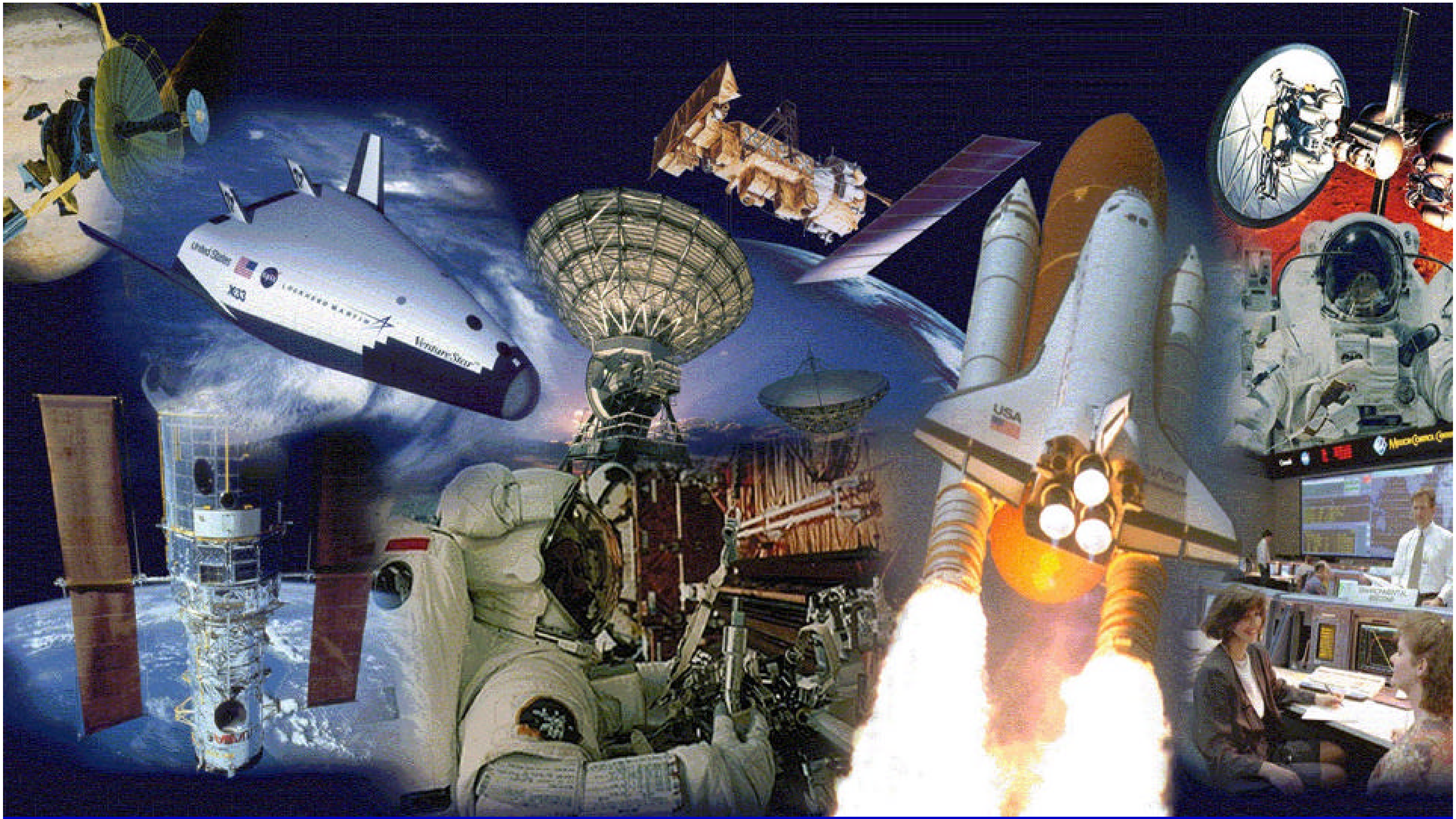


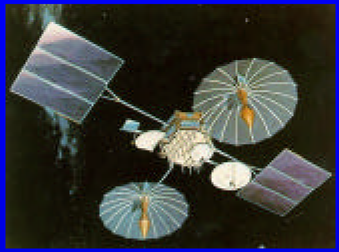
Beacon: a Unified Communications Architecture

January 12, 2001

TE/Pat Duffin

Background

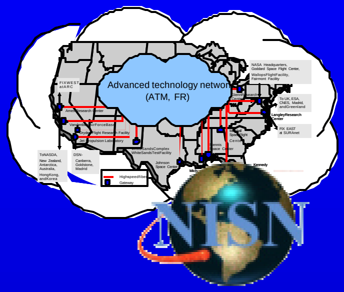
- **Our space communications architecture has evolved into distinct systems**



SN

GN

DSN



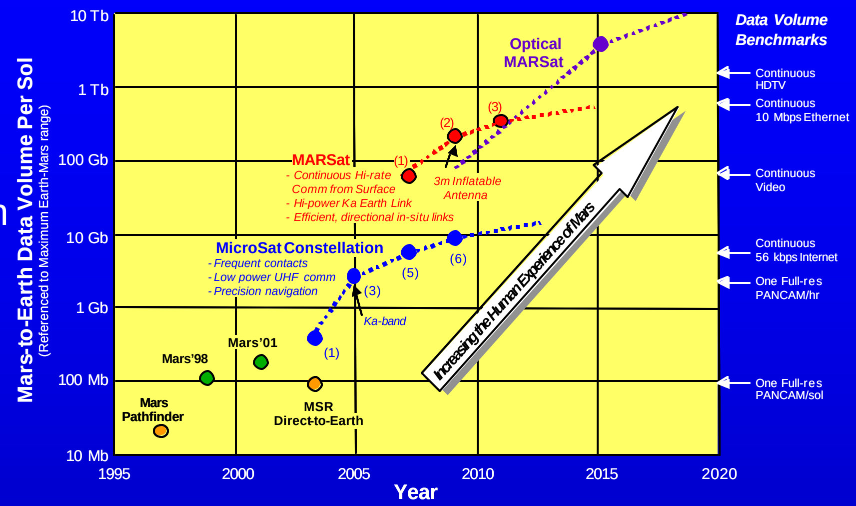
WAN

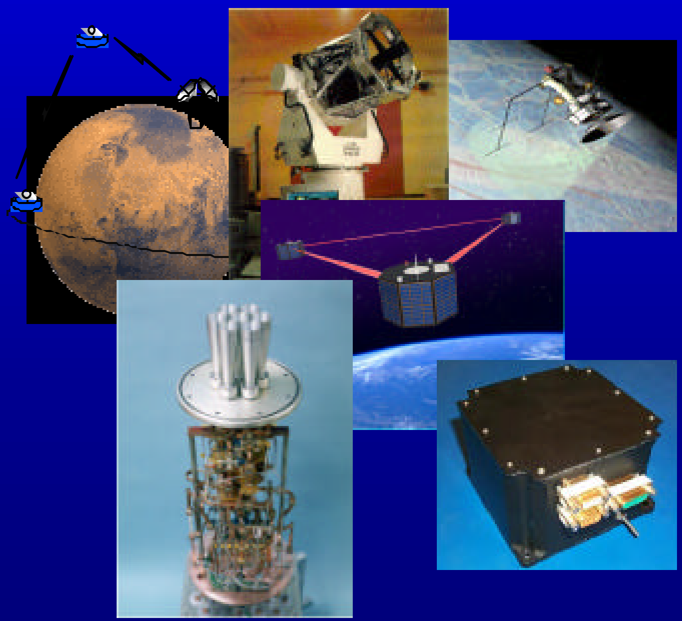
- **Currently, the agency's communication infrastructure is aging with no unified architecture direction**
  - 70 meter replacement study
  - Mars armada capacity needs (3 year aperture development life cycle)
  - TDRS Follow-on (7 to 9 year development life cycle)
  - GN Commercialization Integration
  - Multiple Ka-band initiatives
  - Lack of unified architecture
- **New strategies are emerging for near-Earth and deep space exploration**
  - Gradually build toward sustained robotic with eventual human presence, further and further distant from Earth
  - Concurrent expansion of space communication capability is required
  - Formation flying, constellations, and cooperative missions are requiring a more internet like approach

It is SOMO's role to provide NASA's future communications infrastructure

Drivers For Communication Architecture Unification

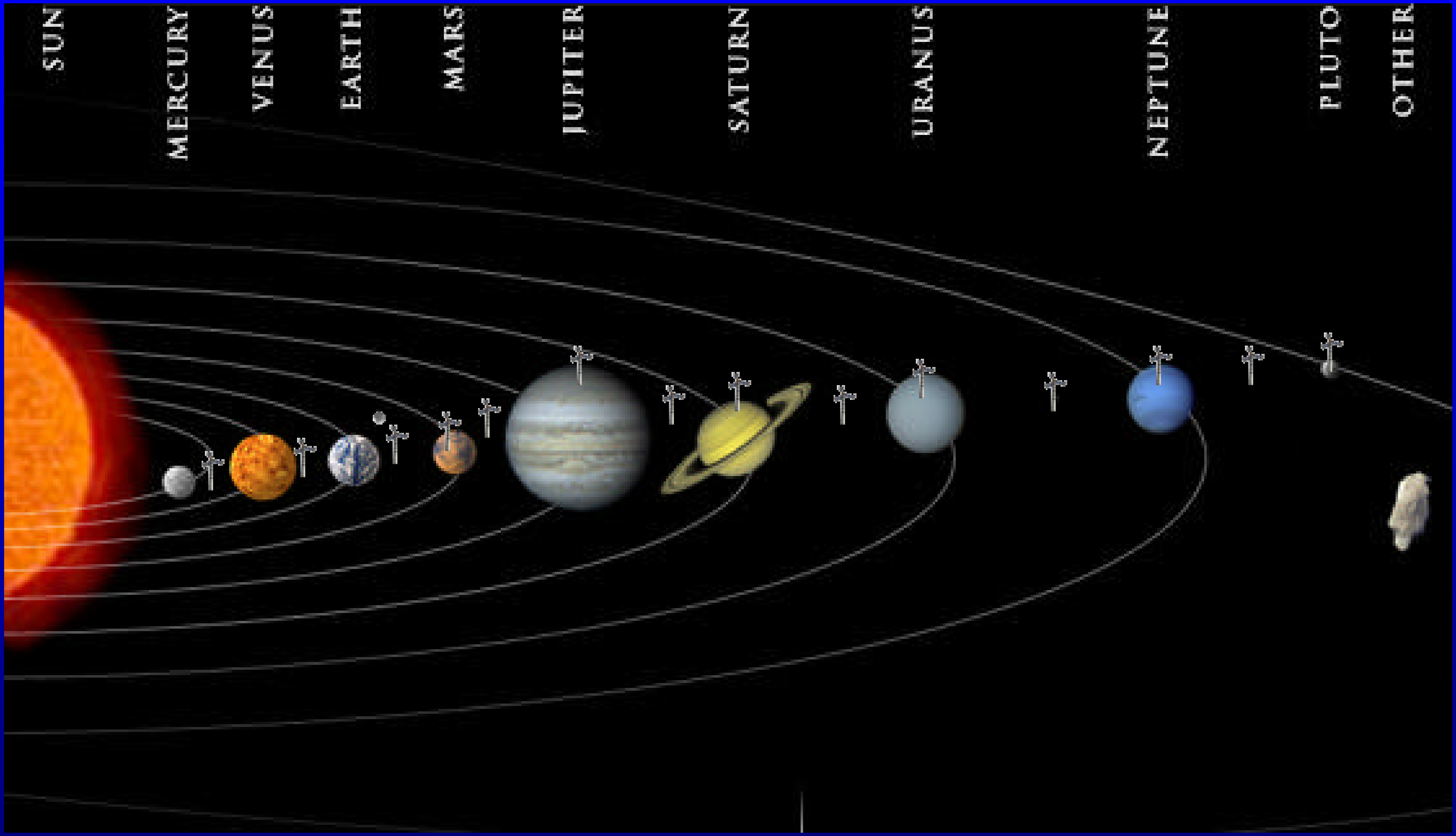
- **More communication capacity is needed**
  - Higher data rate
  - Contention for resources with ability to view high activity regions of space
  - Continuous connectivity for human presence
  - Continued support for legacy missions



