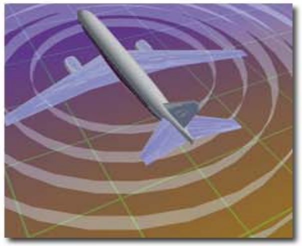
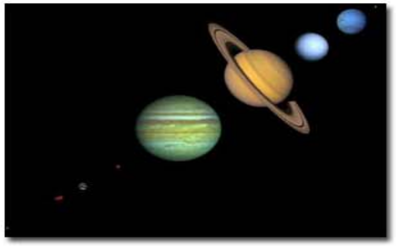
Overview of NASA Networking and IT Research Priorities and Programs





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Agenda

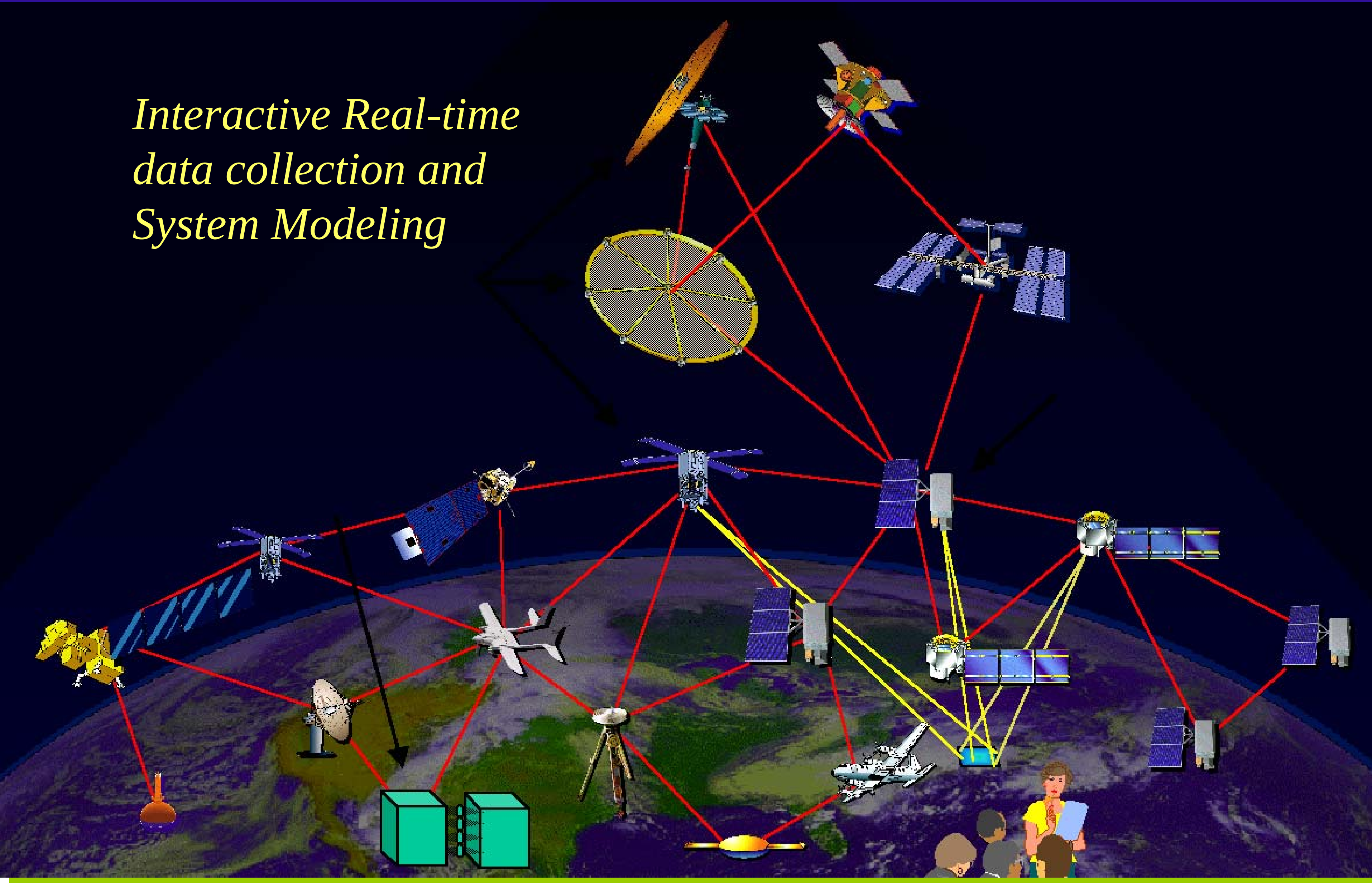
- Earth Science
- Space Science
- Aerospace Technologies
- Human Exploration and Development of Space
- Technologies
- Wide Area Networks
- NASA Programs

Earth Science

- **Goal**
  - Develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations.

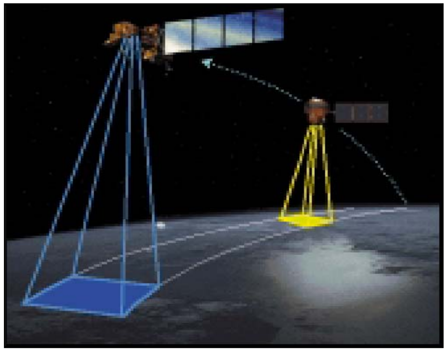
- **Relevant mission requirements**
  - Increased computational capability aboard observational platforms and instruments
  - Communication infrastructure to enable secured and efficient incorporation of observational data into Earth system models
  - Support mining large heterogeneous databases with widely-diverse data
  - High resolution multi-disciplinary Earth system modeling and simulation
  - Integrated assimilation of observational data and simulation results
  - Dissemination of scientific data and simulation results to community at large

Sensor Web Example
- Real-time Earth System Modeling



Earth Science Communications Needs

- Inter-spacecraft links (Gbps class) for in-space distributed processing and relaying of science data from autonomous formations and sensorwebs.
- Distributed architectures and communications for formations that act as a single mission spacecraft for coordinated observations or in situ measurements, or act as a single virtual instrument.
- Integrated communication and navigation to enable formation flying of small scientific spacecraft/aircraft.
- Near real-time delivery of data and information products to customers requires on-demand throughput.
- On-board data fusion to allow transmission of tailored information products directly to a user's desktop.
- **Technologies**
  - Communications for distributing control, relative position, and timing between multiple spacecraft formations
  - Interoperable Air/Space to Ground Communications
  - Adaptive networking architectures to provide seamless end-to-end data delivery

