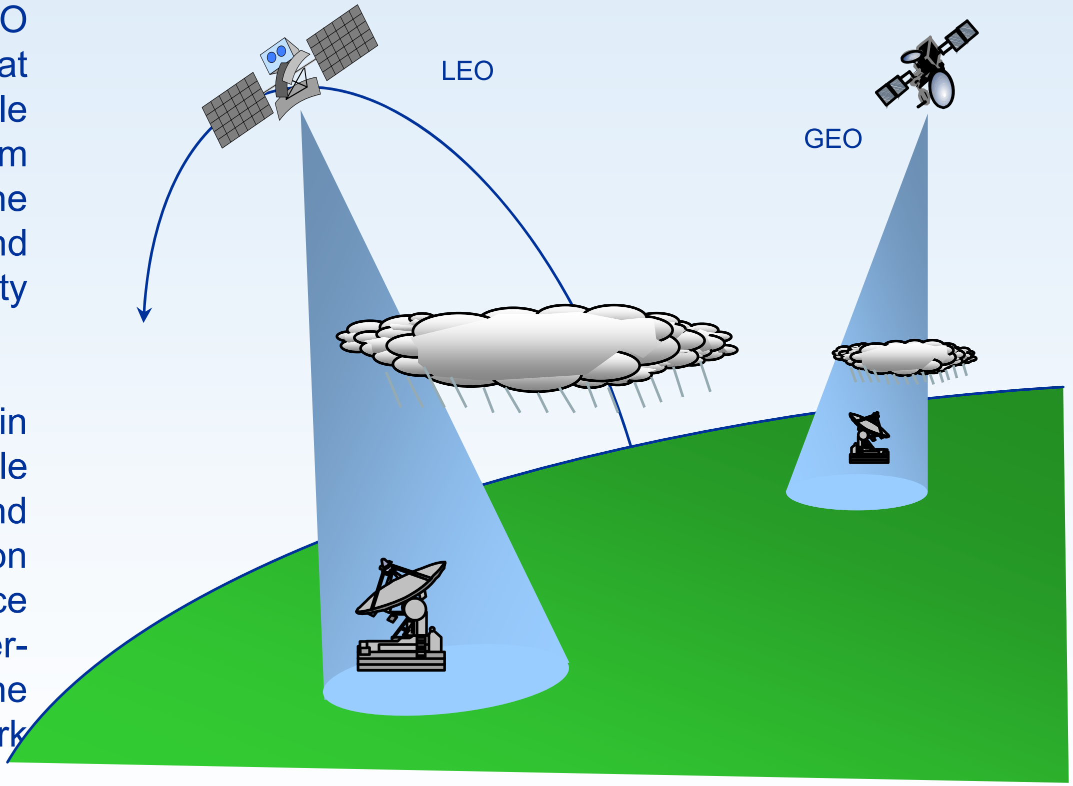
Ka-Band Propagation Measurement & Analysis

Program Goals

- Develop and evaluate LEO and GEO propagation models that will enable communication system designers to reduce the uncertainty of Ka-Band system availability predictions.
- This reduction in uncertainty will enable NASA, DOD and commercial mission planners to reduce mission cost by not over-designing the communication network system link margins.



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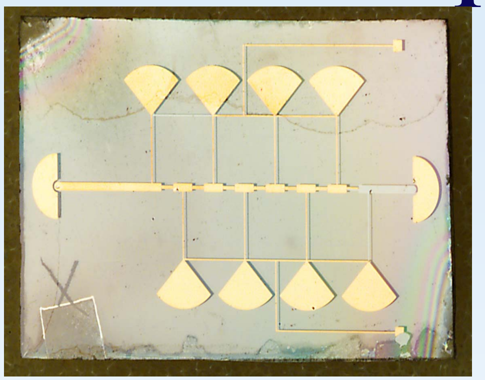
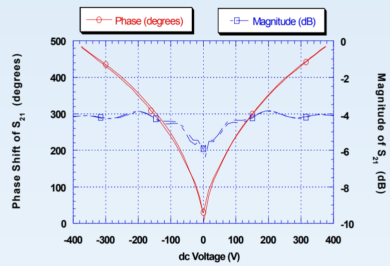
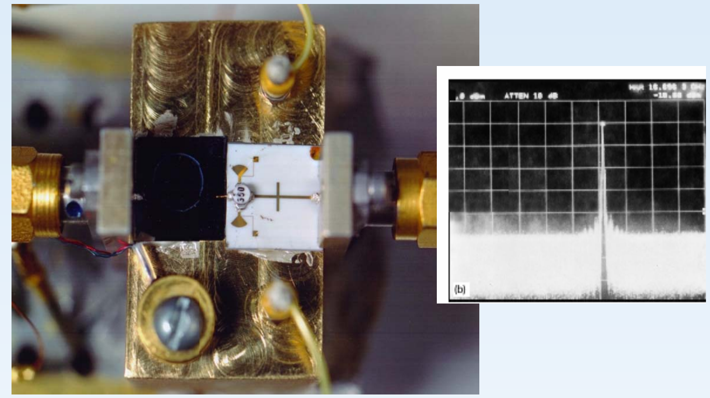
MICROWAVE PRODUCTS AND TECHNOLOGIES