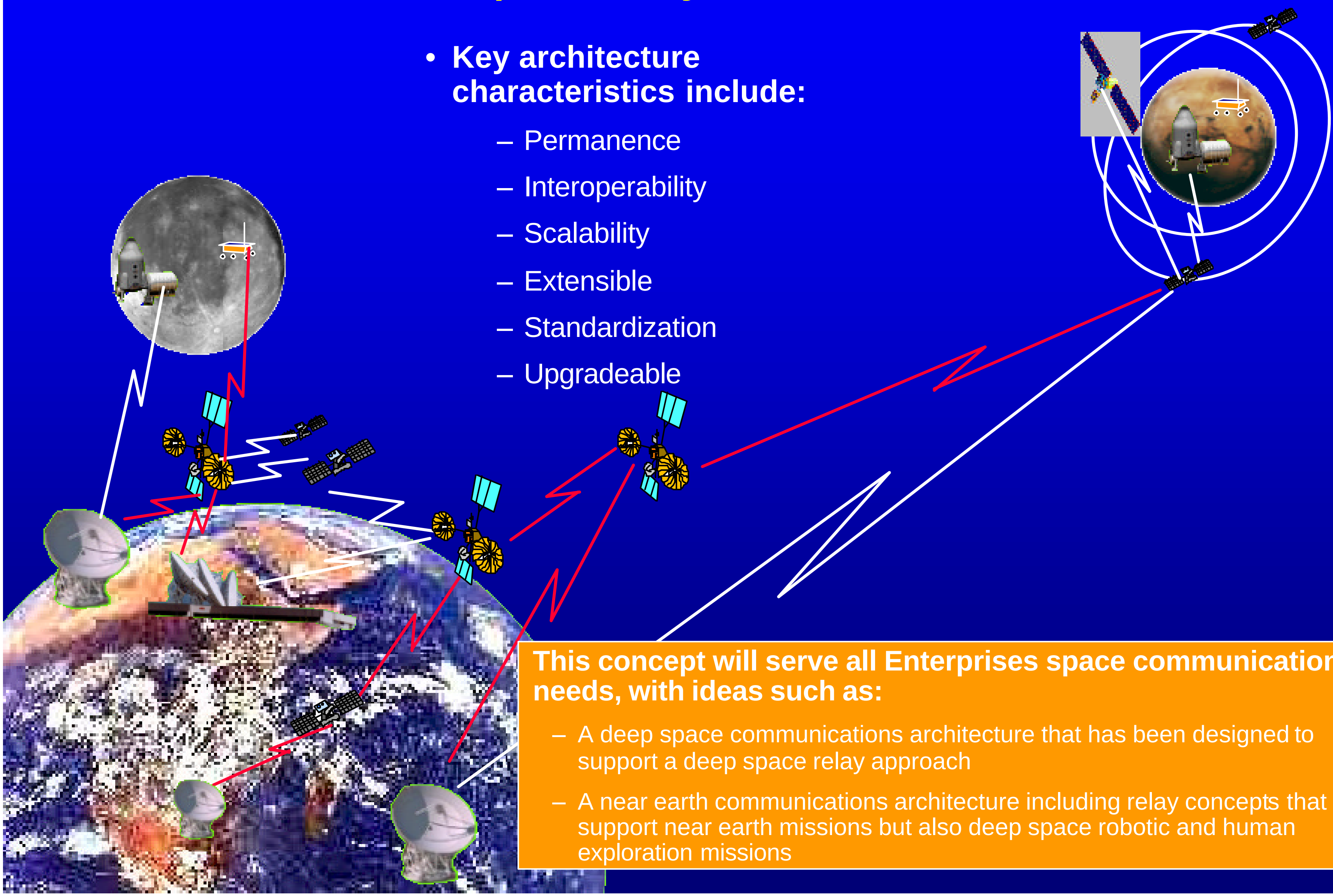


- **New Technology for communication applications are under development**
  - Higher frequencies
  - Optical communication
  - Relay and navigation systems
  - Constellations and Formation Flying
- **Communication needs are currently a bi-product of mission design**
  - Space Science missions envision "tag-along" communication components (S and X-bands)
  - Human Exploration missions envision using communication components "left behind" by the Code S science missions (S and X-bands)
  - Earth Science mission focus on communications which are oriented towards earth orbit services and direct to earth relays

Beacon Vision



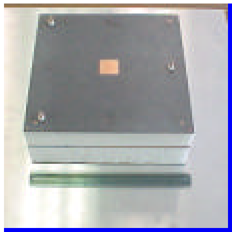
A Unified Communications Architecture Concept – Key Characteristics



- **Key architecture characteristics include:**
  - Permanence
  - Interoperability
  - Scalability
  - Extensible
  - Standardization
  - Upgradeable

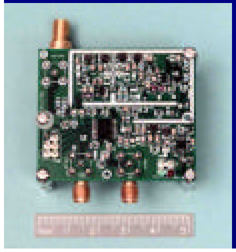
This concept will serve all Enterprises space communications needs, with ideas such as:

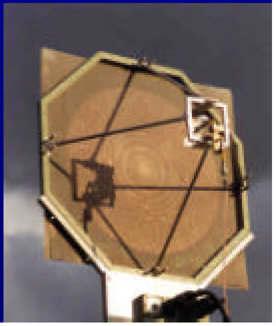
- A deep space communications architecture that has been designed to support a deep space relay approach
- A near earth communications architecture including relay concepts that can support near earth missions but also deep space robotic and human exploration missions



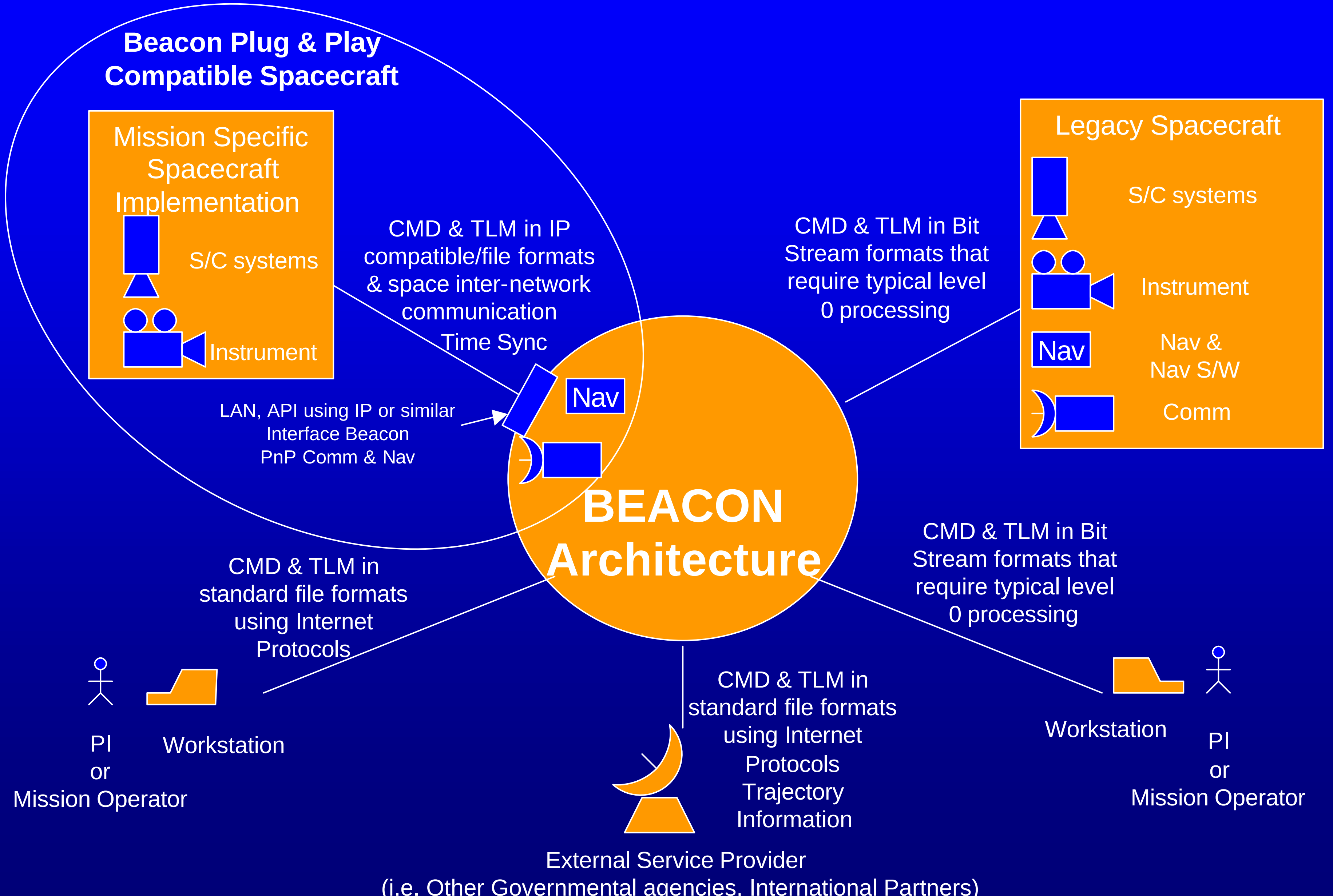
Scope

- Beacon will integrate the Enterprise communication requirements
  - Covers SN, GN, DSN evolution towards a unified space communications architecture that meets future enterprise needs
  - Integrates Space Architecture with evolving ground IT standards
  - Includes Upgrades, Technology, Standards, Commercialization, Spectrum, and Development activities to realize the unified architecture
  - Encompasses robotic and human programs
  - Addresses ELO/ETO, L1, L2, lunar, asteroid, and planetary destinations
  - Incorporates commercial modules as available
- Includes Spacecraft communications and navigation components along with Infrastructure
  - Plug and Play communication and navigation modules
  - Product Line approach for communication modules
    - Inflatable antennas
    - Reconfigurable radio technology
    - Low cost, power, and weight spacecraft communication components
    - Optical communications
    - etc
- Ultimately supports human presence on Moon/Mars