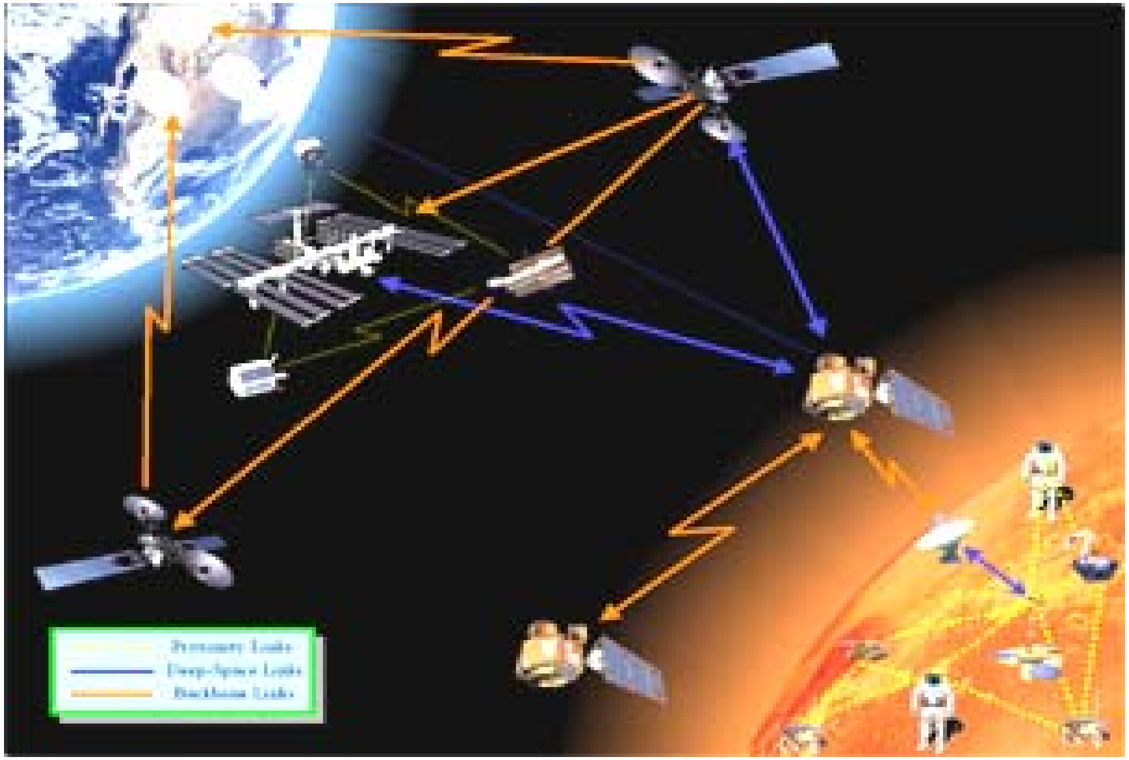


Space Science

- **Goal: To Discover…**
  - how the universe began and evolved
  - how we got here
  - where we are going
  - whether we are alone
- **Mission requirements**
  - Support unique spacecraft and sensors on remote scientific explorations
  - Transmission, archival, processing, analysis and mining deep space data
  - Modeling galactic processes and planetary climate
  - Dissemination of scientific data and simulation results to community at large

Autonomous Space Exploration

- **Autonomous Spacecraft & Rover Control**

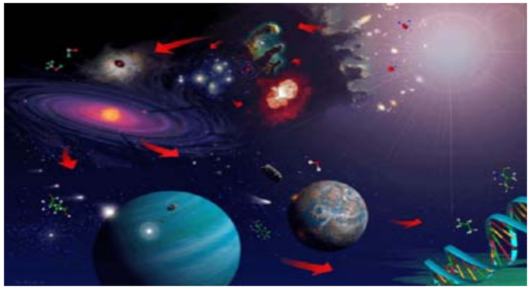


- **Context-based Communications Response**

Space Science Communications Needs

- **Very high data rate communications for missions that require platforms at the Lagrangian points.**
- **Distributed architectures and communications for formations that act as a single mission spacecraft for coordinated observations or in situ measurements, or act as a single virtual instrument.**
- **Establish high bandwidth data return capabilities to support the "seek, in situ, sample" approach to be implemented in the planetary program.**
- **Inter-spacecraft links (Gbps class) for in-space distributed processing and relaying of science data from autonomous formations and sensorwebs**

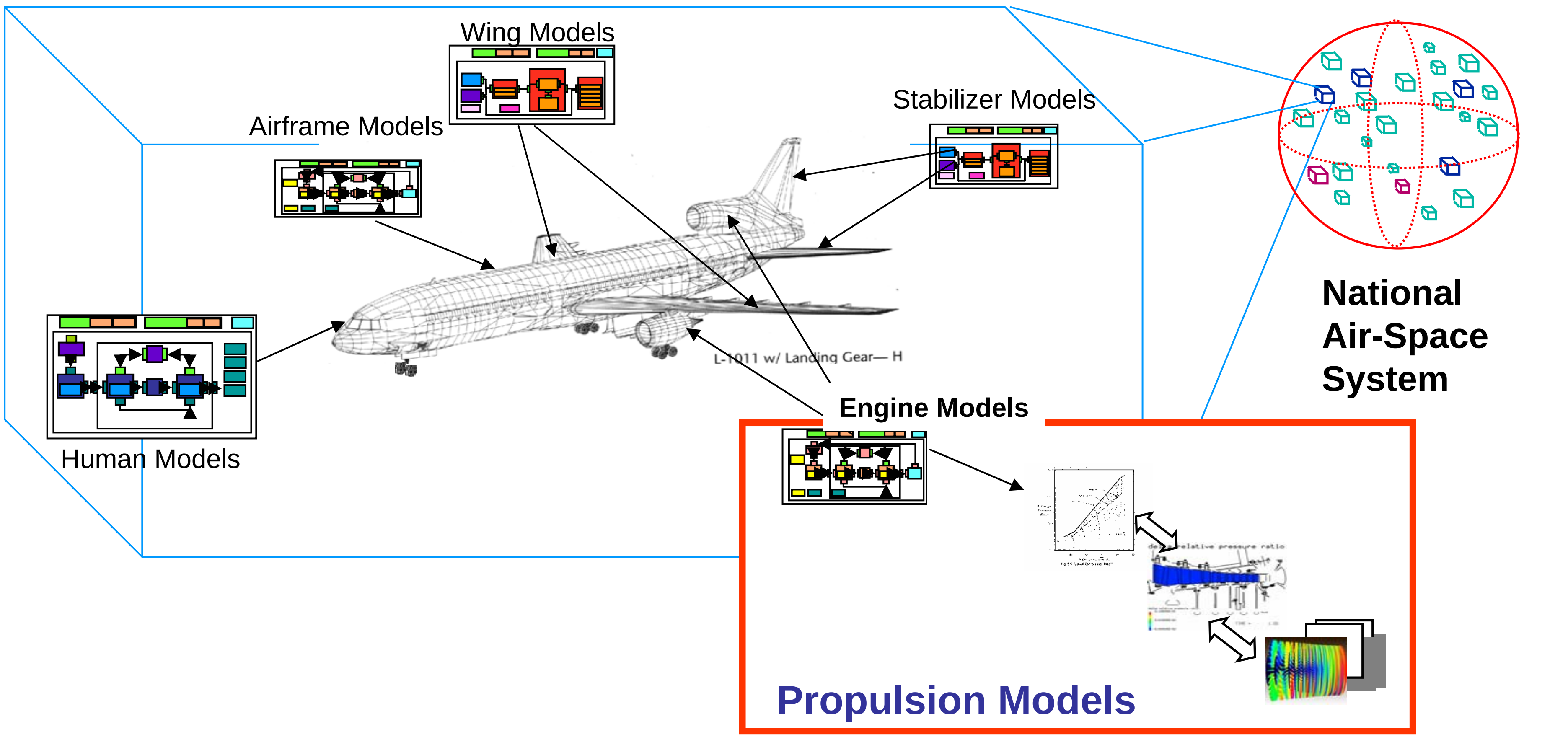
- **Technologies**
  - Optical Communications
  - Adaptive Networking, based on critical events or information
  - Interoperable Air/Space to Ground Communications



Aerospace Technology

- **Goals**
  - Revolutionize aviation
  - Advance space transportation
  - Pioneer technology innovation
  - Commercialize technology
- **Relevant mission requirements**
  - Collaborative design
  - Multi-disciplinary analysis
  - Novel component technology
  - Large scale modeling of distributed real-time system

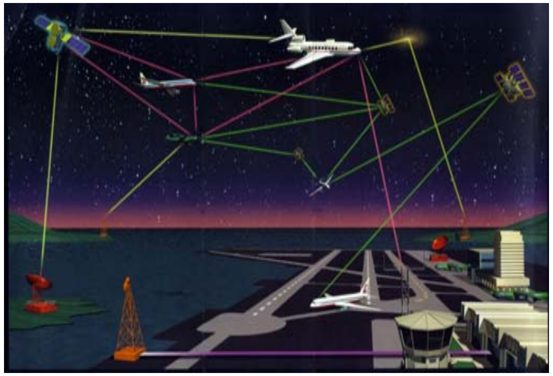
Multidisciplinary Problem Example
Aviation Safety



A wing CFD model and a turbo-machine model are combined as one of the first steps toward whole aircraft simulation in operational environments.