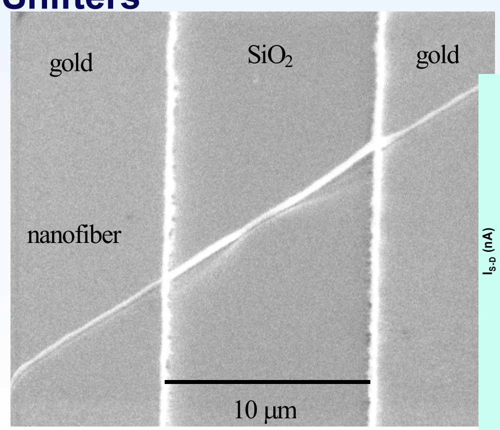


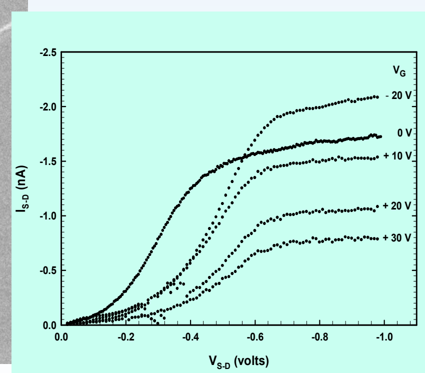


Thin Film Ferroelectric Phase Shifters

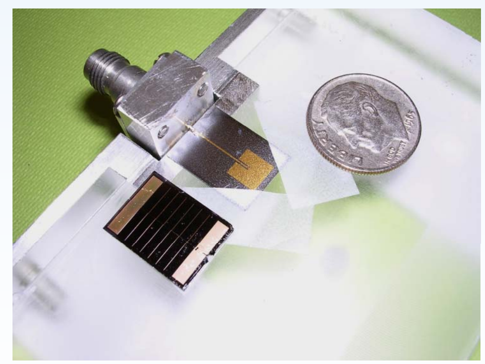


K-band Cryogenic tunable Oscillator



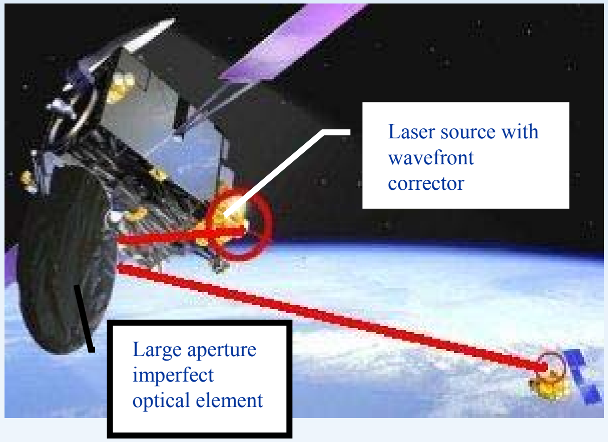


Polymer Nanowires nanoFETs



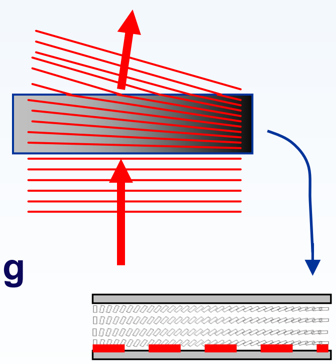
X-band Integrated antenna/solar cell

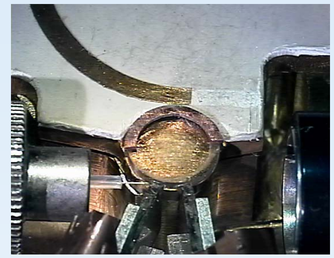
OPTICAL SYSTEMS

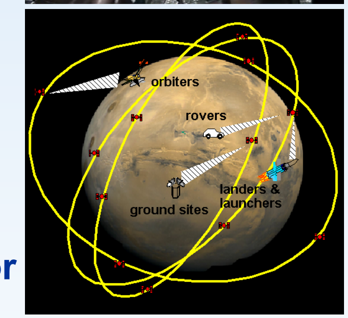


Liquid Crystal OPA and Wavefront Corrector

Beam steering using LC



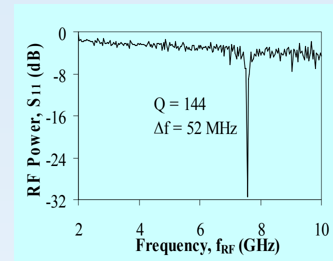




Conventional Receiver

Most power consumed in analog MMIC front-end:
For 60 *GHz* receive *electronic* analog RF front-end module power consumption– 0.4 Watts Volume-- 900 *mm*3

Microphotonic Receiver



Enterprise Relevance

Mars exploration requires new, efficient Ka-band receivers for surface-to-surface and surface-to-relay communication.

Examples: Rovers, orbiters, landers and launchers

Microphotonic Receiver
10 X reduced weight, size, and power consumption.

At 60 *GHz*
Power consumption-- 0.04 *W*
volume -- less than 40 *mm*3

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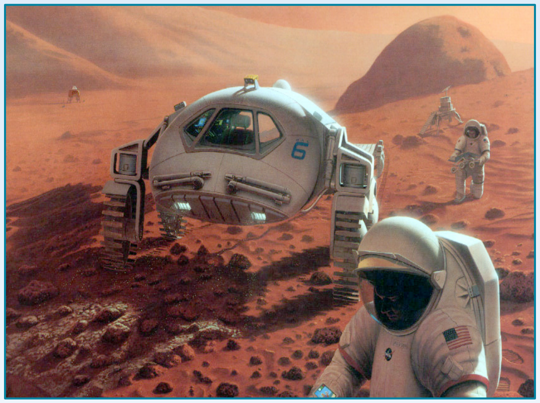
Gene Fujikawa



Multi-Function, Multi-mode Digital Avionics

- Digital and Wireless Subsystems
- Low Power Transceivers
- Onboard Network Interface Controllers and Hubs
- Software Defined Radios
- Aeronautical Digital Avionics
- FPGA, ASIC Development
- Digital Modulation and Coding
- Routers, Packet Switching
- Computer Aided Design, Analysis, and System Simulation

Digital Communications Technology

GRC Software Defined and Reconfigurable Radio Technology

Objectives

- Near term: Define an open architecture to provide software portability and re-use, scalability, and hardware/software independence
- Mid term: Develop a test-bed for architecture development, testing, and evaluation
- Long term: Perform a flight demonstration in a relevant Mission-Class

Top Challenges for GRC and Partner Centers

- Achieve desired SDR flexibility required by mission class while minimizing the spacecraft resources (i.e mass, power, volume)
- High density digital devices required for high data rates for the space environment