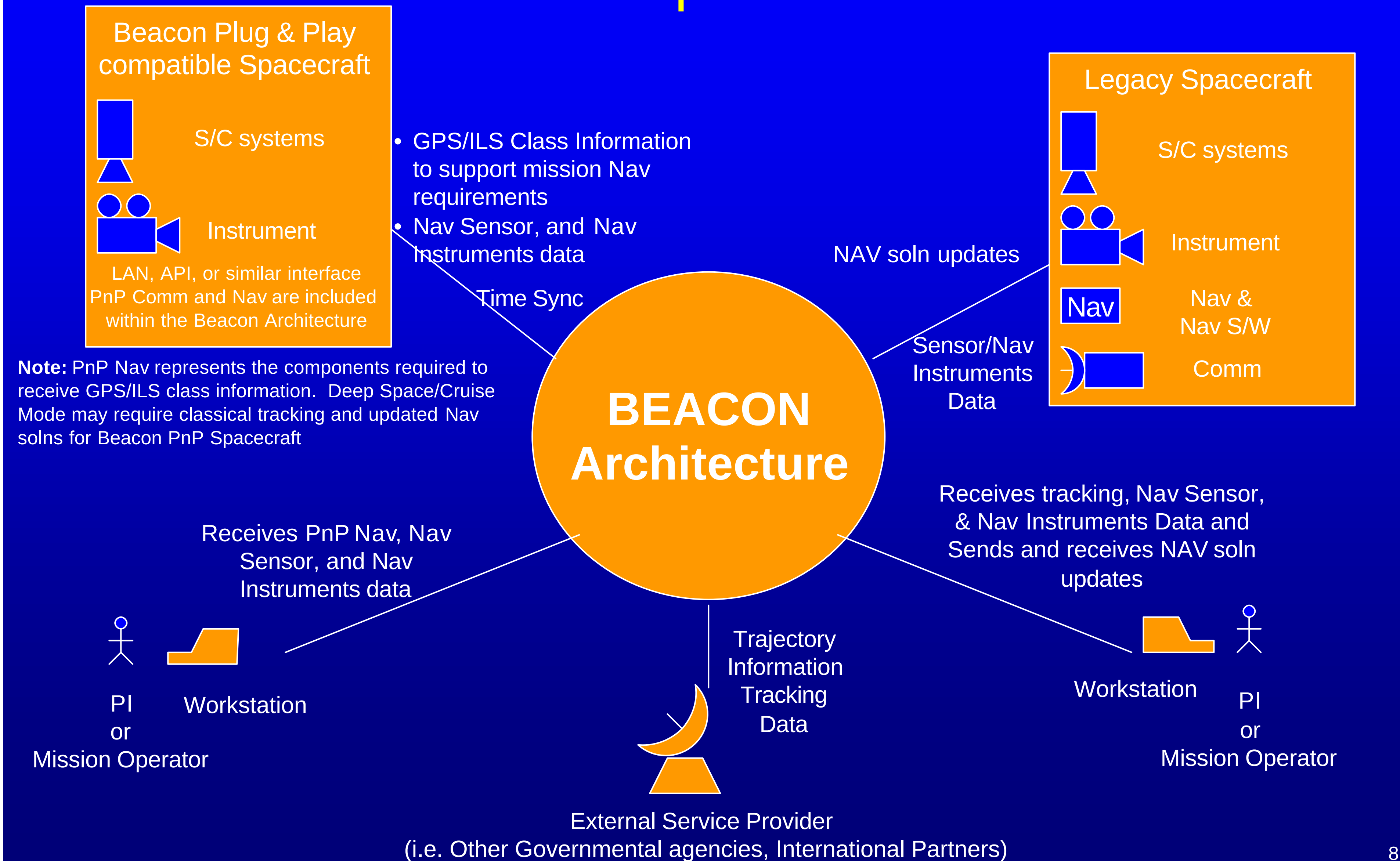




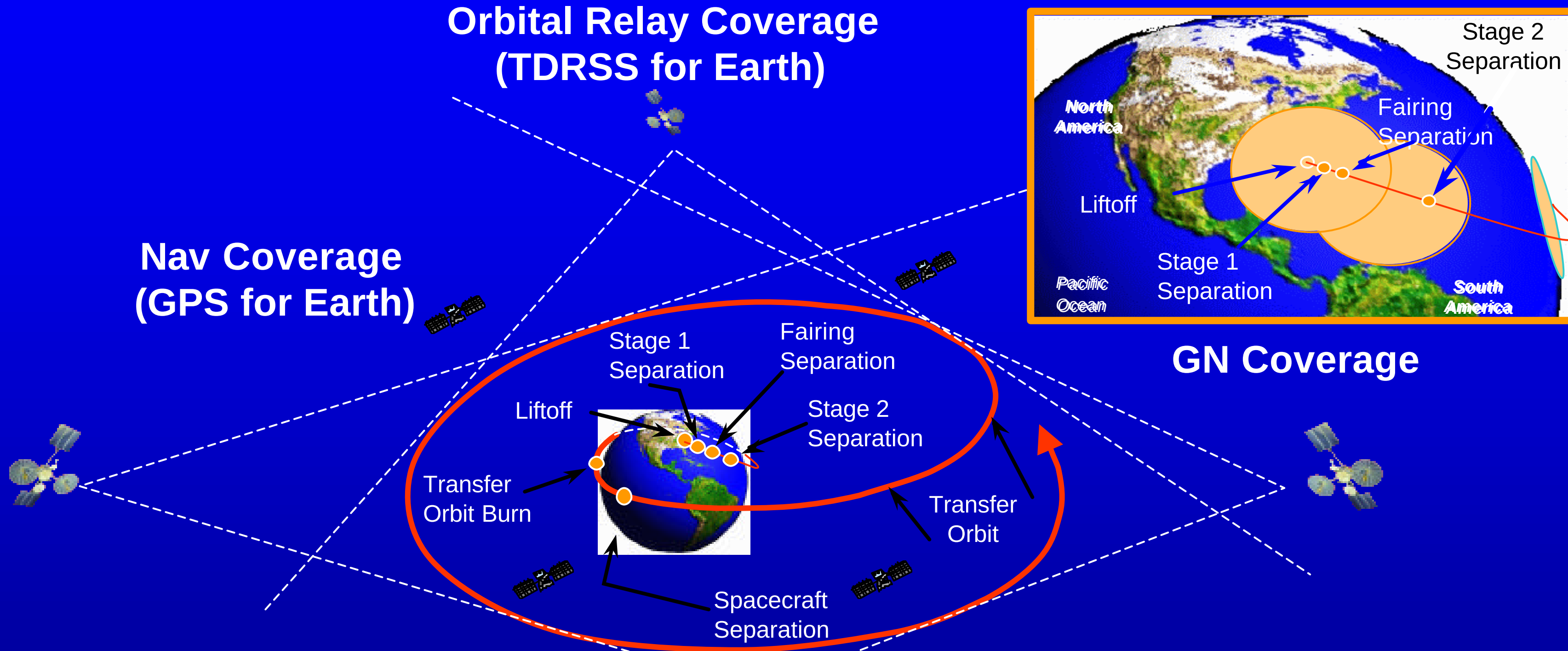
Communications Context Diagram

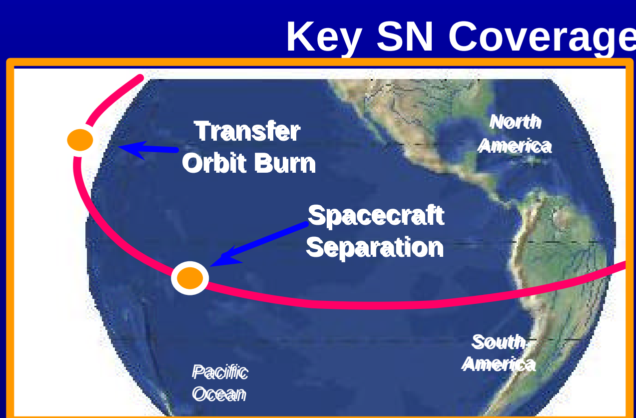


Navigation Context Diagram – NAV Support Option



Support to Launch Vehicles
(Earth Architecture with Migration to Mars)





- Shuttle, X-Vehicles
- Current ELVs:
  - –Titan/Centaur, Atlas/Centaur, Navy P-3, SeaLaunch, Atlas 3
- Future ELVs:
  - –Delta IV (EELV), Atlas V (EELV), Ariane V (ATV missions), H-IIA, Kistler Aerospace (Reusuable)

Beacon Products

- A unified data services communication and navigation architecture
  - Requirements
  - Architecture
  - Ops Concepts
  - Upgrades/Technology requirements
  - Obsolescence Replacement
  - Standards
  - Spectrum
  - Risk Management
- Roadmaps that contain the logical steps for the projects required to implement this vision
- Program Operating Plan and FY Ops Plan Products
  - FY02 Funding Levels are already set – Potential work plan changes
  - Decision Packages to start required near-term activities
  - Follow-on lower level architecture studies
  - Position SOMO to support capital investment proposals