Aerospace Technology Communications Needs

- Collaborative use of many compute and data resources, including geographically dispersed supercomputers and large-scale data storage systems
- Continuous presence and coverage for high rate data delivery throughout the National Airspace to the users
- Technologies
  - Design tools for a distributed emulation environment
  - Interoperable Air/Space to Ground Communications
    - Long Delay Tolerant Protocols
  - Data Grids
    - middleware that provide uniform, collaborative access to distributed computing, data, instrument, and communication resources

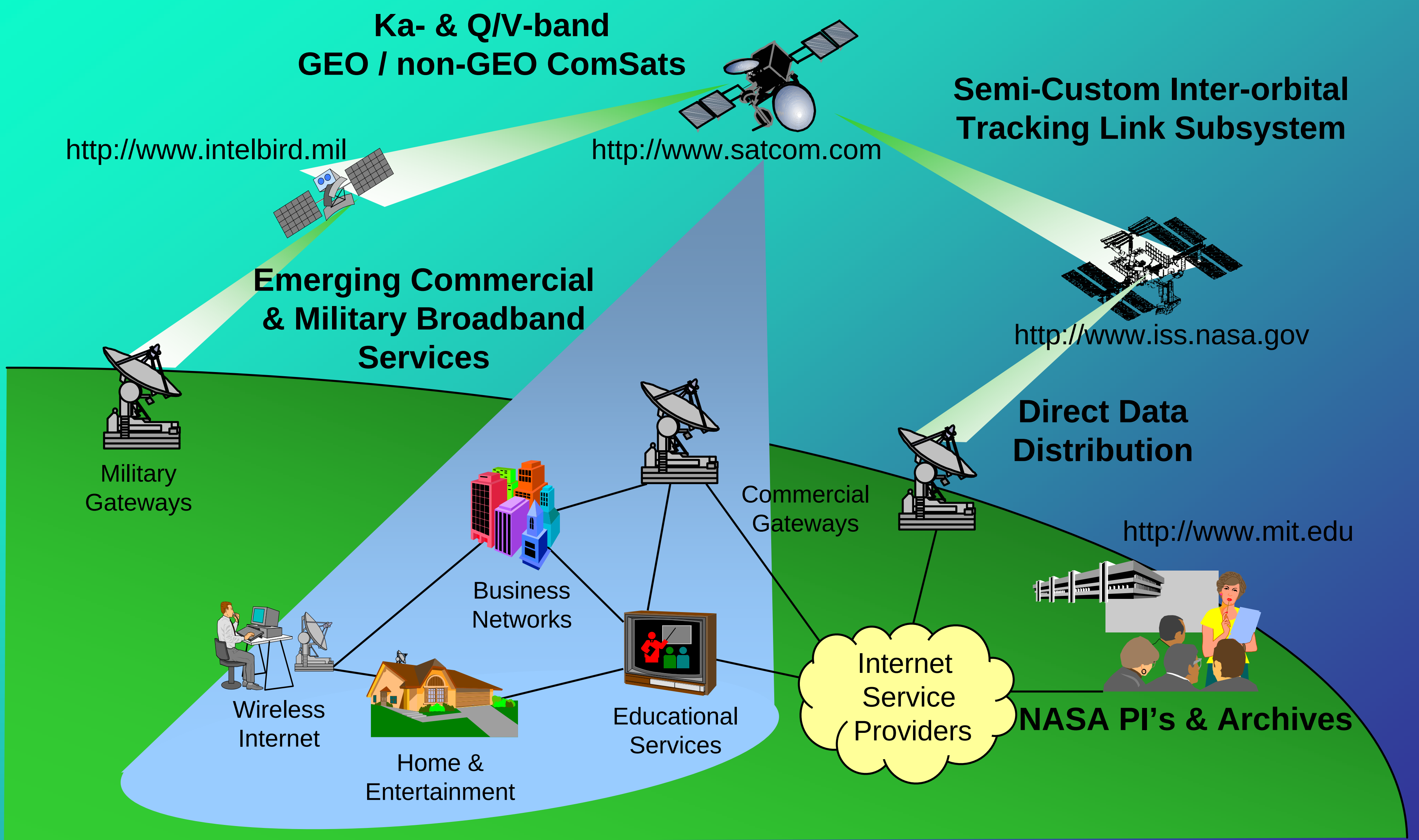


Human Exploration & Development of Space

- **Goals**
  - Explore the space frontier
  - Enable humans to live and work permanently in space
  - Enable the commercial development of space
  - Share the experience and benefits of discovery

- **Relevant mission requirements**
  - One-of-a-kind, complex vehicles: operation,in-space assembly and upgrade
  - Geographically distributed teams and databases

Human Exploration & Development of Space



NASA Strategic Plan

http://www.nasa.gov/pdf/1968main_strategi.pdf

Technologies

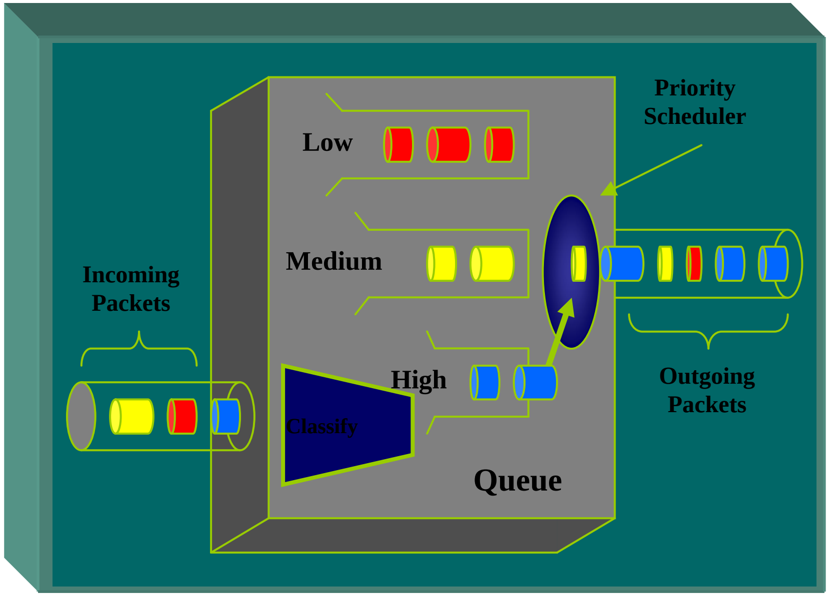
- Adaptive Networking
- Network Management
- Bandwidth Reservation
- Nomadic Networking

Adaptive Networking

- Overview
  - Commit resources to specific applications to ensure that performance parameter values stay within an acceptable range
  - Enable efficient resource sharing among multiple users
  - Provide preferential treatment to specified traffic flows when network resources become scarce
  - Develop a passive network monitoring and management tool for high-bandwidth networks
  - Enable detailed analysis of individual traffic flows
  - Enable autonomous network resource estimation/ request of local and distributed ground-based stations

Adaptive Networking

- Challenges
  - Determining network congestion per critical traffic flow
  - Incorporating feedback into network measurement techniques
  - Providing timely network response and adjustment per critical flow
  - Analyzing measurement data at high data rates



Quality of Service uses network queuing to separate and give preference to packets classified with high priority.

