5.1 - Partnering to Change the Way NASA and the Nation Communicate Through Space

By Pete A. Vrotsos
NASA Glenn Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
E-mail: Pete.A.Vrotsos@grc.nasa.gov

James M. Budinger
NASA Glenn Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
E-mail: James.M.Budinger@grc.nasa.gov

Kul Bhasin
NASA Glenn Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
E-mail: Kul.Bhasin@grc.nasa.gov

Denise S. Ponchak
NASA Glenn Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
E-mail: Denise.S.Ponchak@grc.nasa.gov

Introduction

For at least 20 years, the Space Communications Program at NASA Glenn Research Center (GRC) has focused on enhancing the capability and competitiveness of the U.S. commercial communications satellite industry. GRC has partnered with the industry on the development of enabling technologies to help maintain U.S. pre-eminence in the worldwide communications satellite marketplace. The Advanced Communications Technology Satellite (ACTS) has been the most significant space communications technology endeavor ever performed at GRC, and the centerpiece of GRC's communication technology program for the last decade.

Under new sponsorship from NASA's Human Exploration and Development of Space Enterprise, GRC has transitioned the focus and direction of its program, from commercial relevance to NASA mission relevance. Instead of one major experimental spacecraft and one headquarters sponsor, GRC is now exploring opportunities for all of NASA's Enterprises to benefit from advances in space communications technologies, and accomplish their missions through the use of existing and emerging commercially provided services. A growing vision within NASA is to leverage the best commercial standards, technologies, and services as a starting point to satisfy NASA's unique needs. GRC's heritage of industry partnerships is closely aligned with this vision.

NASA intends to leverage the explosive growth of the telecommunications industry through its impressive technology advancements and potential new commercial satellite systems. GRC's partnerships with the industry, academia, and other government agencies will directly support all four NASA's future mission needs, while advancing the state of the art of commercial practice. GRC now conducts applied research and develops and demonstrates advanced communications and network technologies in support of all four NASA Enterprises (Human Exploration and Development of Space, Space Science, Earth Science, and Aero-Space Technologies).

Human Exploration and Development of Space (HEDS)

The Space Operations/Communication Technology Project sponsors development of advanced communications and space Internet technologies at higher levels of readiness for infusion to increase data return and decrease costs for support of NASA's missions. Through strong partnerships with industry leaders and innovators, GRC is committed to the development of high performance communication products for use in future NASA spacecraft and the ground and space assets that support them. GRC is identifying, developing, and infusing high

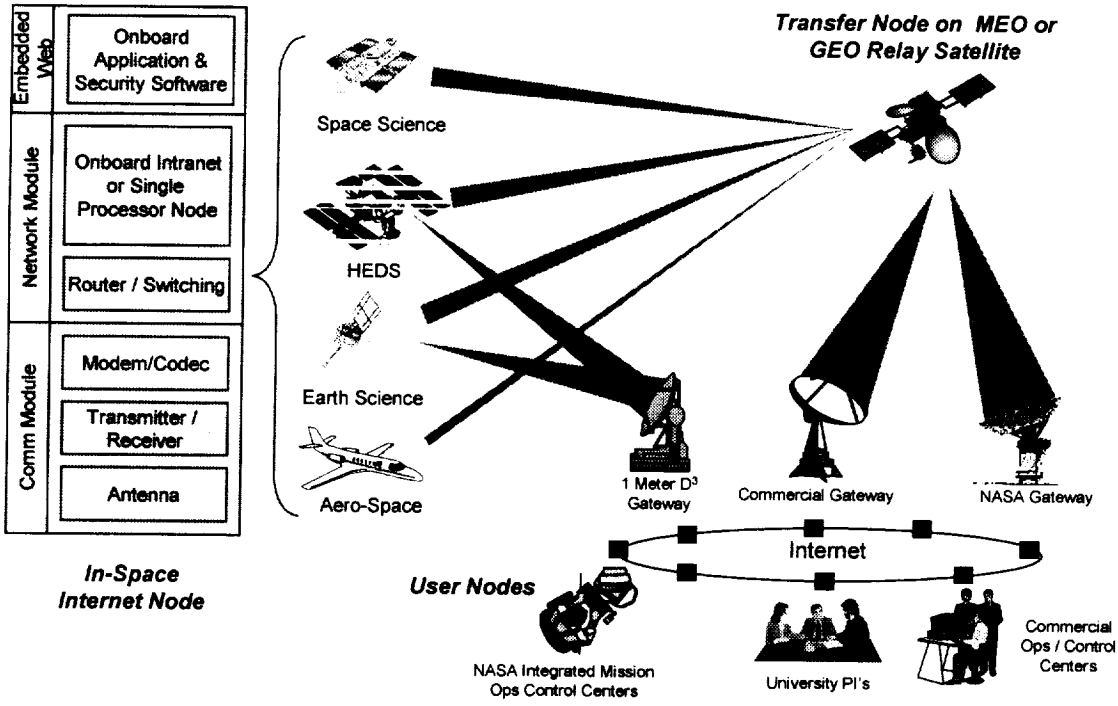
performance communications technologies necessary to enable or enhance mission data services and to achieve seamless interoperability among NASA, commercial satellite, and terrestrial communications systems. These technology products will leverage commercially provided capabilities to support inter-orbital, inter-satellite links with commercial space networks, intra-network links within science spacecraft constellations, while interoperating with terrestrial networks.