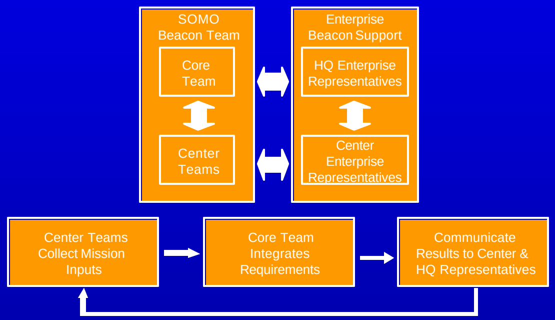
Beacon Status

- A Kick-off meeting was conducted November 8 & 9 at the Johnson Space Center
  - Participation by GRC (5), GSFC (4), JPL (6), JSC(19), KSC (3), MSFC (3)
    - Included JSC Exploration Office and Engineering Directorate support
  - Kick-off meeting addressed the following:
    1. Beacon: A Unified Communications Architecture Vision
    2. Enterprise Future Needs
    3. Potential Architectural Components
    4. Process/Study Team Structure

The kick-off meeting established a unified Agency-Wide Team that is dedicated and contains the skills and experience to develop the Beacon Architecture

Beacon Status/Results

- Enterprise participation and support is key to Beacon success (requested in Joe Rothenberg letter)
  - Code S and M representatives have been provided
- The Beacon Team, with working level Enterprise representatives, developed the Time Phased Agency Communication and Navigation Needs
  - December Team meeting held to review draft needs document
  - Included JSC Exploration Office and Engineering Directorate support



- The Beacon Team progress at the 1/9/01 – 1/12/01 meeting
  - Identified a set of architecture options
  - Established the approach to evaluate the options
  - Carnegie Mellon University supported the effort with their Architecture Analysis expertise (support will continue)
  - Time Phased Agency Needs document ready for Enterprise review
- POP 2001 guidelines will include trade study proposals with industry and academia

Beacon Core Team

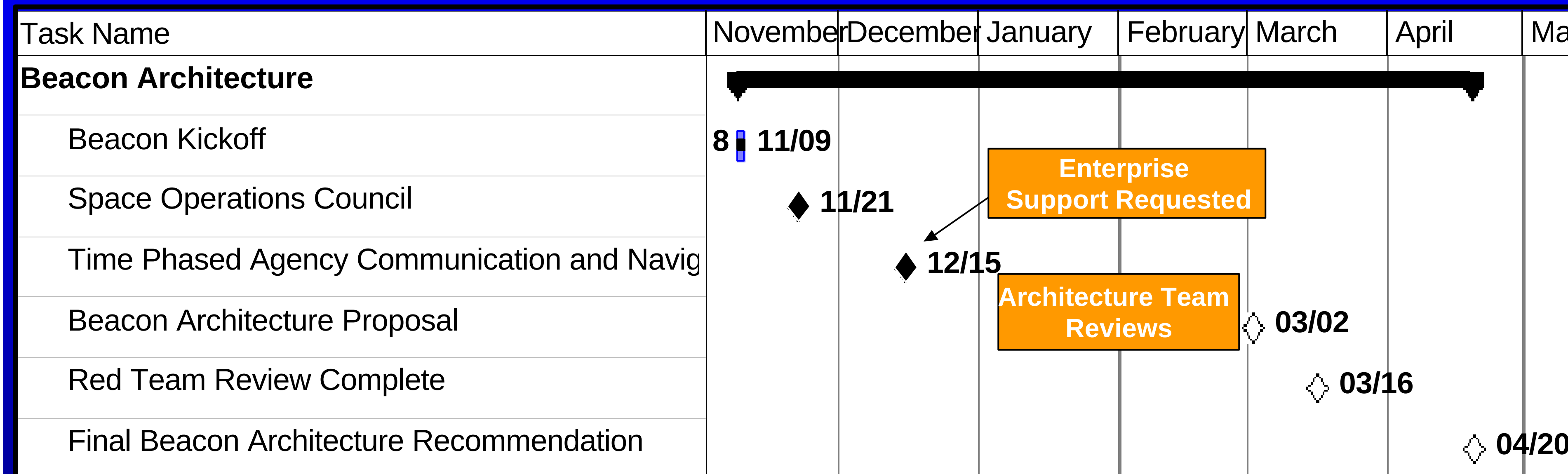
- ARC
  - Ken Freeman
- GRC
  - Sina Javidi
  - Richard Kunath
- GSFC
  - Badri Younes
  - Al Levine
- JPL
  - Jay Breidenthal
  - Peter Shames
- JSC
  - Bill Teasdale
  - Keith Williams
- KSC
  - Chuck Brown
- MSFC
  - Bessie H. Whitaker

Scope of the Beacon Mission Model

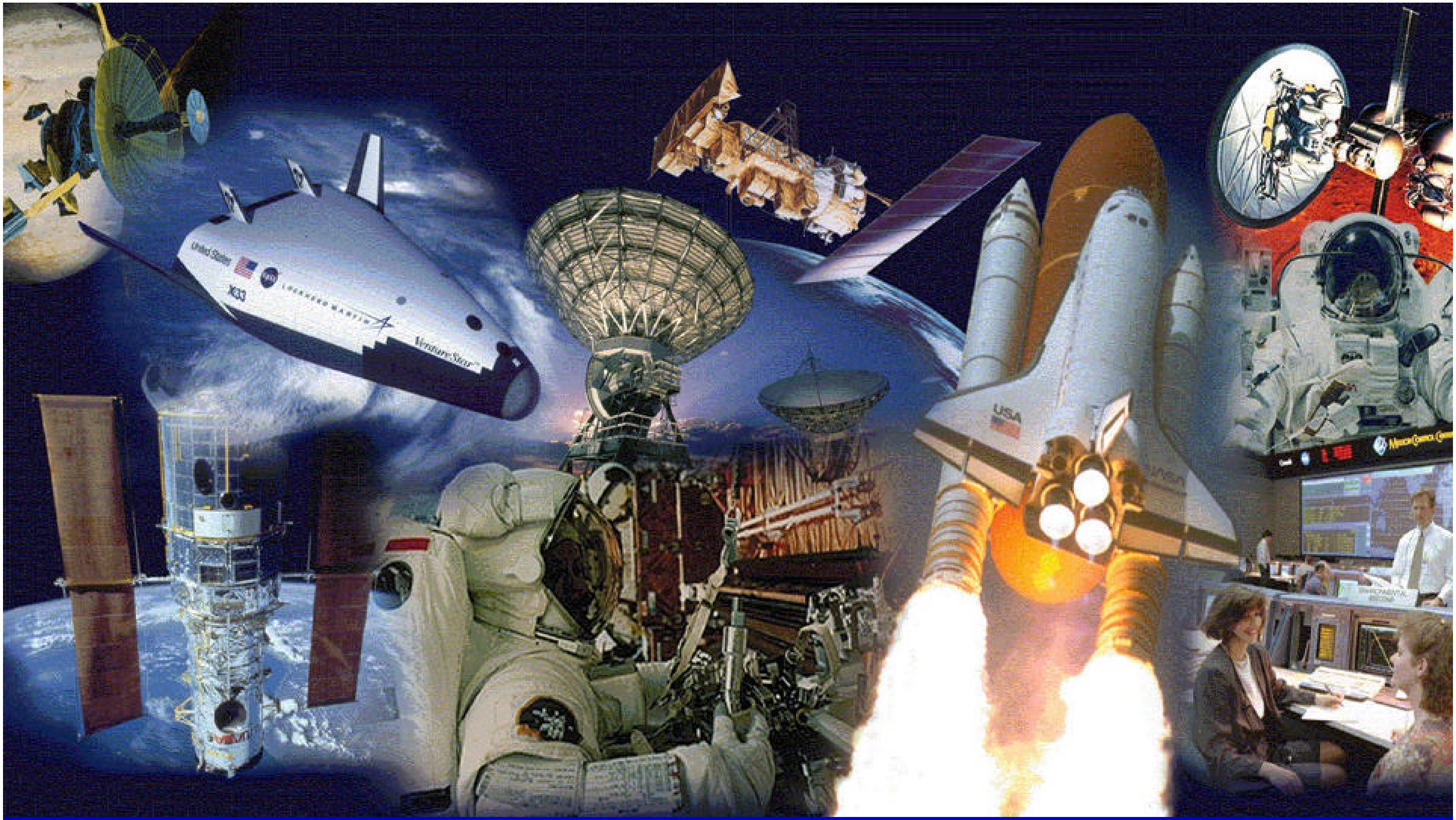
	Number of Missions/Vehicles				
Target Location	2000	2005	2010	2015	2020
LEO		*14/24*	*12/32*	*12/31*	*10/27*
Human LEO	*2/2*	*2/2*	*2/2*	*2/2*	*2/2*
HEO	10	*2/9*	*4/63*	*5/110*	*4/140*
L1	2	*1*	*1*	*1*	*1*
L2	0	0	*4/7*	*2/5*	7
Lunar			1/3		
ETO	0	*3/6*	*3/5*	*3/9*	*2/6*
Mars	2	6	6	6 2/3HEDs	6 2/3 HEDS
Comets & Asteroids	3	5	1	1	1
Near-Sun	0	0	2	*2/5*	*1/4*
Inner Planets	0	1	6	0	0
Outer Planets	3	1	1	3	3
Outer Heliosphere	2	2	2	3	3

Note: Interagency information is not included and will be added at a later date.

Schedule



Task Name
November
December
January
February
March
April
Ma
Beacon Architecture
Beacon Kickoff
8
11/09
Space Operations Council
11/21
Time Phased Agency Communication and Navig
12/15
Beacon Architecture Proposal
03/02
Red Team Review Complete
03/16
Final Beacon Architecture Recommendation
04/20
Enterprise Support Requested
Architecture Team Reviews



Beacon: a Unified Communications Architecture

January 12, 2001

TE/Pat Duffin

Space Internet Beacon Scope

The SOMO Beacon Architecture plans to provide Internet-like functionality in space.