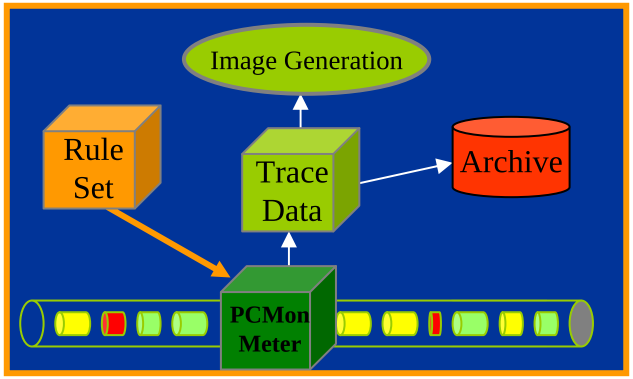
- Benefits
  - Enhance performance of NASA mission applications

Network Management -Passive Monitoring

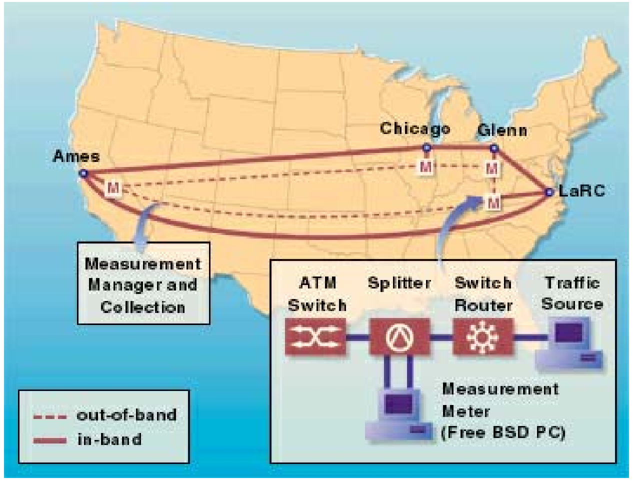
- **Overview**
  - Monitors high-bandwidth data flows (OC-3/OC-12 links; can upgrade to OC-48 today, OC-192 soon)
  - GUI enables user-defined specifications to designate traffic of interest and types of information to collect on the designated flows
  - Data collection summarization is delivered to a central process/control management system that archives summaries and generates graphical representation

Network Management - Passive Monitoring

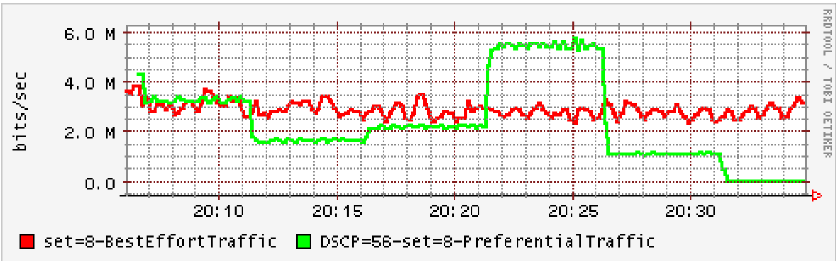
PCMon is a general networking monitoring and measurement tool that enables detailed analysis of individual traffic flows

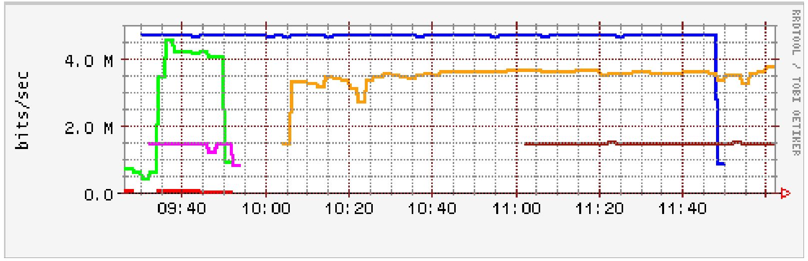


PCMon measurement configuration



PCMon deployment

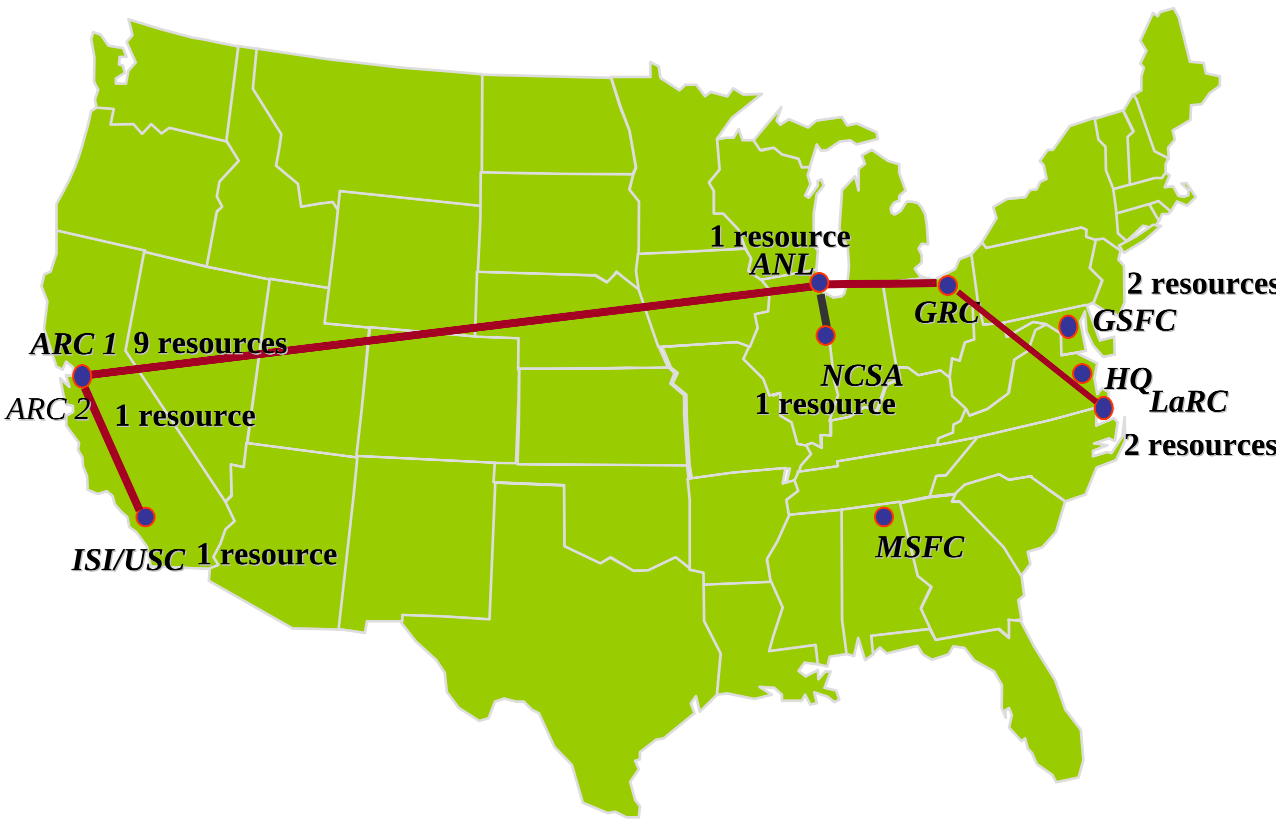


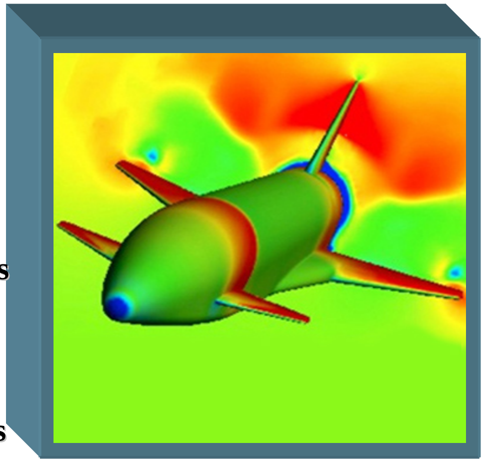


These graphs illustrate the ability to monitor individual traffic flows. The left graph shows two traffic classes, and the right graph shows multiple traffic types such as data, audio, and video.

Network Management—Grid Monitoring

Grid-Enabled Automatic Data Base Generation—
PCMon was used to capture the data





Liquid Glide-Back Booster Data Base Generation with High- Confidence Tools on Distributed Heterogeneous Resources - 100 Overflow & 1000 Cart3D cases in One Week using the Grid.