As much as possible, future communications system architectures will draw on existing and planned commercial satellite constellations and ground-based infrastructure to meet NASA's needs. Using future NASA systems in conjunction with anticipated commercial space networks at higher frequencies (Ka-Band and above) will provide higher rate capability and enable reduction in component size, thereby reducing NASA mission development and operational costs. Commercial capability (both space-based and terrestrial-based) will enable improved connectivity to mission operations centers, principal investigators, and the technical and science community. Advanced physical and data link layer technologies in both space and ground systems will enable the extension of Internet type services to NASA spacecraft.

Advanced Communications

GRC will continue to partner with the industry on development of new products with enhanced performance and efficiency, and their demonstration in environments suitable to retire operational risk. These products include electronically steered antennas, such as MMIC-based phased arrays and ferroelectric based reflectarrays, bandwidth and power efficient high rate modems, low noise receivers, solid state and traveling wave tube amplifiers at Ka-band frequencies and above, and other service enabling technologies. The advanced components are intended to increase data rate capability, reduce component size and improve power efficiency and spectrum utilization.

New system designs will include the transition to higher frequencies. GRC's propagation data collection and analysis play a key role in satellite link analysis and future component capability and requirements. Ground system architectures will include satellite acquisition and hand-off techniques, and advance tracking algorithms using electronically steered phased array and reflect-array antennas designed to improve and automate station operations and reduce costs.