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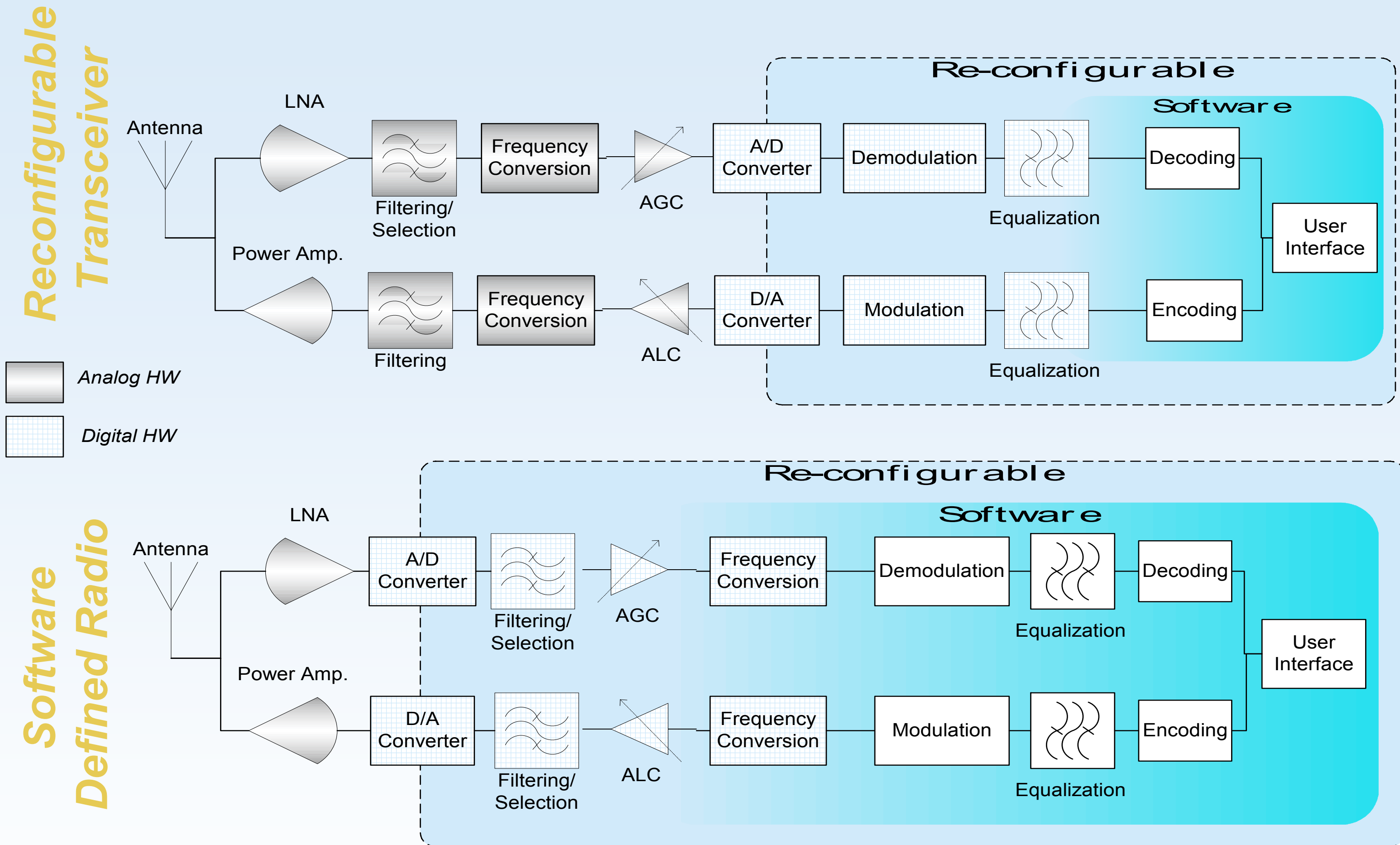
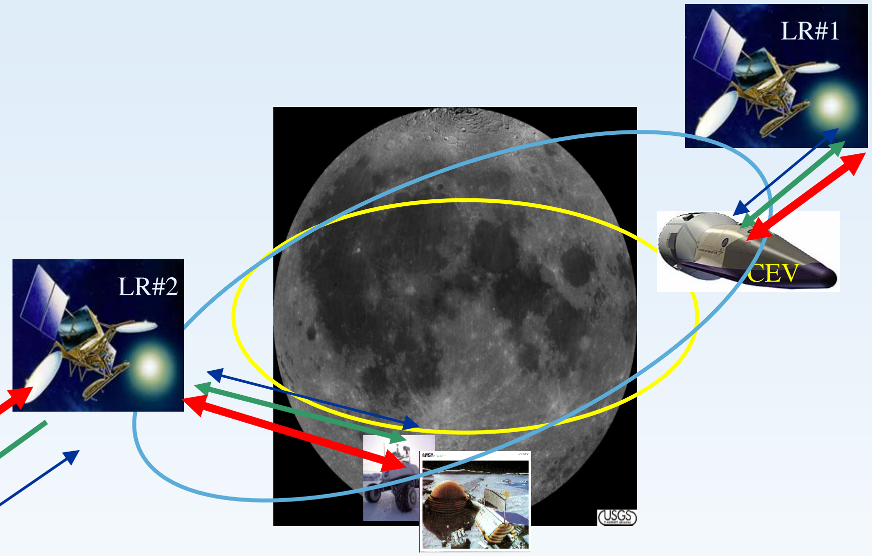


Reconfigurable transceivers and Software Defined Radios are the future of telecommunications

Digital Communications Technology

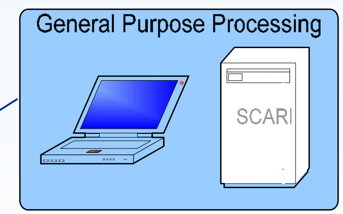
Software Defined Radio Application
From Electronic Components to Software
To Make Reconfigurable Communications For Space

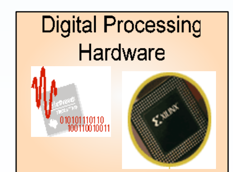


Older legacy space radios using electronics components have limited change possibilities…

GRC is developing newer software defined radios that can be changed in flight by simply uploading new programs…

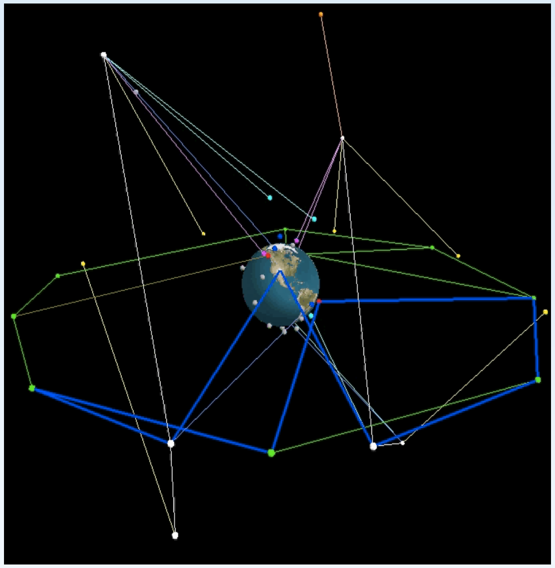
Software Defined Radio

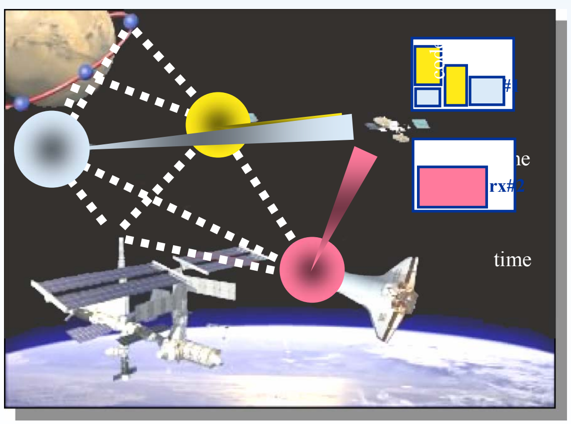




Satellite Networks and Architectures

Calvin T. Ramos





- **Protocol performance and characterization**
- **Network Simulation & Mgmt**
- **Internet Protocols (primarily transport, network and MAC layers) & Standards Development**
- **Interoperability Testbeds & Experiments**
- **Next Generation Aeronautical and Space-Based Network Architectures and Protocols**
- **Network Applications Development (Internet-Based) for NASA Missions**