ISI/USC = Information Sciences Institute, University of Southern Calif.
ANL = Argonne National Lab (US DOE)
NCSA = National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign

Bandwidth Reservation

- Overview
  - Solution based on GARA tool (Global Architecture for Reservation and Allocation)
  - GARA derived from DOE-ANL design to support QoS for Globus
  - GARA functionality
    - Request is placed for bandwidth reservation
    - Reservation is processed immediately or staged for future activation, depending on requested start time
    - Reservation specification triggers change to all routers along the path; can be implemented with various mechanisms
    - Hooks provided to support NASA Grids

Nomadic Networking

- **Objectives**
  - Provide NASA scientists and engineers access to the same computer and communications services while working off site or in the field as at their home site
  - Provide access to these services via the same familiar user interfaces
  - Provide self-configuring sensor networks in challenging environments

Nomadic Networking

Nomadic Networking

Network Technologies

- ***Hybrid networking***: Connecting different types of network infrastructures
- ***Mobile networking***: Provision of communication services in mobile environments
- ***Ad hoc/sensor networks***: Self-configuring networks
- ***Temporary network infrastructures****:* Creation of temporary networks that can be quickly established to serve a particular requirement and that can be just as quickly disassembled

Nomadic Networking - Challenges

- Seamless integration of heterogeneous networking technologies via IP
- Extending nomadic technologies into space
- Protocol and application performance in satellite/wireless environment
- Route discovery and management in portable networks
- Delivering Quality of Service in hybrid terrestrial/satellite environments
- Providing sufficient bandwidth to remote sites to support video imaging and multimedia applications

Nomadic Networking—Mobile IP/IPv6

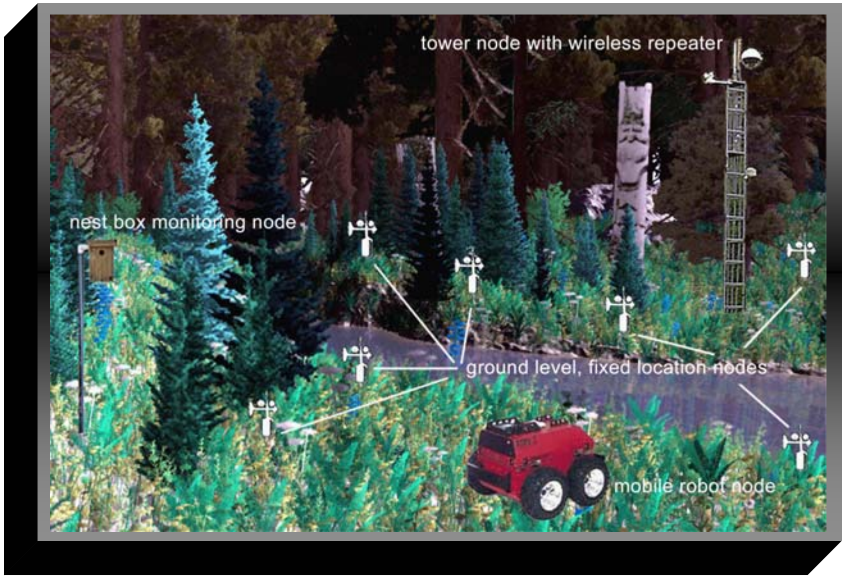
- **Goal**
  - Evaluate and demonstrate mobile technologies in context of the “next generation” IPv6 protocol
  - Benefit from increased sized of IPv6 address space
  - Benefit from improvements of IPv6 over IPv4
- **Issues**
  - Maintaining a mobile node’s identity as it changes its physical location
    - Address management
    - Handovers
    - Application performance
  - IPv6 support for mobile routing

Nomadic Networking
Transportable Earth Station (TES)

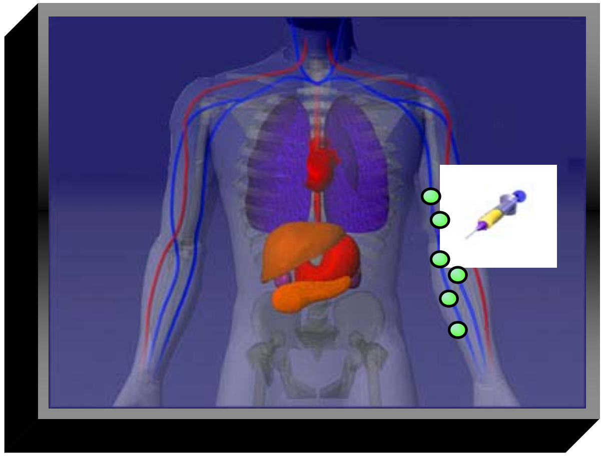
- Background
  - Facility developed in 2001
  - First used at Mobile Networking Workshop in June 2001 to support cross-country tetherless connectivity into conference room
- Capabilities
  - Completely self-contained Ku-band system
  - Able to simultaneously send and receive up to 50 Mbps
  - 3.7 meter (12 foot) antenna
- Uses
  - Prototyping mobile networking technologies
  - Supporting scientific field studies

Nomadic Networking—Ad Hoc Networking

- **Goal**
  - Evaluate and demonstrate ad hoc/sensor network technologies
- **Issues**
  - Routing
  - Resource discovery
  - Application performance
- **Approach**
  - Conduct technology survey
  - Test routing and resource discovery alternatives



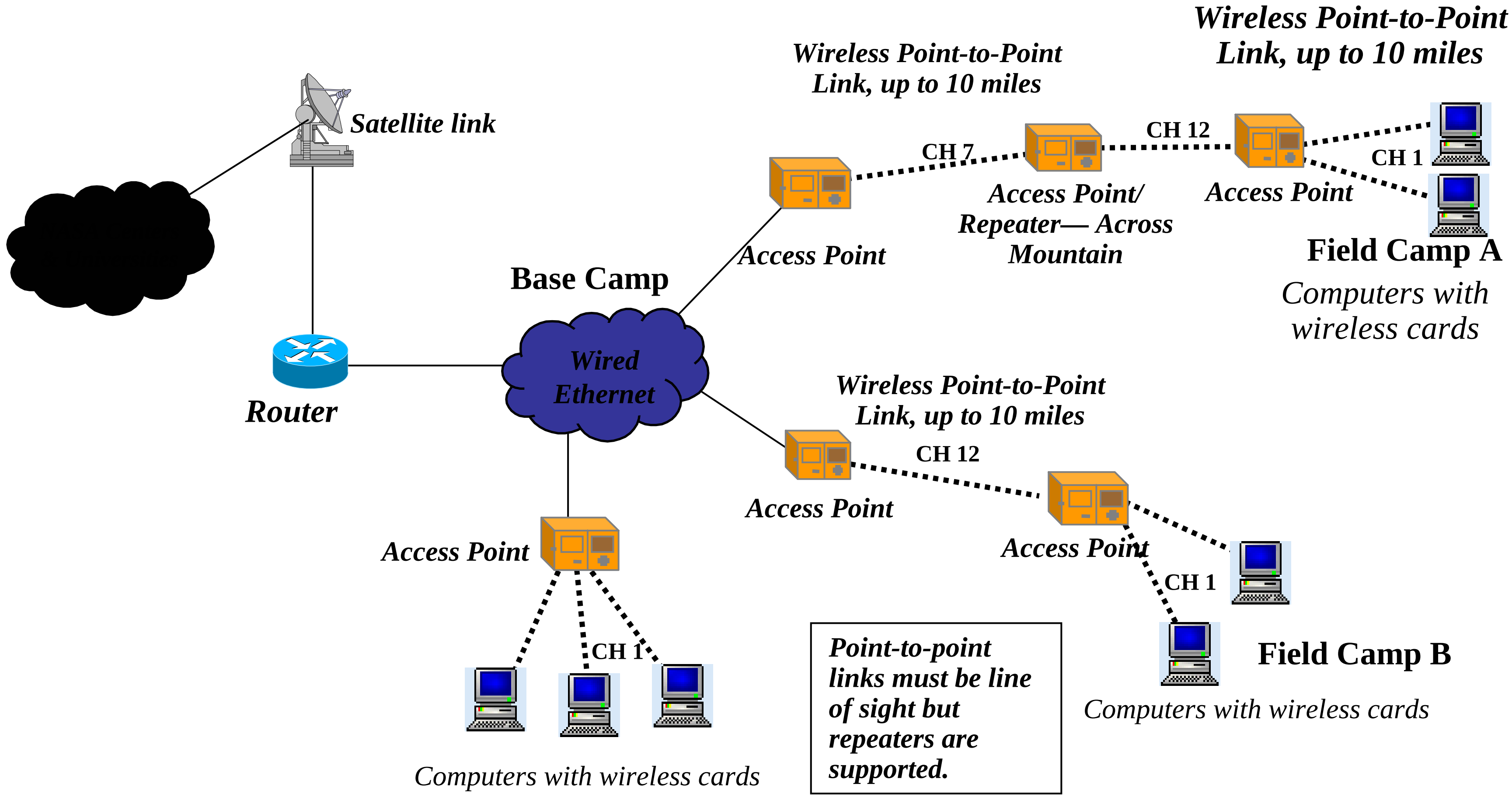
Environmental Sensors in Hawaii



Medical Sensors

Nomadic Networking—Field Support

Goal: Develop and demonstrate emerging networking technologies to support scientific field exploration at remote sites