The Beacon architecture team, as a multi-center team with responsibility for establishing this space communications and navigation architecture, will take responsibility for

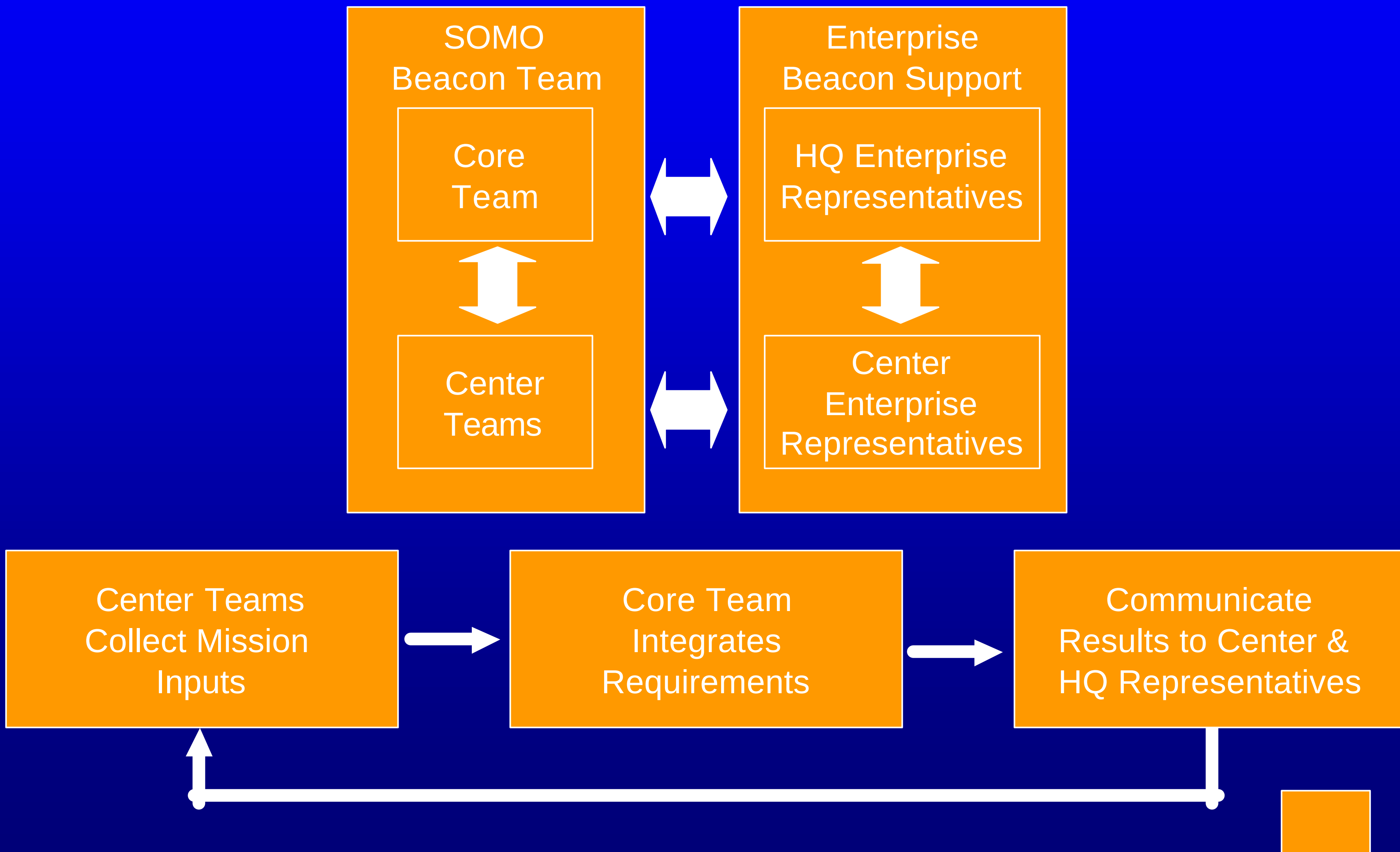
- coordinating with the relevant parties working to define an integrated approach to providing Internet in space functionality.

These parties include:

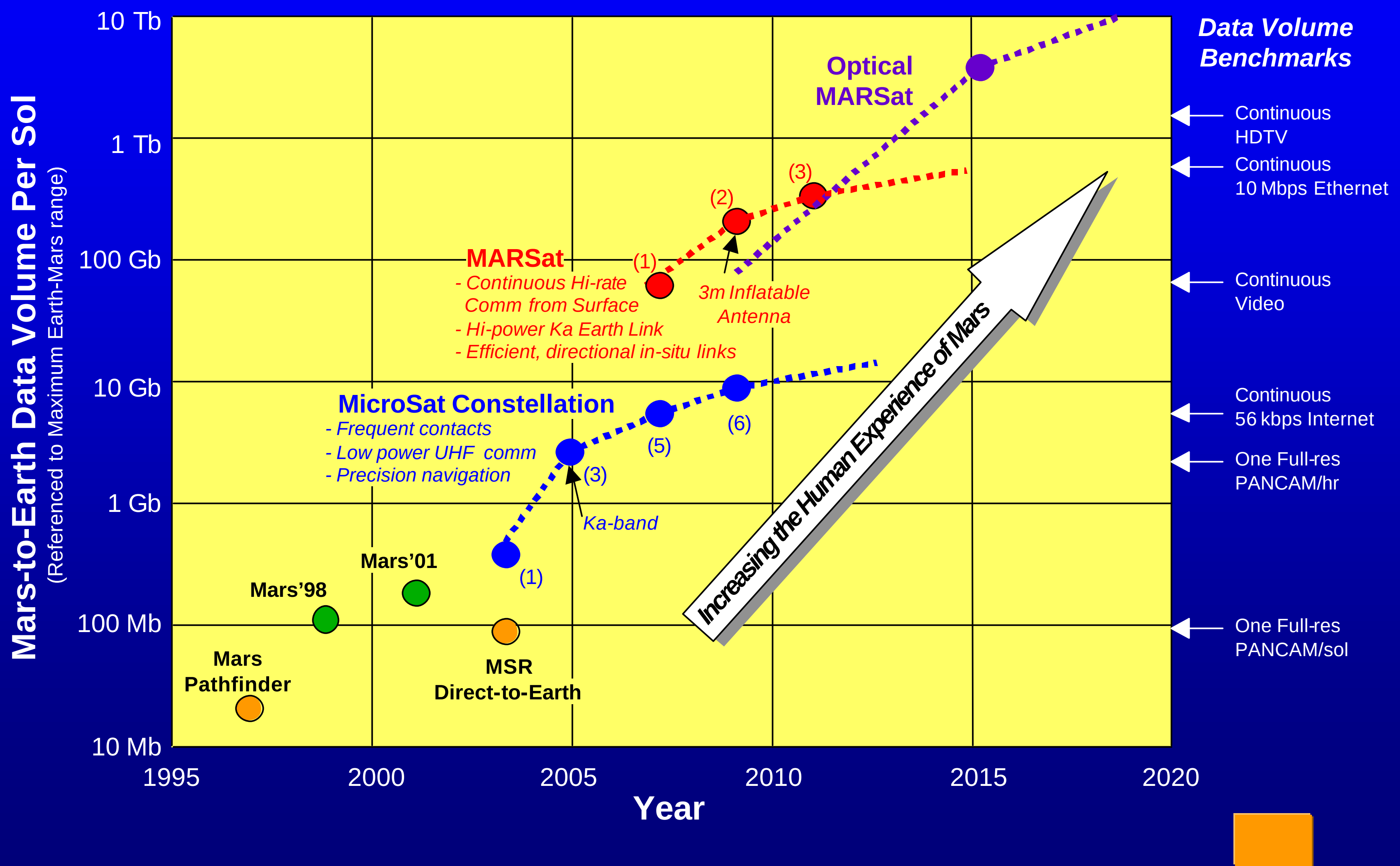
- the Internet Research Task Force (IRTF) research group for Interplanetary Networking (IPNRG),
- groups within the Internet Engineering Task Force (IETF), and
- with research and technology groups at the NASA centers.

The resulting architectural specification is expected to guide future SOMO investments in research, standards, and technology.

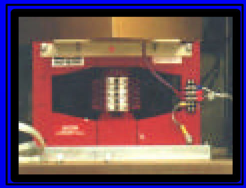
Time Phased Agency Communication and Navigation Needs Development - Organizational Relationships & Process



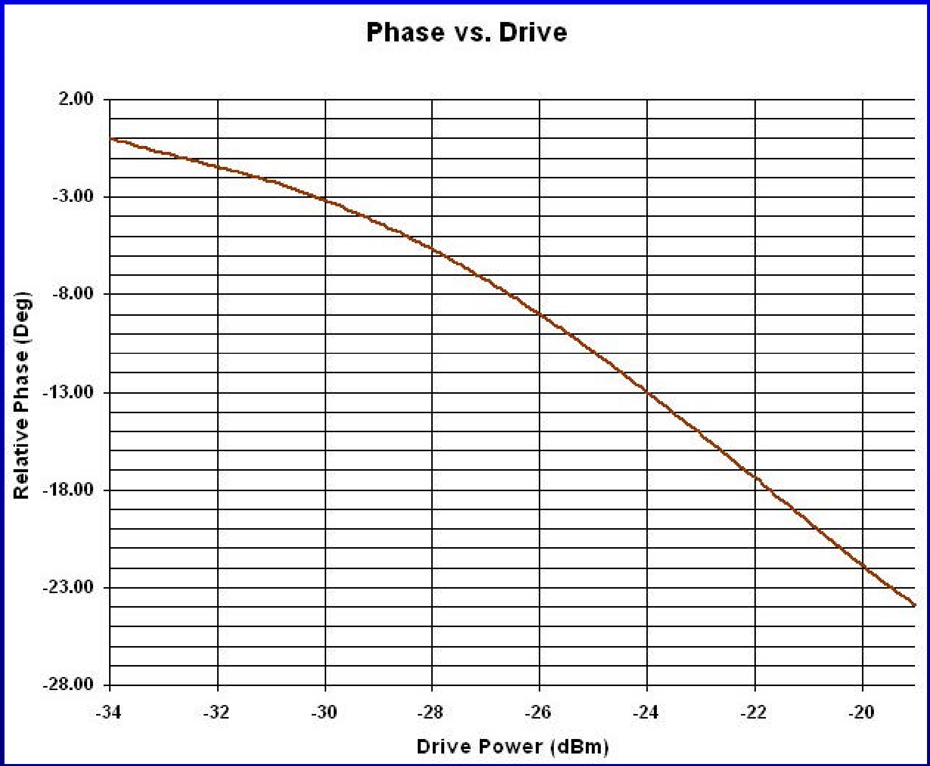
Mars Network Evolving Capability



Single Aperture Uplink Transmitter Studies



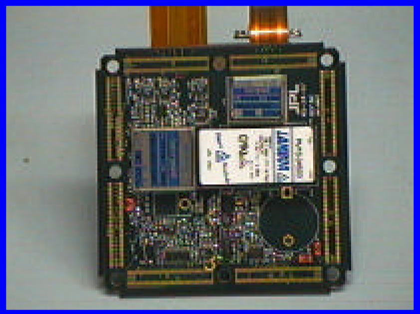
- Characterized non-linearity of DSN 20 kW X-Band Transmitter.
  - Data can be applied to any 5 cavity Klystron Amplifier.
  - Data is being used to develop an input linearizer (procured linearizer)