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Digital Communications Technology

Satellite Networks & Architectures

Communications System Integration

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Space Communications Test Bed

- The SCT is an integrated test bed that is being developed for the detailed testing of advanced space and ground communications networks, technologies and client applications that are essential for future exploration missions.
- The SCT will provide end-to-end emulation of space communications with an emphasis on evaluating live, real-time end user experience and validating mission critical communications components, sub-systems, and systems.
- Enables NASA's Systems-of-Systems vision for Space Exploration by integrating geographically distributed NASA communication test beds and networks.
- The SCT is being developed by ViaSat (Prime) and supported by GRC, JPL, GSFC and LaRC.
- The SCT is a seamlessly integrated test bed that is geographically distributed among ViaSat and the NASA Centers and is remotely accessible from any of the NASA Center locations.
- The SCT is a combination of real and emulated software and hardware components that include the Earth, Lunar and planetary ground stations, orbiters, orbital and relay satellites, CEV, Lunar and planetary rovers.

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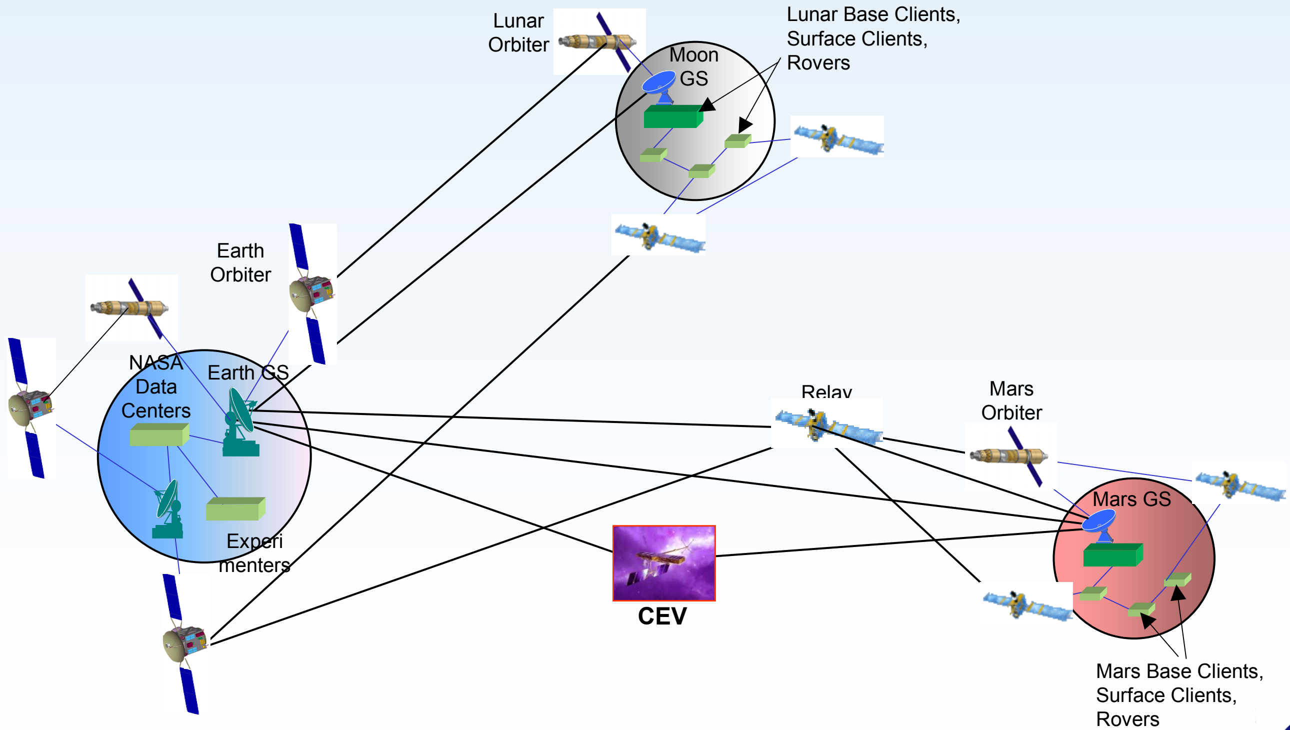
Research Focus: The SCT provides a robust and continuously available communications network emulation environment (from mission planning to operational testing) and enable users to perform the following activities:

- Plan mission by testing requirements for communications.
  - Test and evaluate new technologies for missions.
  - Test and evaluate software upgrades and modifications for operational missions.
  - Testbed platform where researchers can evaluate new ideas.