Conceptual Network Architecture

Field Experiment
Mobile Agents Experiment

Meteor Crater, Arizona, September 2002

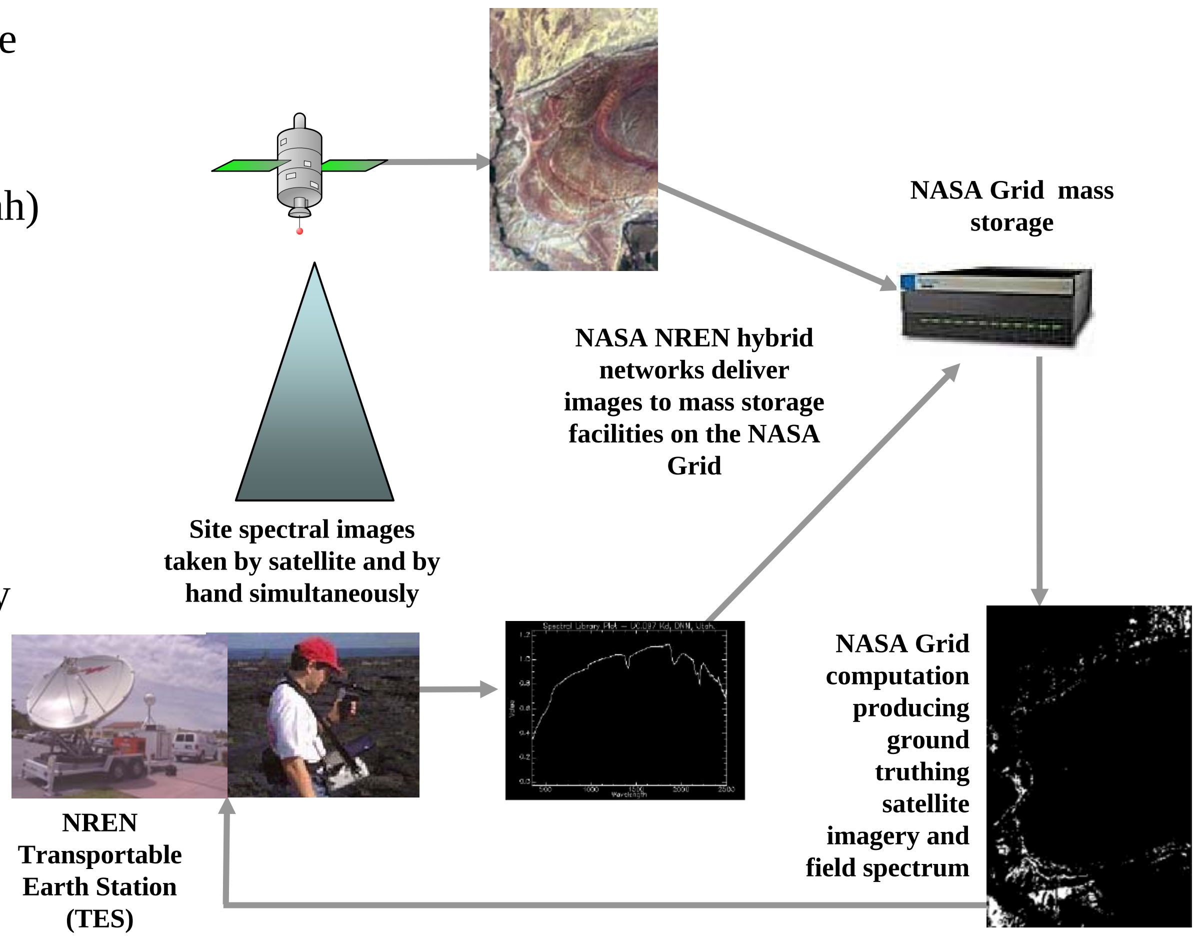
- **NREN Focus**
  - Provide hybrid connectivity between remote site and JSC
  - Emulate communication from Mars by inserting 20-minute delay in data stream
- **Science Focus**
  - Rover commanding
  - Wireless onsite networking
  - Astronaut suit testing
  - Autonomous software testing
- **Experiment components**
  - TES
  - Rover
  - All Terrain Vehicle
  - Astronaut
  - Remote mission support team at NASA JSC

Field Experiment
Ground-Truthing Experiment

Extending Grid computing power to Earth and Space explorers over NREN hybrid networks

Summary:

- Near-real-time Hyperion satellite imagery data is sent to a mass storage facility
- Remotely located scientists (Utah) upload ground spectra data to a second mass storage facility
- Grid pulls data from both mass storage facilities; performs 16 simultaneous band ratio conversions on the data
- Grid results are then accessed by local scientists and sent to the remote science team
- Remote science team uses results to locate and explore new critical compositions of interest