Navigation Technology Overview

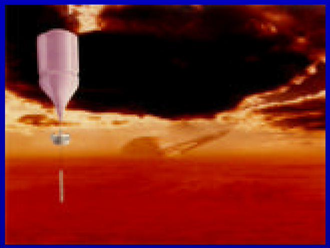
- **This Work Area develops and demonstrates new tracking and navigation technologies needed for planetary exploration.**

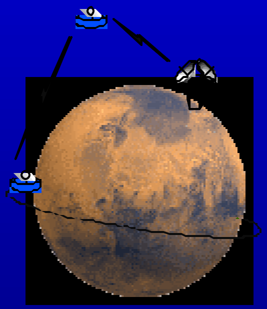
- **Products**
  - New concepts, roadmaps, architectures for tracking/navigation technology development
  - Prototype software and algorithms
  - New tracking sensors, prototypes, and technology testbeds
  - Proof of concept for new navigation approaches in new mission environments
  - System-level feasibility demonstrations
  - Customers/users
    - Projects: ST-3, TPF, ST-5, Mars, Europa, Lisa, comet and asteroid missions
    - Navigation System Services; Next Generation Navigation Software Implementation; MDS



Tracking and Navigation Sensors

Small-Body Navigation





Autonomous, Integrated GN&C: Cruise, Aerocapture, Proximity Link, Precision Landing, In Situ Mission Phases

Wind Effects on Array Feed Compensation System (AFCS) Combining/Tracking Performance

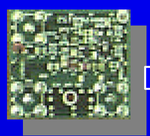
- Re-examined the AFCS data taken in Jan-Feb, 1999 at DSS-14, and devised techniques for locating regions of wind-induced antenna defocusing and mispointing in the recorded data
- Selected “good” Deep Space1 Ka-band tracks for detailed analysis & obtained archived weather data for DSS-14 and incorporated it into AFCS data-base
- Three candidate power-measurement techniques were examined:
  - Spectral analysis of signal power in each AFCS channel
  - Cross-correlation of signal power between central and outer channels
  - Expansion of array signal power into “physically meaningful” coefficients
- The “Coefficients” technique was selected as the most promising rapid-analysis tool.

7 Element Array Feed with 7 Ka-band Low Noise HEMT Amplifiers

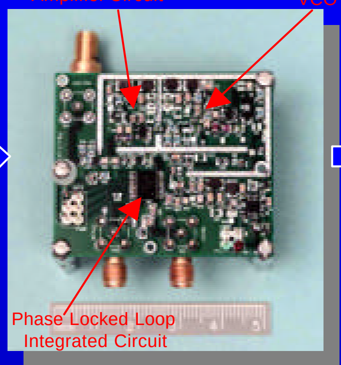
V. Vilnrotter, E. Noorbakhsh, R. Mukai

Micropower Transceiver

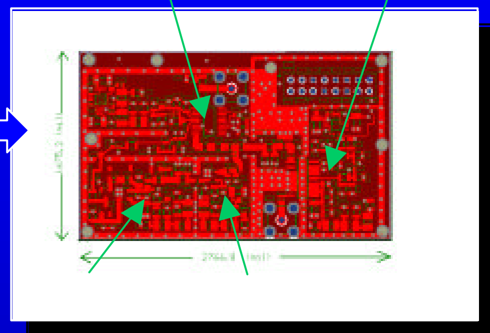
Transmitter Prototype Development: Evolution towards Microtransceiver design goals



UHF GaAs Amplifier Voltage Controlled Oscillator Circuit (25.4 x 28.2 mm)



UHF Programmable Synthesizer Circuit (43.4 x 50.8 mm, 2 layer)



UHF Programmable Synthesizer and Complex Modulator Circuit (70.4 x 42.0 mm, 4 layer)

FY01: Integrated RF and Digital PC Board

FY00 RF Subsystem Development

Significant MCAS1 Modulator Design Re-use

Xilinx 4062 FPGA Evaluation Board (Radiation tolerant version exists)

Transmit data formatting and modulation (FEC, suppressed/residual carrier, Manchester, etc.)

UHF Synthesizer Control (Initialization and Channel Selection)

Designs developed in Verilog and schematic capture

FY00 Digital Circuit Design Development

Hardware Design Methodology

- **RF and analog components selected for radiation tolerance (GaAs process and screened parts)**
- **Utilize re-programmable digital electronics to allow future tailoring of hardware to specific mission needs**
- **Develop RF and digital subsystems in parallel during FY00 and merge in FY01**

N. Lay, P. Estabrook

Autonomous Spacecraft Navigation Receiver

- **Upgraded orbit determination models and estimation capabilities of RTG (Real-Time GIPSY) to better support in-orbit operation**
  - **Previous uses had been primarily in near-Earth applications (ground and airborne tests)**
- **Implemented RTG on PowerPC (used in GPS receivers and in future transceivers)**
- **Implemented onboard maneuver software under ROGUE/GPS operating system**
- **Worked with NASA HQ to plan for GPS flight demos in 2001/2002 with low-Earth constellation consisting of SAC-C, Terra, Landsat-7, and EO-1**

STRV-1C microGPS Experiment

- Completed integration and test at STRV-1C spacecraft
  - Collaborative effort with U.S. BMDO and U.K. Defence Evaluation and Research Agency (DERA)
  - Goal is to demonstrate in space flight dual-frequency microGPS technology needed for nano-satellites
  - Currently awaiting Oct 31 2000 STRV-1C launch
- Ported observable extraction code and RTG to operational platform (G4 Linux)
- Verified that original SNOE microGPS instrument is still tracking and functioning properly after 2-1/2 years in space

Optical Communication

Work Area Overview of Current Activities

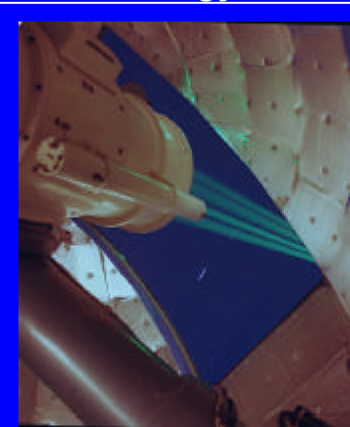
Ground station development for optical channel

1-m telescope system for Optical Communications Telescope Laboratory (OCTL)

Atmospheric Visibility Monitoring (AVM)

System level demos for technology validation

Optical Comm Demonstrator (OCD) performance validation



Multi-beam beacon development

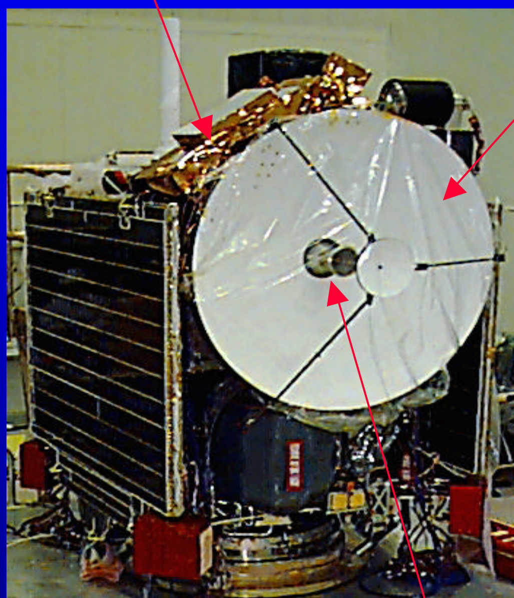
Systems Analysis & Development

- **Optoelectronic detector receiver development**
  - *Develop optical detectors and low noise electronics for receiving weak communications signals transmitted from space*
- **Large Aperture Studies**
  - *Determine requirements, and cost of photon bucket required for collecting faint optical signals transmitted from space*
- **Optical Channel Capacity Studies**
  - *Establish optical channel capacity, its parametric sensitivity*
- **Advanced Concept Studies**
  - *explore concepts which allow the achievement of shot noise limited performance for optical signal reception*
- **Link Analysis tool development**
  - *Helps mission and systems designers evaluate link characteristics*

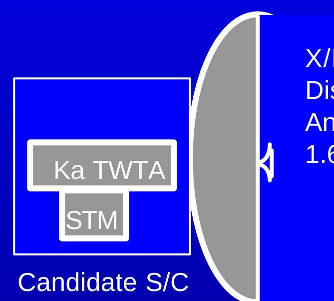
Mars Global Surveyor Ka-Band Example Technology Overview (con't)