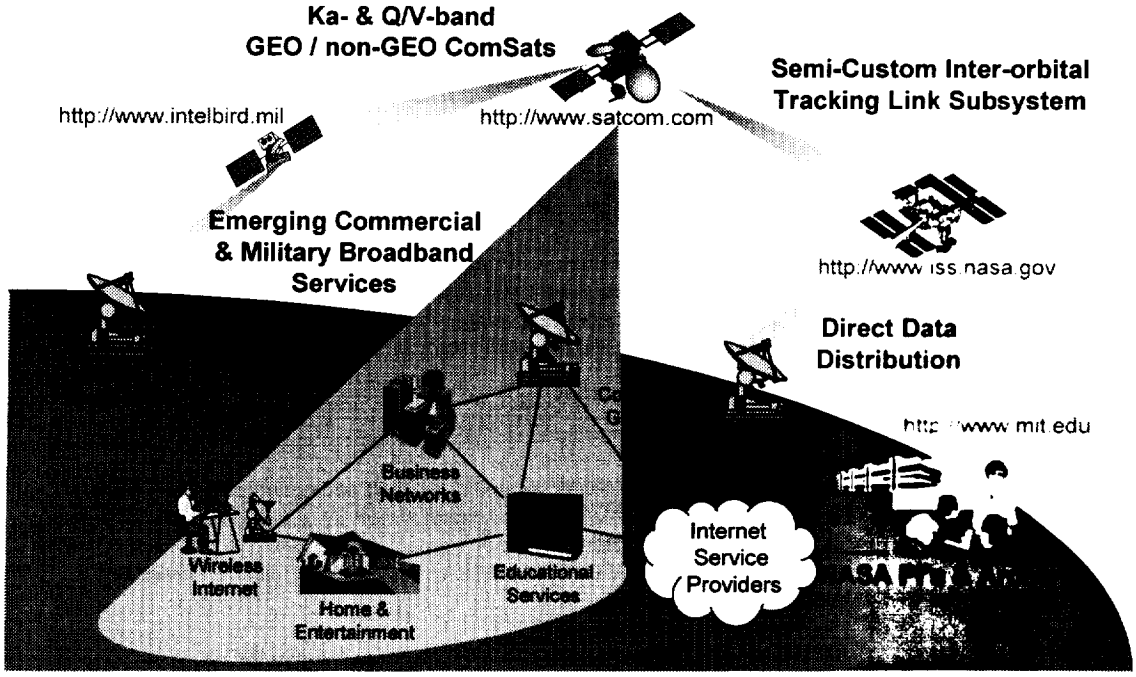


GRC is also integrating these advanced communications technologies into demonstrations of high data rate communications systems. The Direct Data Distribution (D^3) project will demonstrate high-performance array antenna and digital modulation system that transmit information from a low-Earth orbit (LEO) spacecraft at

622-Mbps to an ultra low-noise, 1-meter receiving terminal on the Earth. This revolutionary capability will enable the distribution of substantially increased amounts of data from LEO spacecraft directly to NASA field centers, principal investigators, or into the commercial terrestrial communications network. GRC's industry partners on the array (Raytheon), modem (SiCOM) and ground terminal (Teledesic) have invested more than 50% of the cost of these product developments, because of their potential to satisfy commercial needs as well as NASA's.

Space Internet

GRC is investing in network technologies to extend the capabilities of the terrestrial Internet into space. GRC is partnering with key commercial network hardware and software providers, (such as Sun Microsystems, Digital/Compaq, Microsoft, Intel, IBM, Wind River Systems, Hewlett Packard) communications providers (Cisco Systems, Ampex Data Systems, Fore Systems, Raytheon Telecommunications, Cabletron Systems) and spacecraft vendors (Hughes, Boeing, Space Systems/Loral, Lockheed Martin, Spectrum Astro), U.S. government labs (GRC, Johnson Space Center, Goddard Space Flight Center, Jet Propulsion Laboratory, Ames Research Center, Navy Research Laboratory) and universities (New Mexico State, Georgia Tech, Texas A&M, Pittsburgh Supercomputer Center). This consortium works together to develop, test, integrate, qualify, demonstrate, and infuse the best commercially available Internet and supporting communications infrastructure technologies into NASA space missions.



The space Internet technologies include the network architectures, protocols, and hardware components that are unique to NASA's use of the Internet in space. In each enabling technology, GRC will leverage emerging commercial capability, and partner with industry innovators to satisfy both NASA and commercial needs. Special attention will be paid to user authentication and security of remote operations. Once fully developed and infused, the space Internet technologies will enable the vision for transparent operations, enhance the capabilities for remote access and control of space-based assets, and reduce NASA's cost of providing the communications service. Every NASA space asset will be as accessible to approved users as any node on the Internet.

Space Science

GRC manages the High Rate Data Delivery thrust area under the Cross Enterprise Technology Development Program for the Space Science Enterprise. The long-term objective of this advanced research and fundamental technology development is to establish virtual presence throughout our solar system. The integration of high rate communications, networks and information technologies will enable a telepresence for near-Earth and deep

space scientific missions, and for human and robotic exploration. The transmission of data at high rates permits an increasingly rapid conversion of information to knowledge, and knowledge to new discoveries. Global interoperability among space-based assets and terrestrial telecommunications networks will diminish the gap between the sensors and the scientist. Information technology breakthroughs will enable the management of massive, diverse, multi-terabyte data sets needed to produce high-level information products.

Advance microwave communication research and proof-of-concept technology development is intended to increase data rates (in excess of 1 Gbps) for point-to-point near Earth and deep space communications. Novel Ka-band phased array and inflatable antennas, high-speed digital modems and multi-gigabit receivers are being designed to increase the capacity for the backbone communications. The models for space to ground radio-propagation to enable NASA and U.S. community and U.S. industry to utilize K-Band frequencies will be verified and presented in a handbook.

Micro-electro-mechanical systems (MEMS) switching technologies are being investigated to reduce losses in phased-array antennas. Miniature solid-state amplifiers and ferroelectric microwave components are being developed for future use in micro-spacecraft cross-link communications. A number of research and simulation tasks are underway to extend the advances being made in the terrestrial Internet technologies to the space environment as well as to provide connectivity from spacecraft directly to the users.