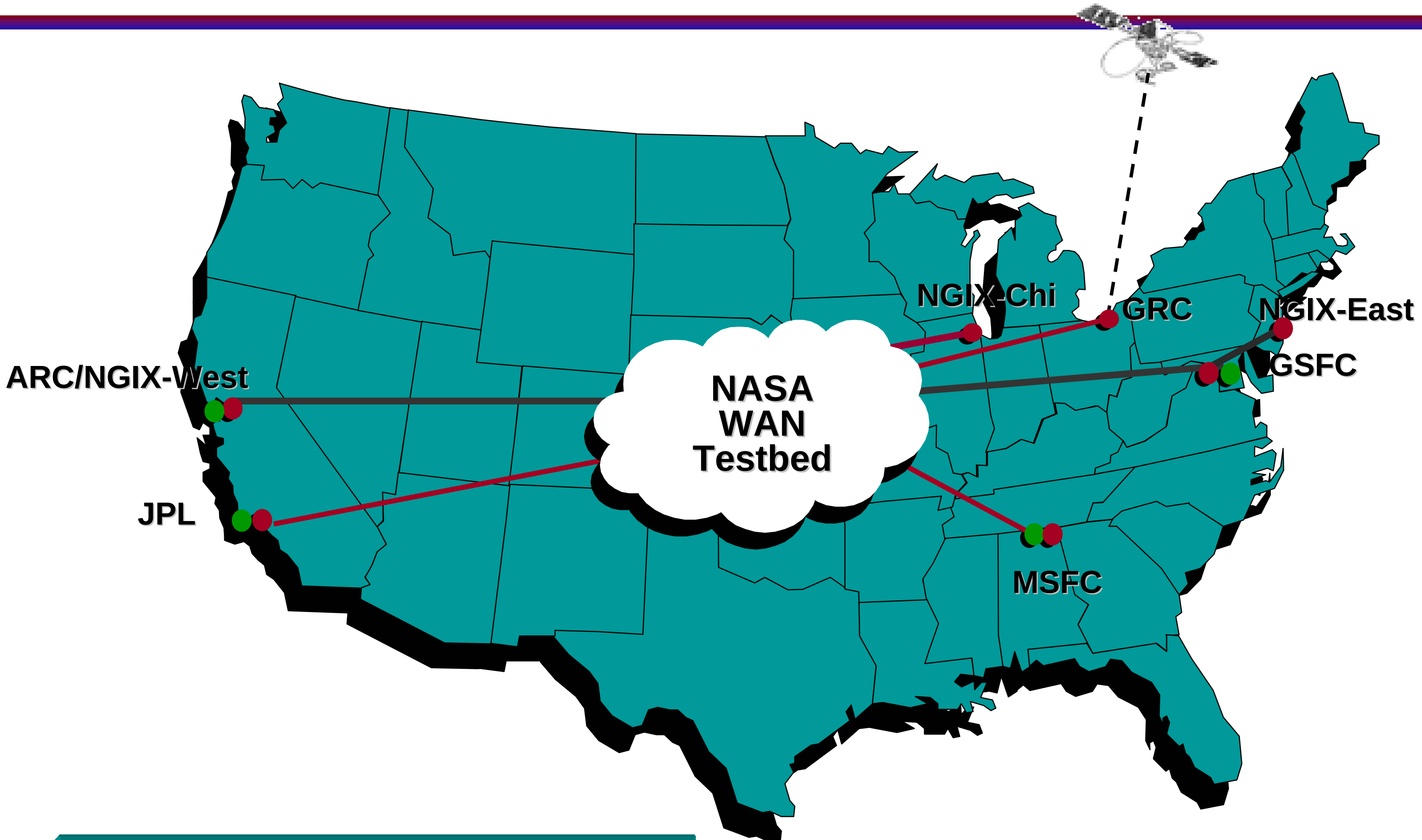


Ground-truthed imagery delivered to field scientists for near-real-time use in the field

WAN Testbed

- Objective
  - Develop and maintain a networking testbed to interconnect unique, high-demand NASA computing and data resources
- Methodology
  - Research and develop technology to enable next-generation NASA missions
    - Enhance science and engineering
    - Incorporate state-of-the-art network advances
  - Transfer technology to enhance capabilities of NASA operational networks

WAN Testbed



NPN Sites
NREN Sites
Hybrid Ground Station (35 Mbps)
OC-3 ATM
OC-12ATM

NASA WAN Testbed:

- NASA Research and Education Network (NREN) [CICT]
- NASA Prototyping Network (NPN) [NISN]

WAN Testbed

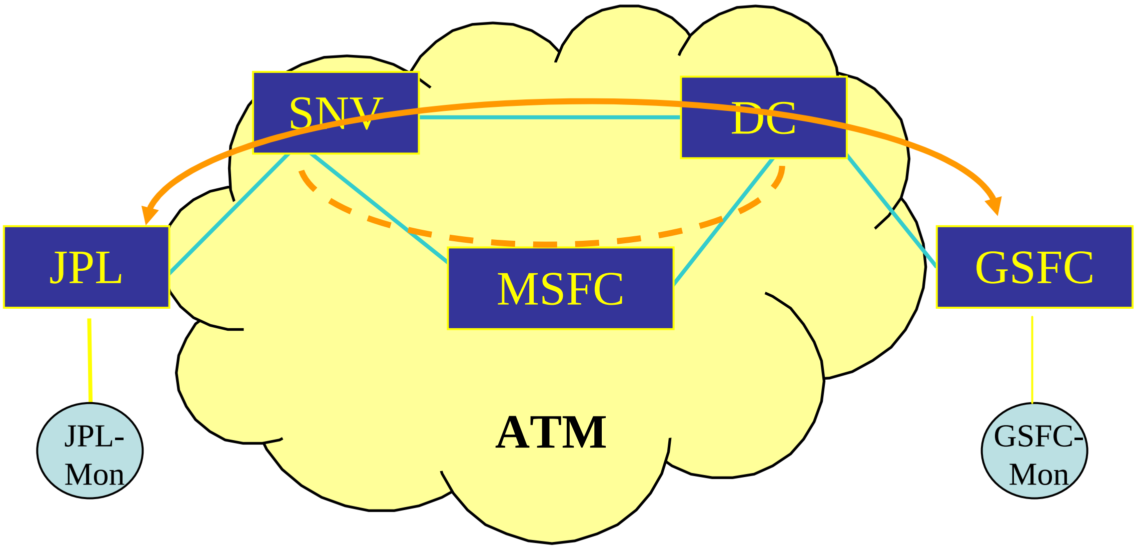
- Approach
  - Prototyping activities
    - Emerging networking, computing and related technologies
    - Grand Challenge Applications
  - Design and implement QoS architecture
  - Deploy passive monitoring meters
  - Evaluate MPLS traffic engineering capabilities
  - Demonstrate NASA Grand Challenge Applications

WAN Technologies—Quality of Service (QoS)

- **Objective**
  - Provide preferential service to a specific application or class of applications
    - Commit resources to specific applications
    - Ensure that values of bandwidth, latency, jitter and packet loss parameters stay within an acceptable range
    - Provide consistent latency and jitter reduction
    - Schedule bandwidth reservations
- **Benefit**
  - Satisfy NASA mission application requirements
    - Guaranteed bandwidth
    - Low-latency data transfer

WAN Technologies
Multiprotocol Label Switching (MPLS)

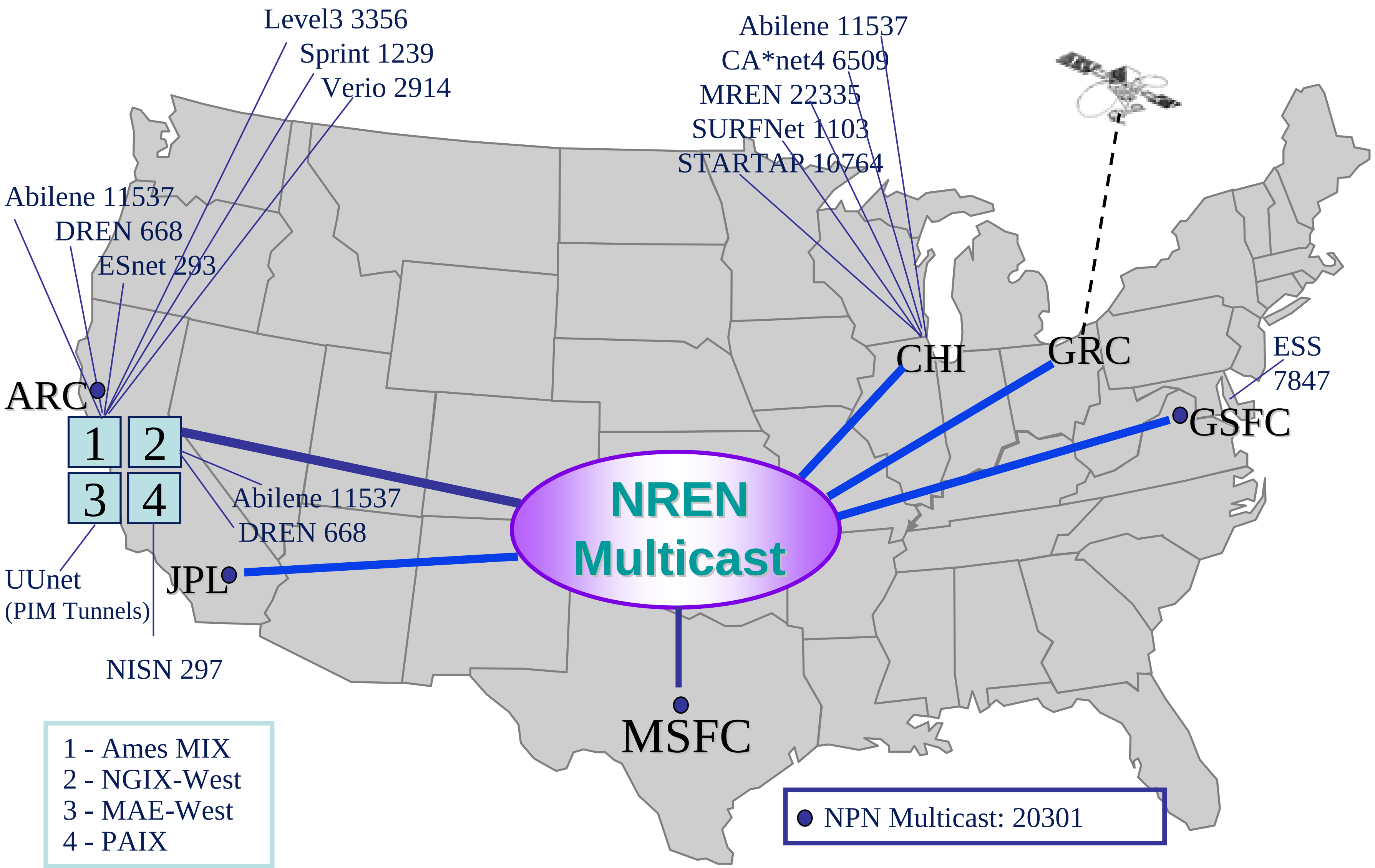
- **Objective**
  - Combines layer 2 (data link layer) switching with layer 3 (network layer) routing to create flexible, faster and more scalable networking
  - Provides a standards-based approach to applying label switching to large-scale networks
  - Enables IP networks to provide ATM/frame relay-like fast switching capabilities