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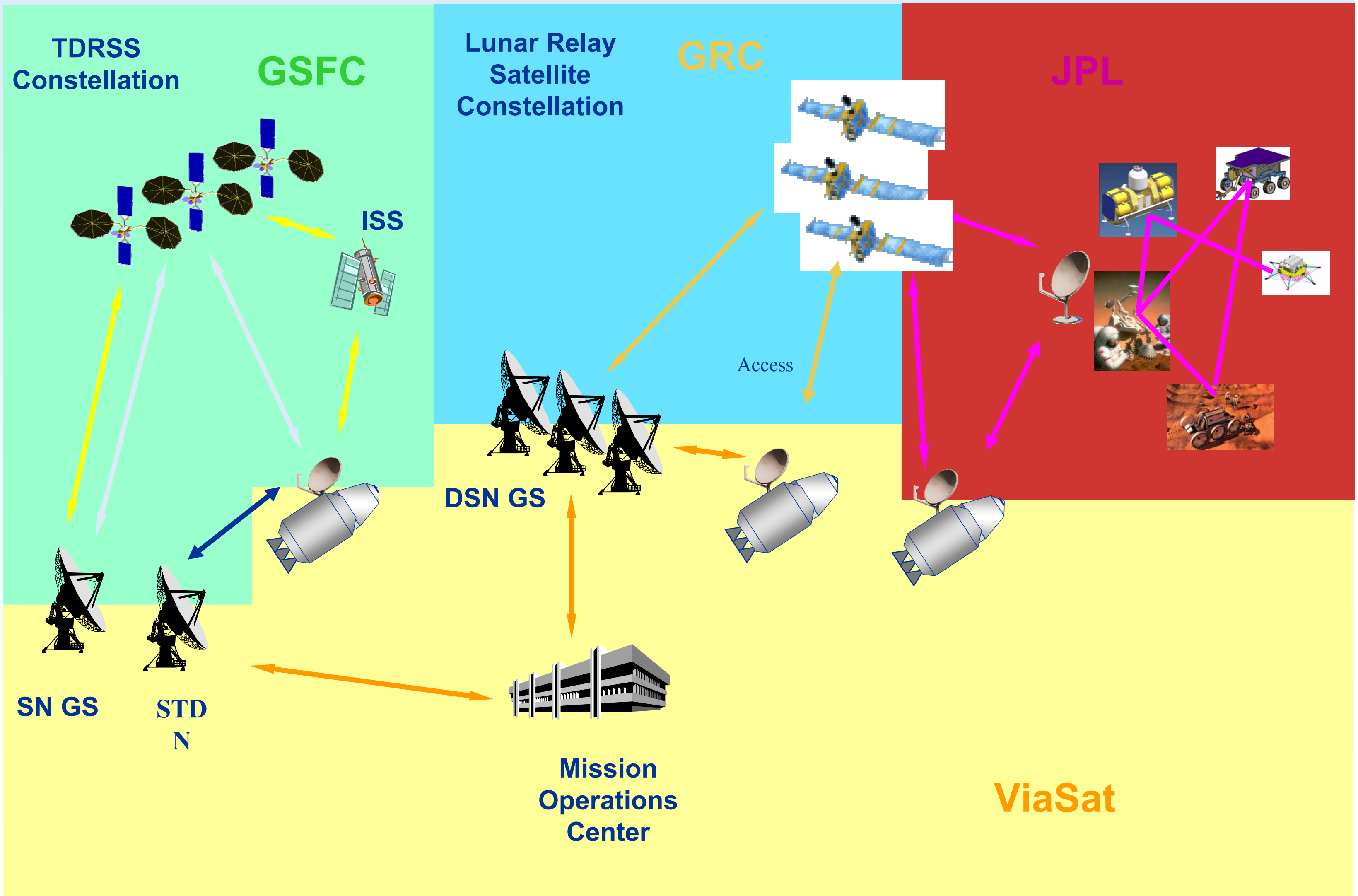
SCT Architecture – Functional Partitions



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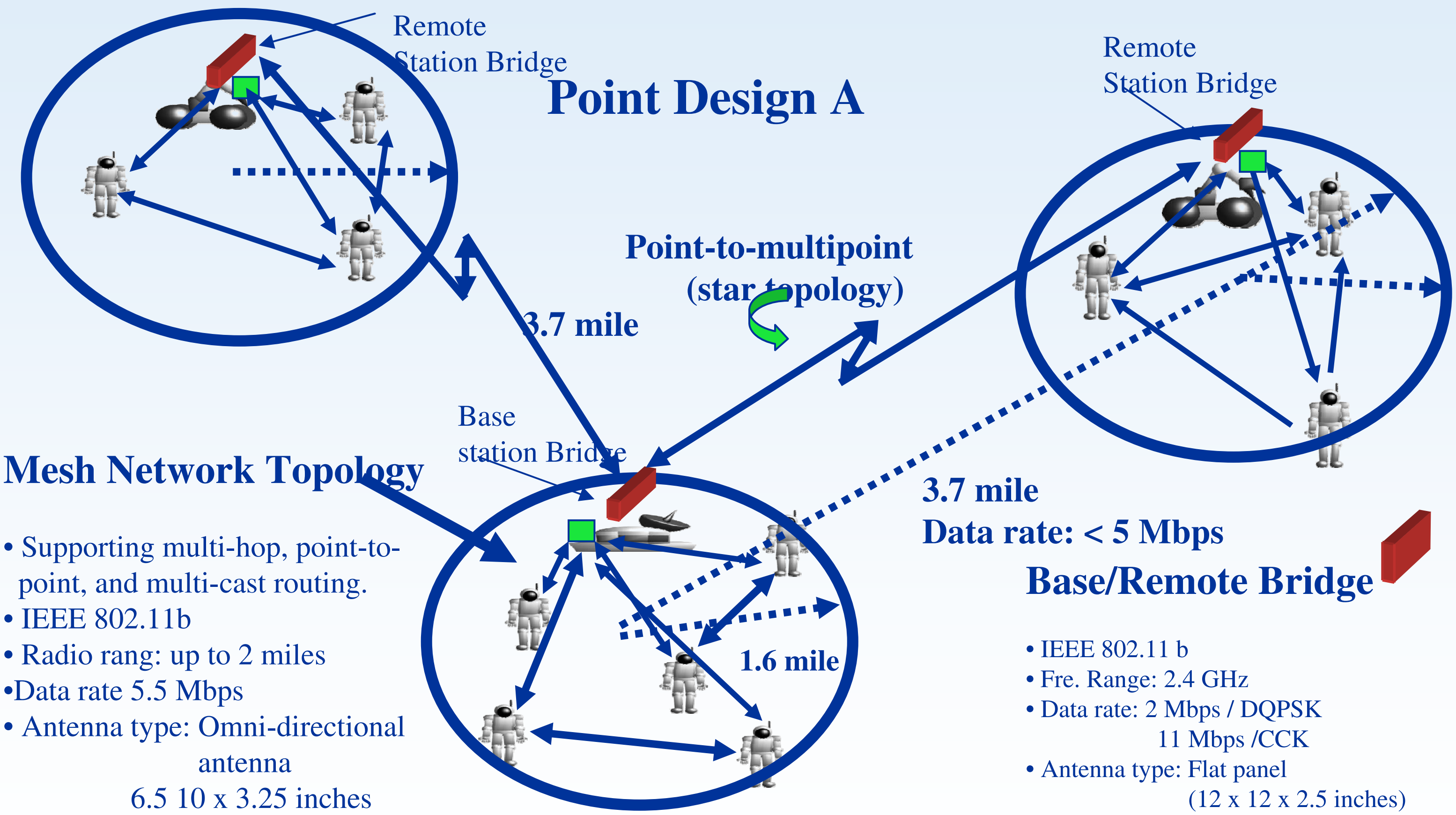
***Surface Exploration Network Analysis Research Focus*:** Assessment and characterization of surface network protocols and standards extensible to support surface planetary exploration and evaluation/development of RF coverage prediction simulation tools to assist mission designers in developing and modeling surface communications-networks for Moon and Mars environments.



Mesh Network Topology

- Supporting multi-hop, point-to-point, and multi-cast routing.
- IEEE 802.11b
- Radio rang: up to 2 miles
- Data rate 5.5 Mbps
- Antenna type: Omni-directional antenna 6.5 10 x 3.25 inches

Base/Remote Bridge

- IEEE 802.11 b
- Fre. Range: 2.4 GHz
- Data rate: 2 Mbps / DQPSK
  11 Mbps /CCK
- Antenna type: Flat panel
  (12 x 12 x 2.5 inches)
- Range: up to 6 miles.