Earth Science

The Earth Science Enterprise desires to improve data collection from various and diverse platforms ranging from in situ buoys to balloons to polar orbiting satellites. Depending on the platform and its instrumentation, the data relay/transfer needs can vary from 10's to 100's of kilobits per second to 100's to perhaps even 1000's of megabits per second. While the Earth Observing System follow-on missions and the exploratory and process research-oriented missions appear to concentrate on individual platforms, concepts such as the "Sentinel Sensorweb", "Distributed Information System-in-the-Sky", and "Earth Science Information Web" scenarios will look at the various and diverse platforms as an integrated whole.

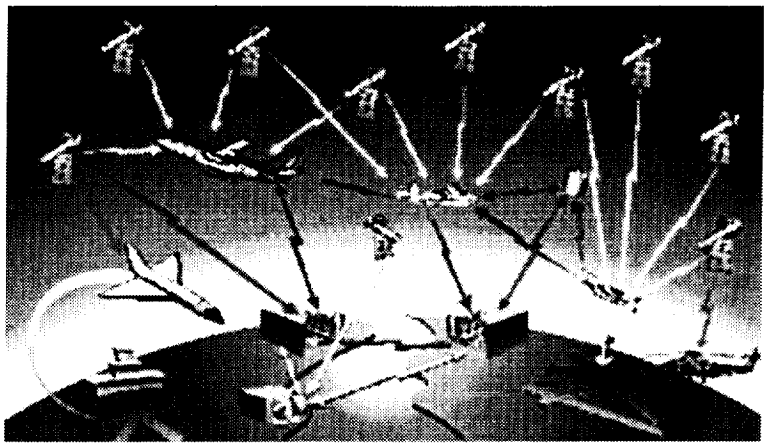
Evolving high data rate communications systems, in support of future Earth observation platforms demand greater attention to subtle aspects of information theory and radio-frequency engineering. GRC is poised to begin developing advanced communications and Internet technologies to provide the Earth Science Enterprise with the high data rate communications components it requires to return ever-increasing science data from advanced Earth observing platforms.

Aero-Space Technologies

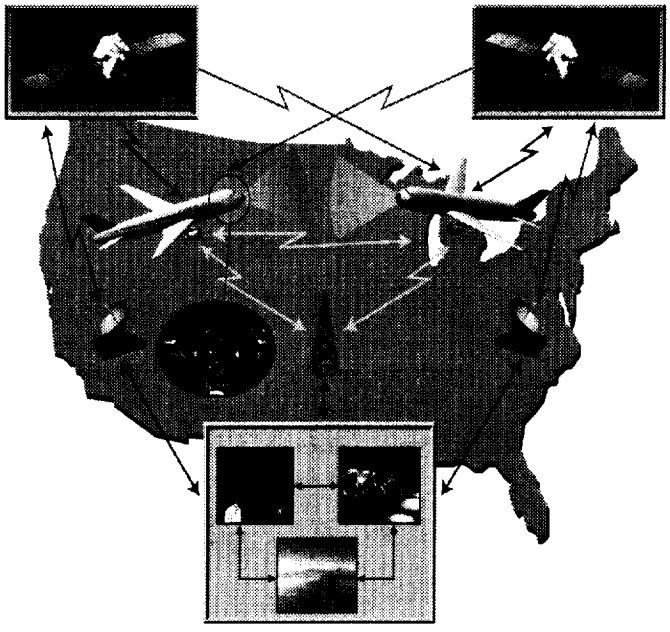
NASA's Aero-Space Technologies Enterprise is organized around three goals and ten objectives. GRC is supporting the Enterprise's first goal, Global Civil Aviation, by helping it meet its objectives in throughput and safety. The throughput objective is to triple the aviation system throughput, in all weather conditions, within 10 years while maintaining safety. The safety objective is to reduce the aircraft accident rate by a factor of five within by 2007, and by a factor of 10 by 2022.

It is widely accepted that today's air traffic infrastructure is capacity constrained due to the use of decades old technology. Twenty-five thousand U.S. daily flights exceed the system's capability to provide efficient service in good weather. Inclement weather further exacerbates the problem. Severe weather in one area can cause delays across the entire national airspace system. The current Air Traffic Management (ATM) system suffers from a number of limitations, including aging computer technology, voice-only communication (primarily), frequency congestion, non-radar coverage (e.g. oceanic) and limited meteorological information.