KaBLE is inside
TWTA Enclosuer

High Gain
Antenna
1.5m



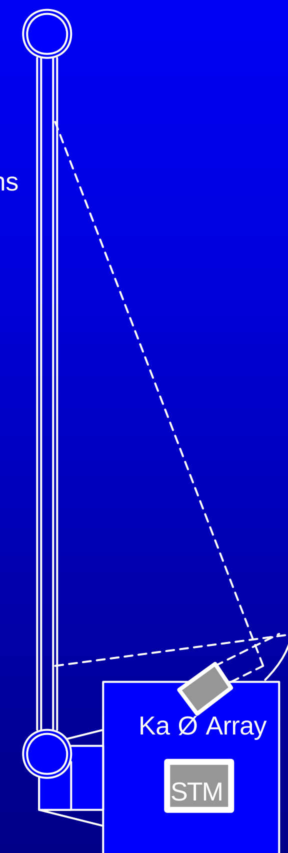
Dual Frequency
X/Ka-Band
Feed



X/Ka-Band
Displaced Axis
Antenna
1.6m

Candidate S/C

X/Ka-Band
Inflatable Lens
Antenna
3m



Candidate S/C

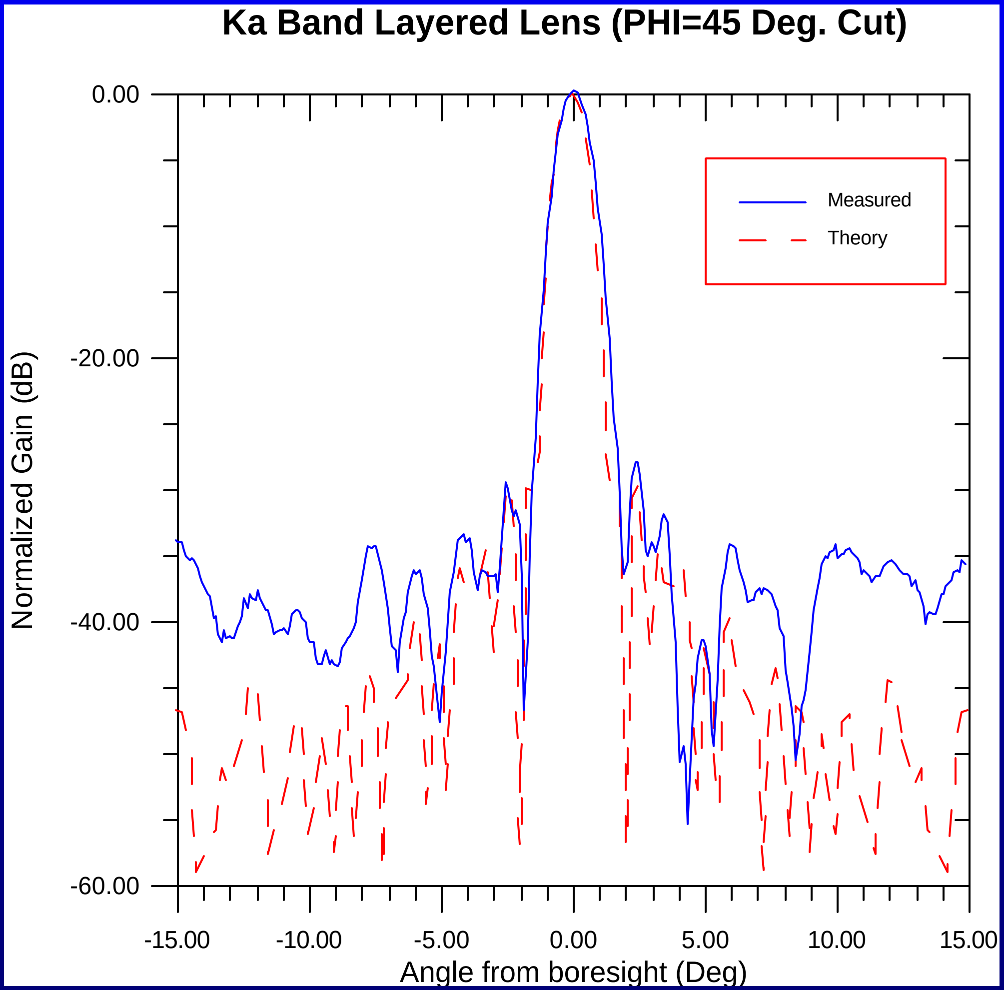
Mars Global Surveyor Example

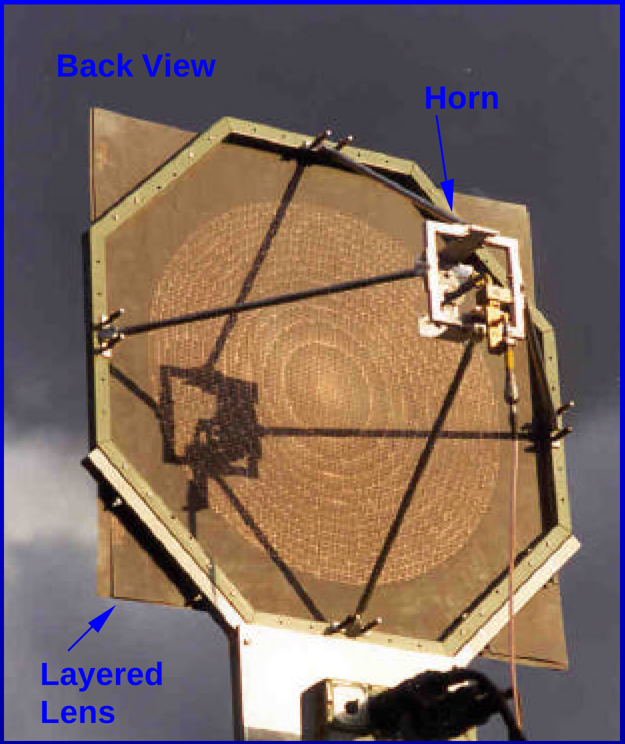
System #1

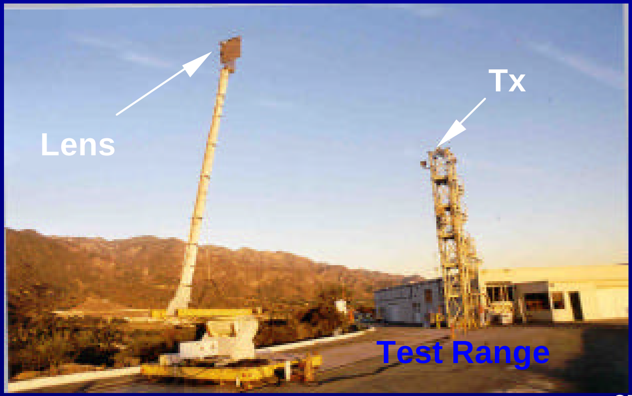
System #2

Ka-Band Inflatable Lens Antenna

- Ka-Band Inflatable Lens Antenna (con't)
  - Measured performance at 32.050 GHz, 610mm Dia (F/D = 0.5), Gain = 41.5dBi, Efficiency = 34%



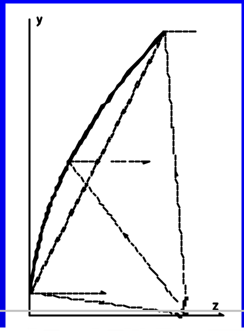




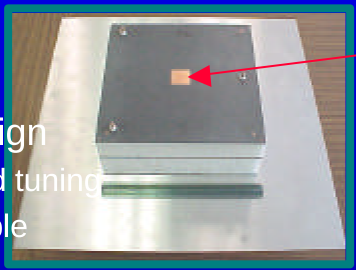
L. Amaro, A. Prata

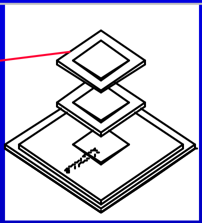
Phased Array Power Amplifier Feed

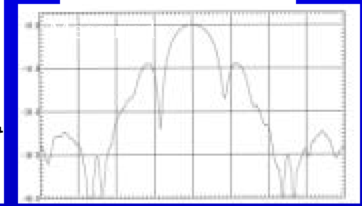
- Phased Array Power Amplifier Feed (con't)
  - Determined offset dual reflector best for inflatable antennas
    - Completed one case of analysis for Cassegrain configuration
    - Adapted software to flat membrane analysis
    - Initiated evaluation of Gregorian system as alternative



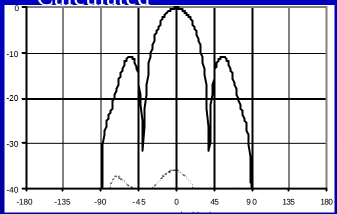
  - S-Band Radiating Patch
    - Completed triple-stacked patch design
      - S-Band used to simplify handling and tuning
      - Completed initial tests with predictable results





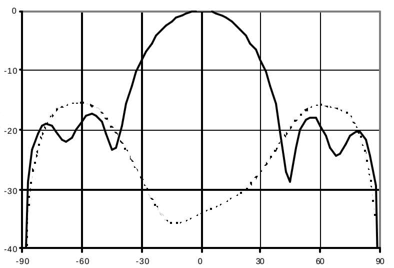


Calculated



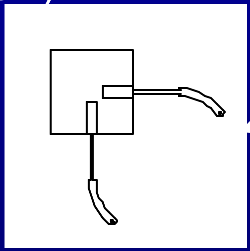
Bandwidth = 1.2%
Gain = 9dBil
Cross-pol < -25dB

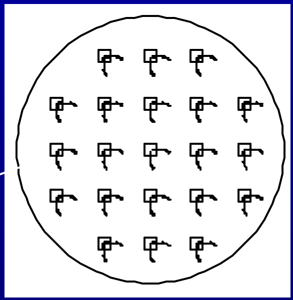
  - Ka-Band Radiating Patch
    - Calculated Ka performance, scaled from S- Band (12.5:1)



Calculations

Bandwidth = 1.2%
Gain = 12dBc
Cross-pol = -20dB (avg)