WAN Technologies—Multicast

- **Objective**
  - Enable point-to-multipoint transmission
- **Benefit**
  - Enhance network performance
- **Activities**
  - Encourage deployment of multicast technologies across research networks and industry
  - Support NASA LANs, Fed Nets and Internet2 multicast implementations
  - Collaborate with partners to standardize common protocol set
  - Deploy native multicast on NASA Collaborative Testbed (NCT)
  - Develop capability to monitor multicast applications
  - Evaluate new multicast technologies as they emerge
  - Educate application developers

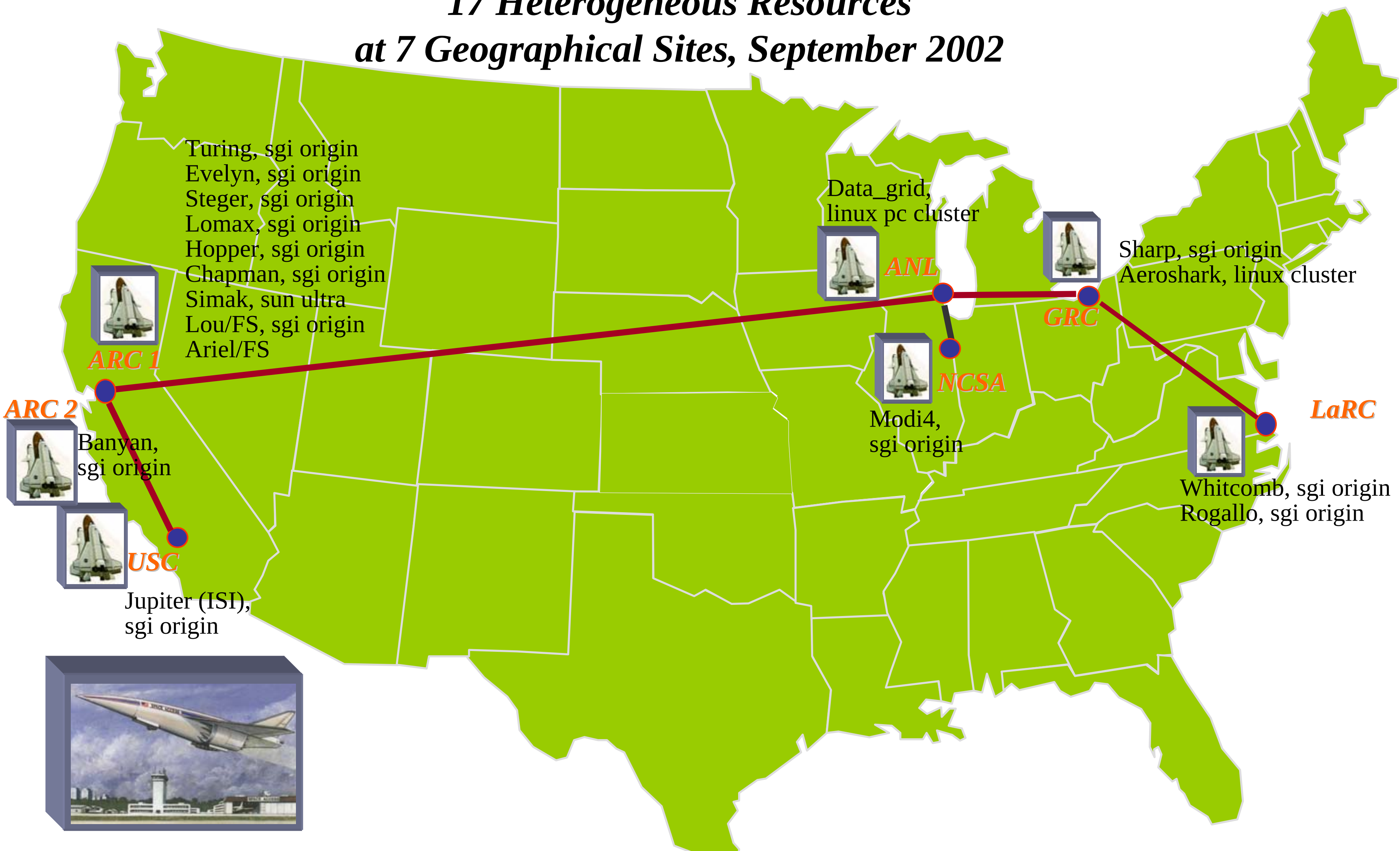
NREN Multicast Architecture



WAN Application - Space Flight Simulation Propulsion: Reusable Launch Vehicle (RLV)

Exploratory Grid Environment

17 Heterogeneous Resources
at 7 Geographical Sites, September 2002



NASA Programs

- **Computing, Information and Communications Technology (CICT) Program**
  - Computing, Networking and Information Systems Project
    - Adaptive Networking
    - Nomadic Networking
    - WAN Testbed
  - Space Communications Project
    - Space-based Proximity Networks
    - Optical Communications
    - NASA Research Announcements

NASA Programs

- **Computing, Information and Communications Technology (CICT) Program**
  - New Projects:
    - Space Communications and Advanced Networks
      - Develop and demonstrate innovative, seamlessly integrated, and multi-functional communication and networking technology products to enable the next generation of NASA distributed architectures and systems to vastly expand the reach of science and exploration.
    - Collaborative Decision Systems
      - Develop and demonstrate improved ground-based and on-board decision making technologies for next generation mission operations, real-time decision-making, human-machine collaboration, and long-term distant exploration, allowing missions to provide increased science return at lower risks and lower costs.
    - Discovery Systems
      - **Distributed data search, access, and analysis:** Develop and demonstrate technologies to enable investigating interdisciplinary science questions by finding, integrating, and composing models and data from distributed archives, pipelines; running simulations, and running instruments. These technologies will support constraints and goals in the queries; and resource-efficient intelligent execution of these tasks in a resource-constrained environment.

NASA Programs

- **Earth Sceince Technology Office (ESTO)**
  - ESTO manages the development of advanced technologies for use in future Earth Science measurements. ESTO aggressively pursues promising scientific and engineering concepts and ensures that the program maintains an effective balance of instrument and information systems investments.
  - ESTO provides strategic investment in advanced instrument, platform, and information system technologies that are essential to accomplishing NASA's Earth Science Enterprise's research goals.
  - http://esto.nasa.gov/

NASA Programs

- **NASA Integrated Services Network**
  - ***The mission of the NISN is to provide cost-effective wide area network telecommunications services for transmission of data, video and voice for all NASA Enterprises, Programs and Centers, utilizing commercial capability wherever possible.***
  - **http://www.nisn.nasa.gov/**