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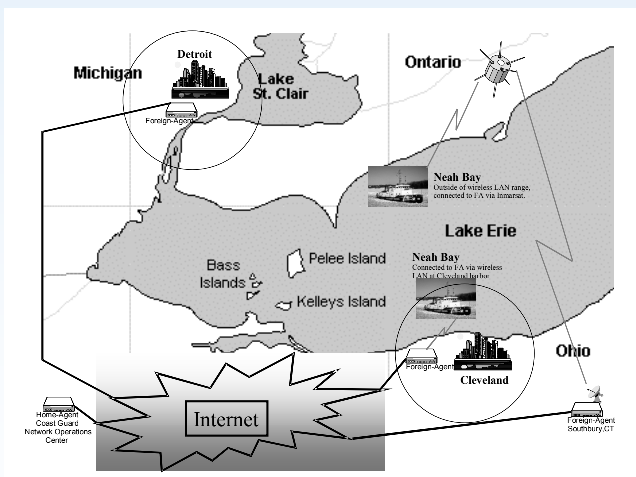
Secure Mobile Network Development & Technology Demonstrations

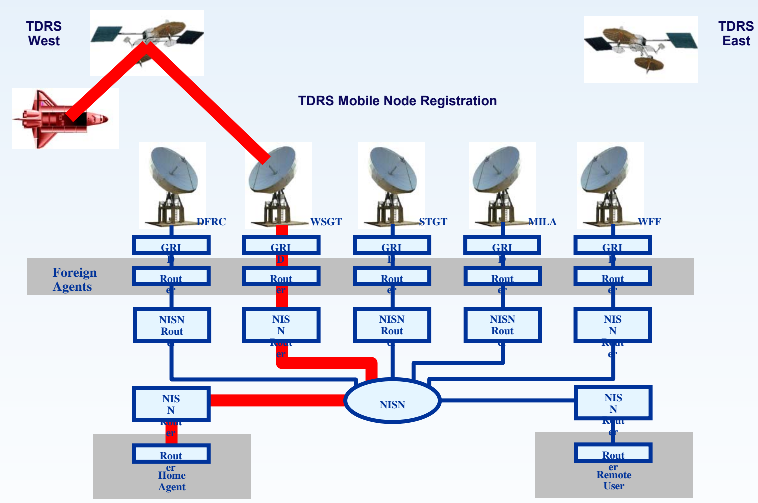
***Research Focus*:** Development and demonstration of mobile network protocols and technologies to enable secure virtual internetworking connectivity (traversing multiple un-secure domains & sharing infrastructure).

Secure Mobile Router Demonstration



November 2002

Mobile IP for Shuttle



January 2003

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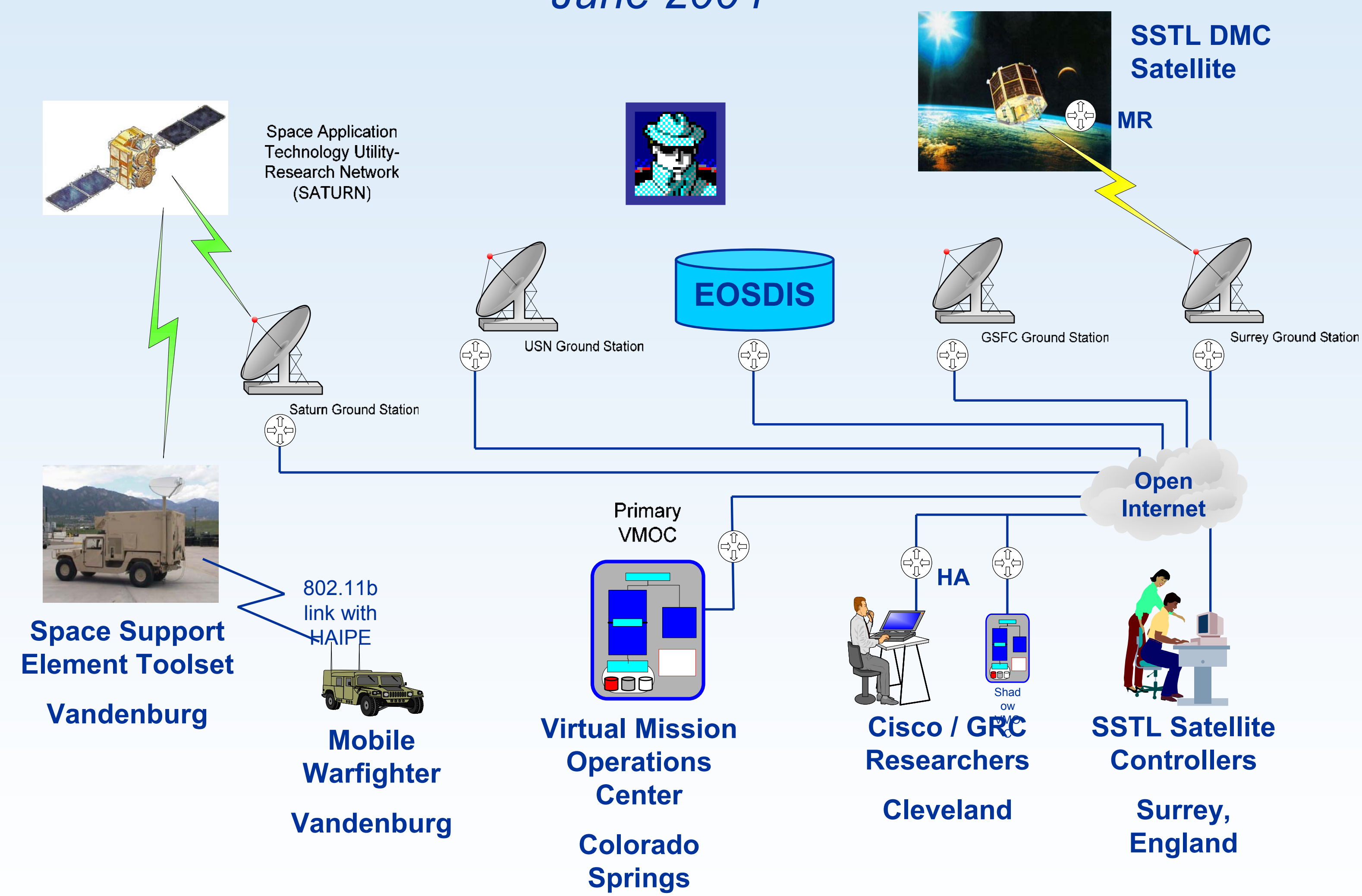
VMOC/Mobile Routing Demo