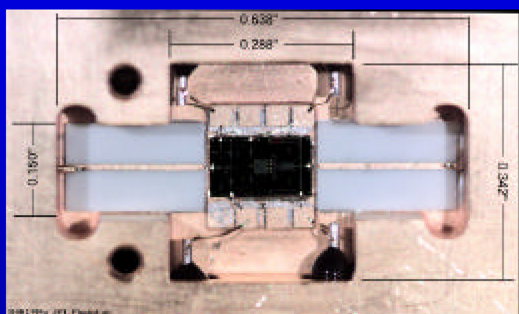




21-element array

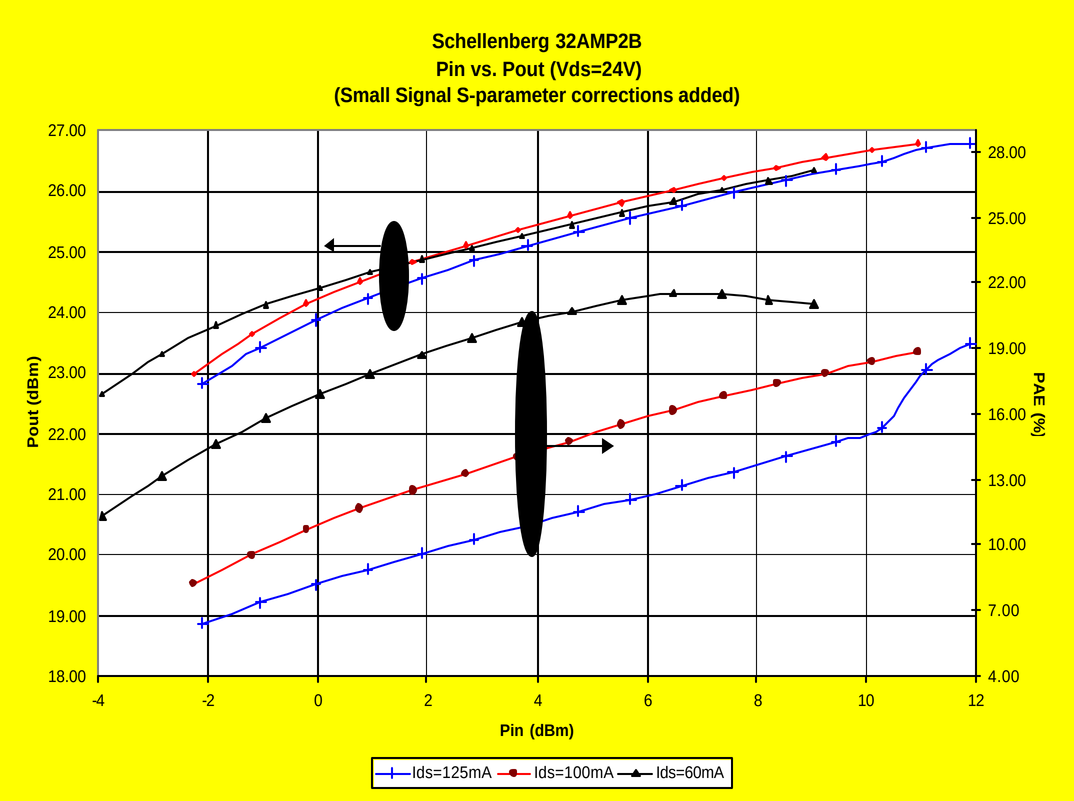
Phased Array Power Amplifier Feed MMIC

- Ka-Band Phased Array Power Amplifier Feed (con't)
  - Selected Schellenburg Associates 32AMP2 Ka-Band Driver MMIC as the output power amplifier
    - Completed testing and electrical characterization of competing devices



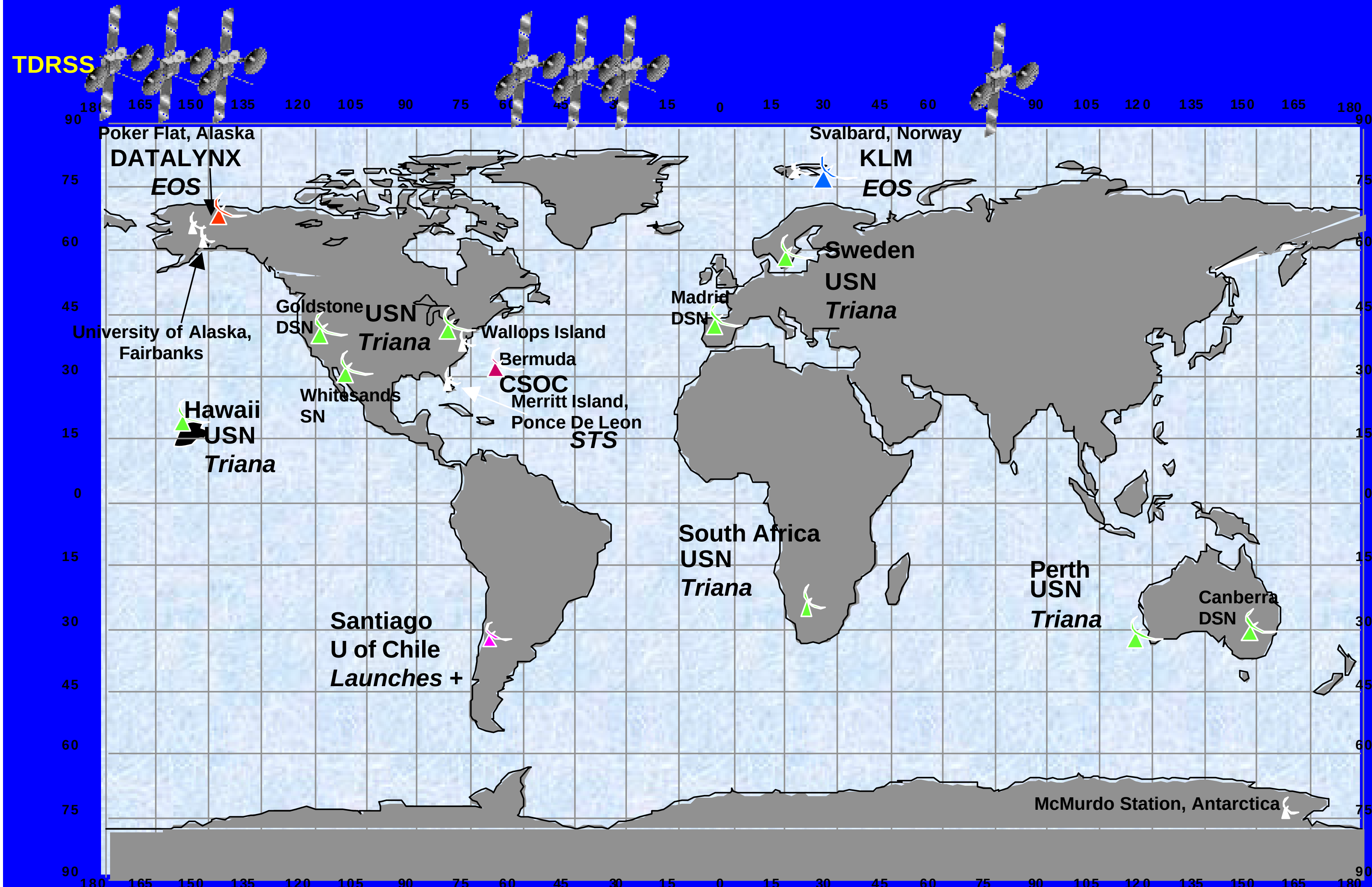
Manufacturer's PN/Data Sheet Specs	Power (dBm)	Gain (dB)	Efficiency (%)
Sanders SGPA07016-CC	32.5	10	15
Sanders SGDA07017-CC	26	13	16
Alpha AA035P2-00	26	12	19
Schellenberg SA-32AMP2	27	19	25

(Shaded devices selected for test and evaluation)



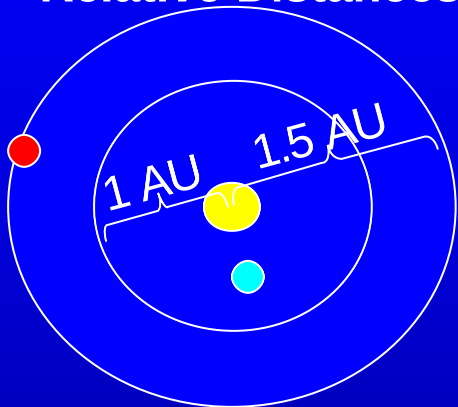
Measured data from Schellenberg 32AMP2 device

Current SOMO Communication & Navigation Architecture

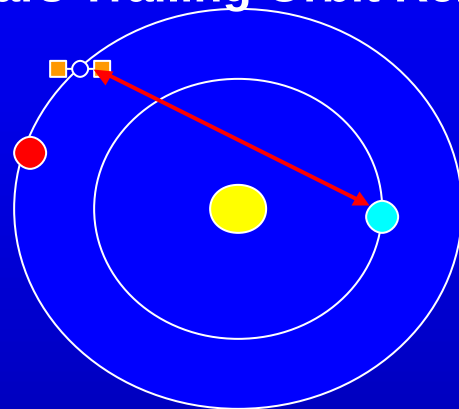


Mars Relay Options

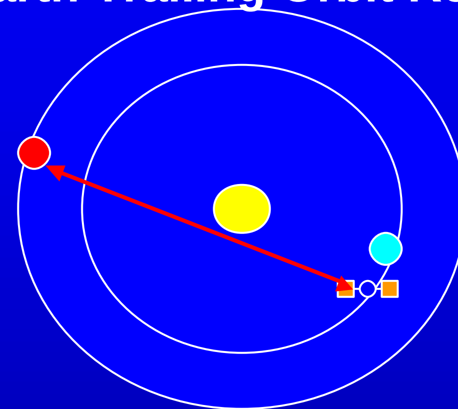
Relative Distances



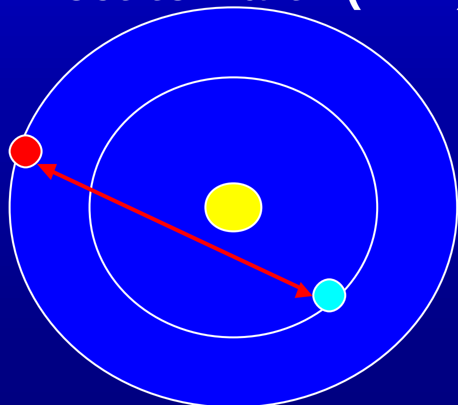
Mars Trailing Orbit Relay



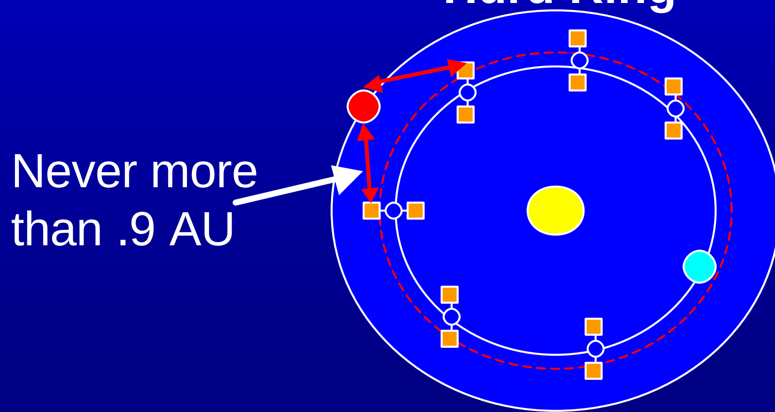
Earth Trailing Orbit Relay



Direct-to-Earth (DTE)



Hurd Ring



Note: DTE has 2 week LOS during time when Human missions arrivals

Note: all options reflect a constellation around Mars

Service Mgt & Accountability Context Diagram