NASA is addressing the through-put objective in the *Advanced Air Traffic Technologies (AATT) Project* by developing new tools and technologies that enable free-flight, an operating system in which pilots have the freedom to select their path and speed in real-time. Free-flight by itself will not provide the necessary increase in system capacity that is required without a state-of-the-art Communications, Navigation and Surveillance (CNS) Infrastructure that supports new applications, higher data-rates, global connectivity, seamless integration, and, rapid reconfigurability. Automatic Dependent Surveillance-Broadcast (ADS-B) will provide the future surveillance capability, GPS will provide the navigational requirement, and satellite communications will enable transparent, split-second, free-flowing data transfer between all system elements. GRC is responsible for the advanced communications for ATM to enable a CNS Infrastructure that will provide the capacity, efficiency, and flexibility necessary to realize the benefits of the future free-flight environment.



The aviation community has enjoyed one of the best safety records of any form of transportation. Although the aviation accident rate is extremely low, the projected growth in air travel through the early part of the next century poses a serious safety challenge to the aviation community. In response to the White House challenge to achieve an 80% reduction in the rate of fatal accidents within 10 years and a 90% reduction within 20 years, NASA initiated the *Aviation Safety Program* in partnership with industry and other government agencies to address the President's National Aviation Safety Goal. The government/industry team recognized that weather was a major contributing factor in aviation incidents and accidents and recommended a significant effort in weather accident prevention. One of the key objectives of the program is to provide accurate, timely and intuitive information to pilots, dispatchers, and air traffic controllers to enable the detection and avoidance of atmospheric hazards.



GRC is developing the technology under the *Weather Information Communication (WINCOMM)* project that will address the communications specific issues associated with the dissemination of weather data:

1. Implement data link capabilities for Flight Information Services (FIS).

2. Expand and institutionalize the generation, dissemination and use of automated pilot reports (PIREPS) to the full spectrum of the aviation community, including general aviation.

3. Improve aviation weather information telecommunications capabilities for ground-ground dissemination of aviation weather products.

Concluding Remarks

It is unlikely that NASA will ever sponsor a single communications technology satellite project as large and significant as ACTS any time soon. Future technology developments will be smaller and more focused on the needs of NASA's Enterprises. In many cases commercial technologies and services are more advanced than

NASA's. However, the industry does not utilize space as a working environment as much as NASA does, with both data sources and destinations in space. In this regard, NASA has unique needs that are not met by commercially available solutions alone. GRC seeks to leverage the best commercial services and technologies to help satisfy NASA's mission needs. GRC's efforts will continue to serve as a catalyst to make the environment of space more suitable for human and robotic exploration, and increase the capacity and safety of the airspace for the benefit of all. Together with our industry partners, GRC is working to help helping to change the way NASA and the Nation communicate through space.

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Denise Ponchak
NASA Glenn Research Center
Cleveland, Ohio

Sixth Ka-Band Utilization Conference/ACTS Conference 2000, May 31 - June 2, 2000, Cleveland, Ohio

GRC Space Communications Historical Perspective

- **From the early 1970's to 1998 GRC's Space Communication program's (SCP) primary responsibility was to open new frequency bands and provide enabling communications technology to the commercial SATCOMM industry**

- **The successful emergence of commercial Ka-band systems and explosion of the commercial SATCOM provided services has enabled NASA and GRC Space Communications program to shift our technology investment focus to enable NASA's use of these commercial services in support of its future missions.**

- **The shift in GRC's Space Communication focus is to develop communications and networking technologies that leverage to the maximum extent possible the commercial SATCOM industry for the benefit of NASA Enterprises and missions**

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GRC Space Communications Focus

- Develop revolutionary space communication systems and networking technologies for NASA Enterprises
- Develop advanced communications and networking technologies that will enhance NASA's current communications infrastructure
- Develop gap-filling technologies that will enable NASA's transition to commercial communications services
- Develop communication and networking technologies that will enhance the National Airspace System