June 2004



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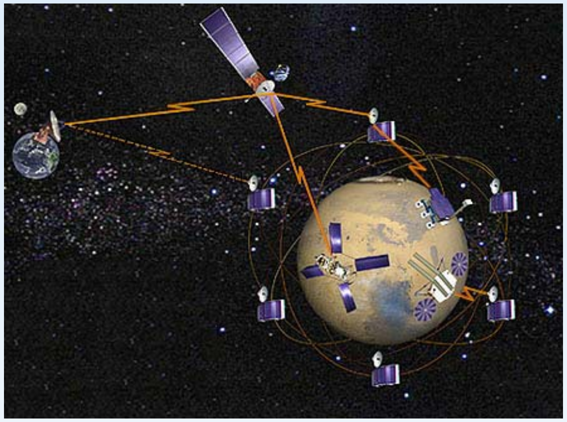
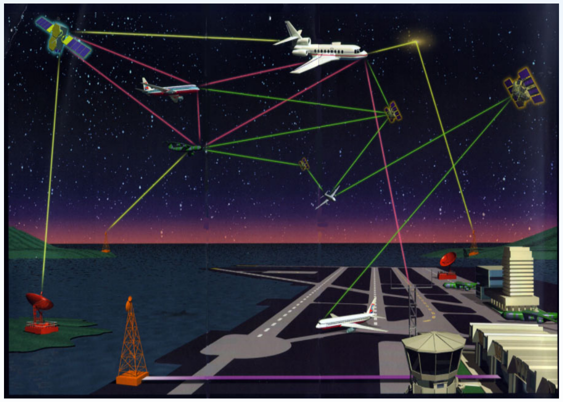
Denise Ponchak





- **Comm Systems Research**
- **Link and Network Analysis**
- **Technology Trades**
- **Orbital Analysis**
- **Comm System Design**
- **Laboratory System Integration**
- **System Level Experiments & Demonstrations**
- **Performance Measurements**
- **Customer Focus & Outreach**

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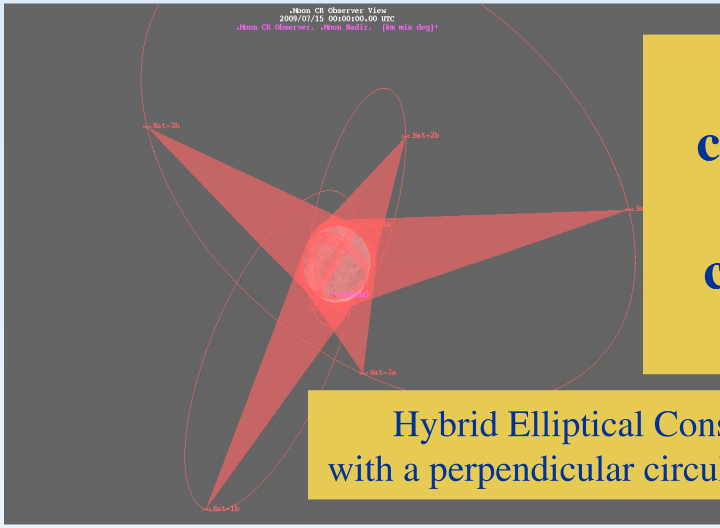
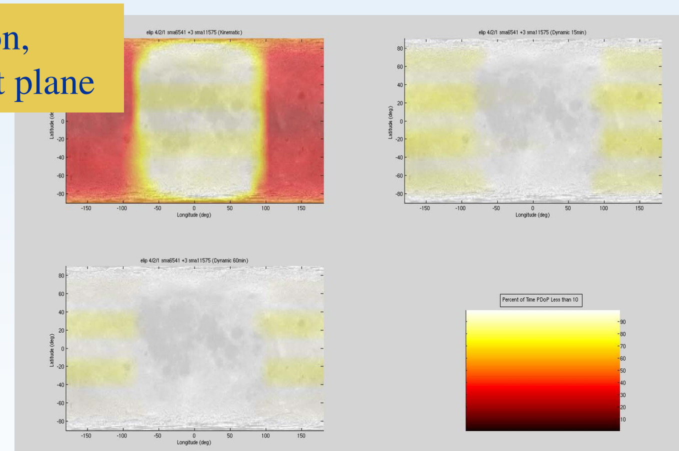
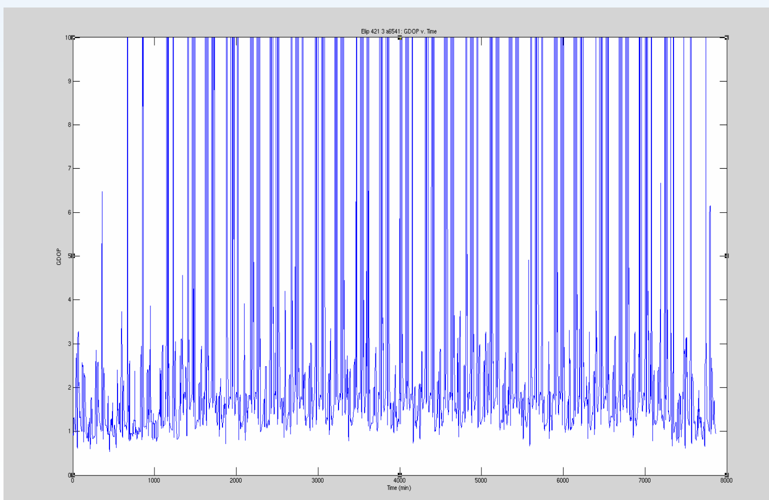
Lunar Navigation Analysis using Dilution of Precision



Providing Analysis of position-fixing capability brought by introduction of a constellation of lunar orbiting communication/navigation satellites at the moon

Hybrid Elliptical Constellation, with a perpendicular circular orbit plane





GDoP v. Time for 1 lunar month at the South Pole

Color indicates percent of time the Navigation Capability is provided by hybrid elliptical constellation in conjunction with Earth-based augmentation as a function of lunar latitude and longitude. Results given for real-time (kinematic), 15 minutes delay and 1 hour delay

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ADVANCED EXTRA VEHICULAR ACTIVITY SPACE SUITS

CEV Launch, Return and Contingency EVA Suit

Flight Suit	In-Space Suit	Surface Suit

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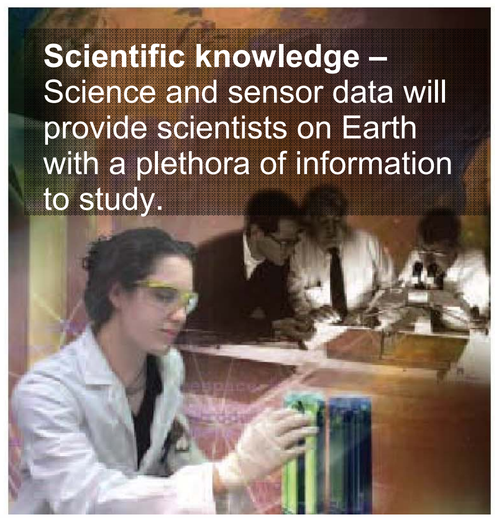
Communications, Avionics and Informatics Enabling Technologies



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Secure Mobile Networking

Collaborative Research with Industry

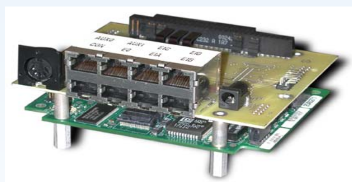
Aero and Spacecraft as nodes on the Internet

Standards-based Protocols to Reduce Infrastructure Costs

Secure Data Transfer and Handling (General Dynamics)

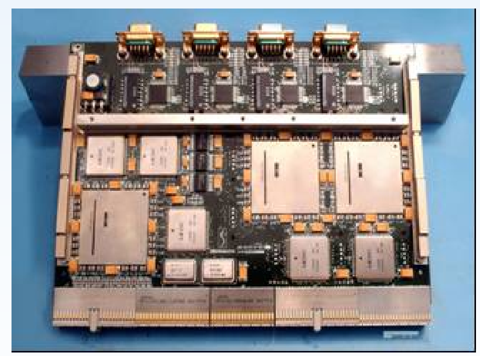
- VMOC - Virtual Mission Operations Center
- On-the-fly response to real-time events
- Allows remote access to sophisticated systems by "unsophisticated" users

Mobile Router Modules (Cisco)



Low Power Transceivers (ITT)

Space Network Devices (Spectrum Astro)



Smart Network Interface Ethernet Controller (10/100BASE-T)

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Mobile Communications for the NAS

***Research Focus*: Development and demonstration of advanced air-ground communications network architectures, protocols and technologies that will enable NAS (National Airspace System) system-wide information management.**

Advanced CNS (Comm/Nav/Surveillance) Architectures and System Technologies

- Architecture Development
- Systems Analysis
- Modeling and Simulation Tools
- IPv4 and v6 Interoperability
- Software Defined Radios
- Conformal Antenna Tech.
- Advanced VHF Tech.
- Security Protocols/Tech.
- Technology Development & Demonstrations
  - Terminal and Surface Area
  - Oceanic and Remote Areas

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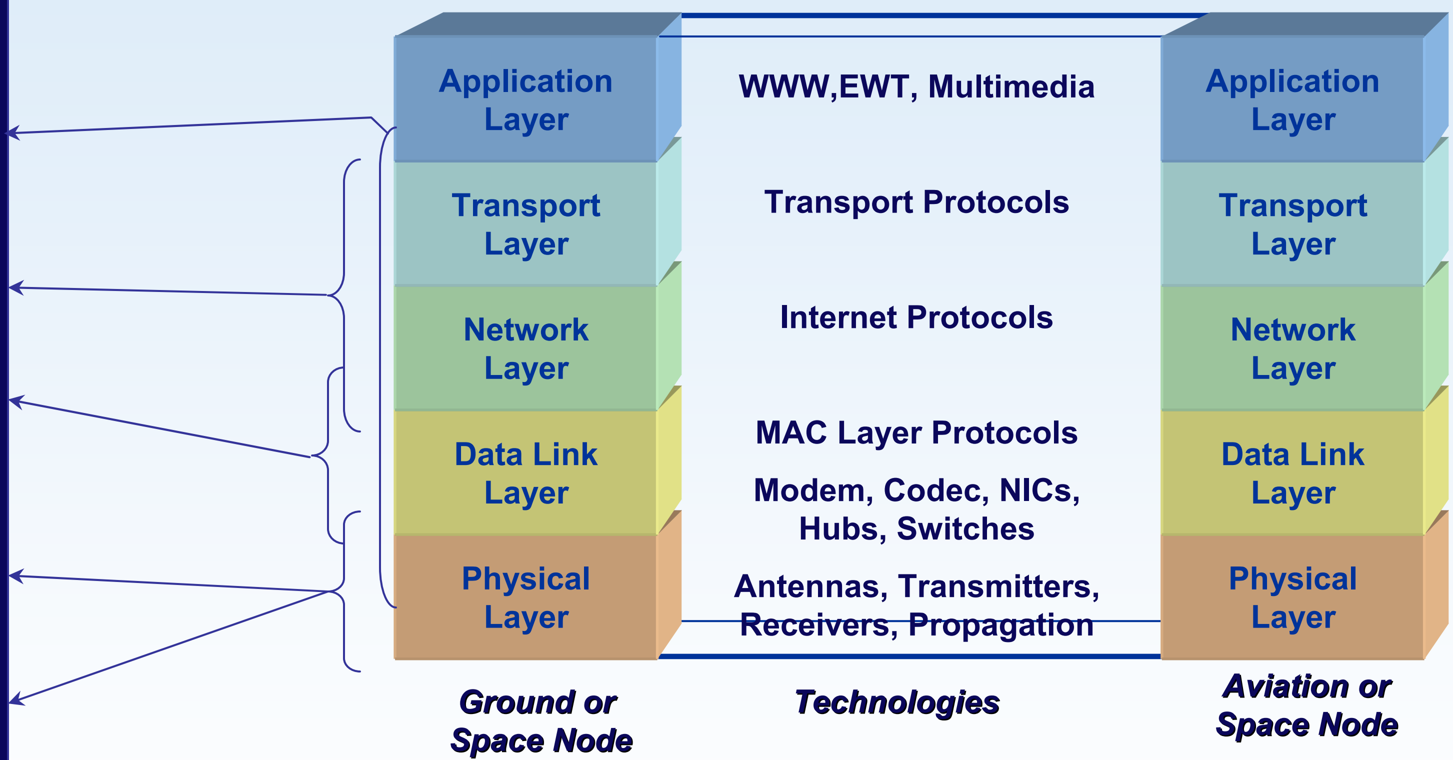
Communications Technologies in Context with OSI Stack



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Summary

Goal: Key Agency Source for Communications-Networking Research, Expertise, Technologies and Products

- End-to-end system analyses (modeling, simulation)
- Prototype development and technology demonstrations
- Secure mobile network architectures and technologies
  - Enabling technology for Homeland Security
  - Relevant for Disaster Recovery
  - IP-compliant aircraft and spacecraft
- Advance communications, navigation, and surveillance (CNS) architectures and system technologies
  - Aviation security technologies
  - Technologies for airport surface, terminal and oceanic areas
- Advance communication device and component specialties;
  - High power electronic and monolithic microwave integrated circuit (MMIC) devices
  - Phased-array antennas, and processing electronics
- Advanced frequency spectrum utilization & signal propagation analyses