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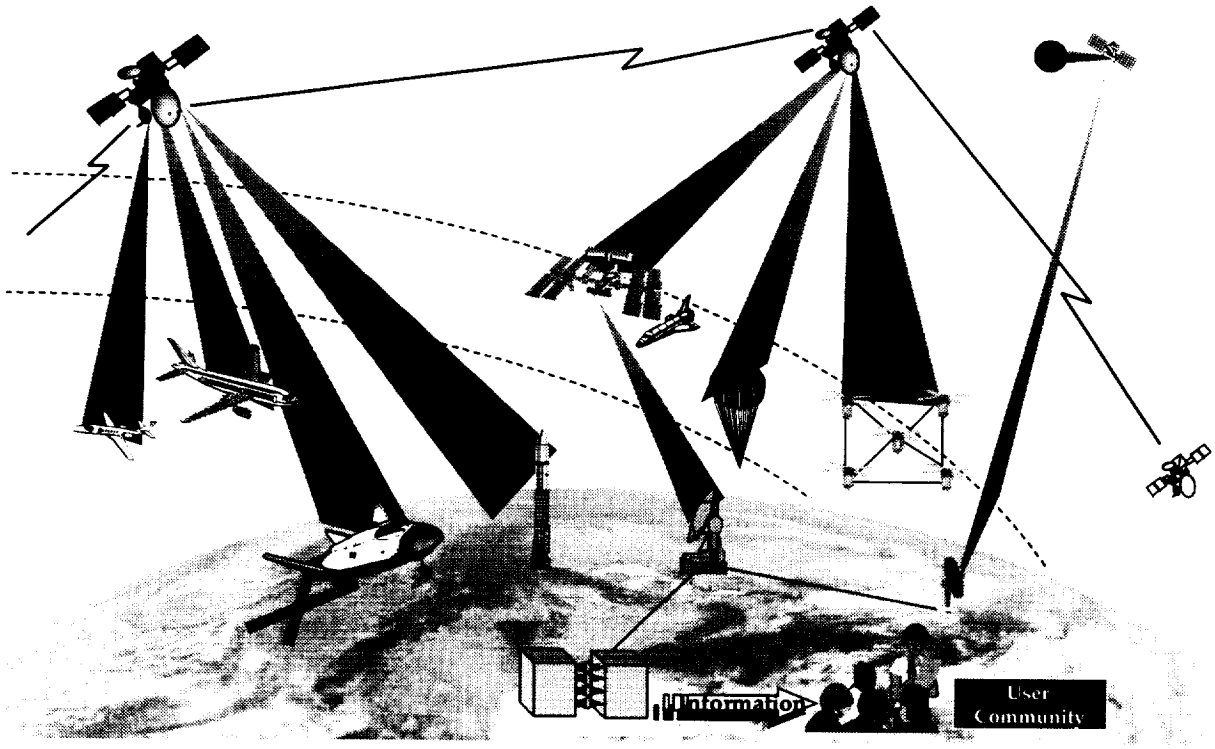
Space Communications Program Vision to Enable NASA Communications Infrastructure



High Rate Data Delivery Program

Goal: Enable affordable virtual presence throughout the solar system by increasing volume and timeliness of space data transfer directly to users while minimizing the cost and the impact of communications subsystems on future spacecraft.

Technology Development:

- Ka-Band Amplifiers, Receivers, Modems, Antennas
- Optical Technologies - 1st Generation
- Internet Protocols and Network Technologies Space Environment
- Hyperspectral Imaging

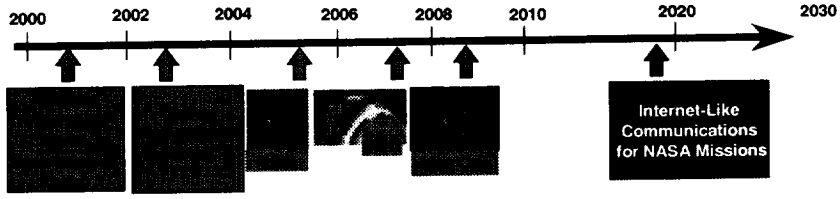
- On-Board Processing
- Multicasting Networks
- Low Cost, Miniature, Low Power Integrated Components
- 10 Gbit-Rate Comm. Systems
- Ad-Hoc Networks for Multiple Spacecrafts

- Seamless High Data Rate Information Delivery
- Intelligent, Ad-Hoc User-Centric Communication Networks
- Communication Technologies for Multiple Spacecraft Networks Connected to Deep Space Backbone

Capabilities:

Point-to-Point Communications → Point-to-Multipoint Communications → Autonomous, Ad-Hoc Multiple Comm.

Demos/Missions:



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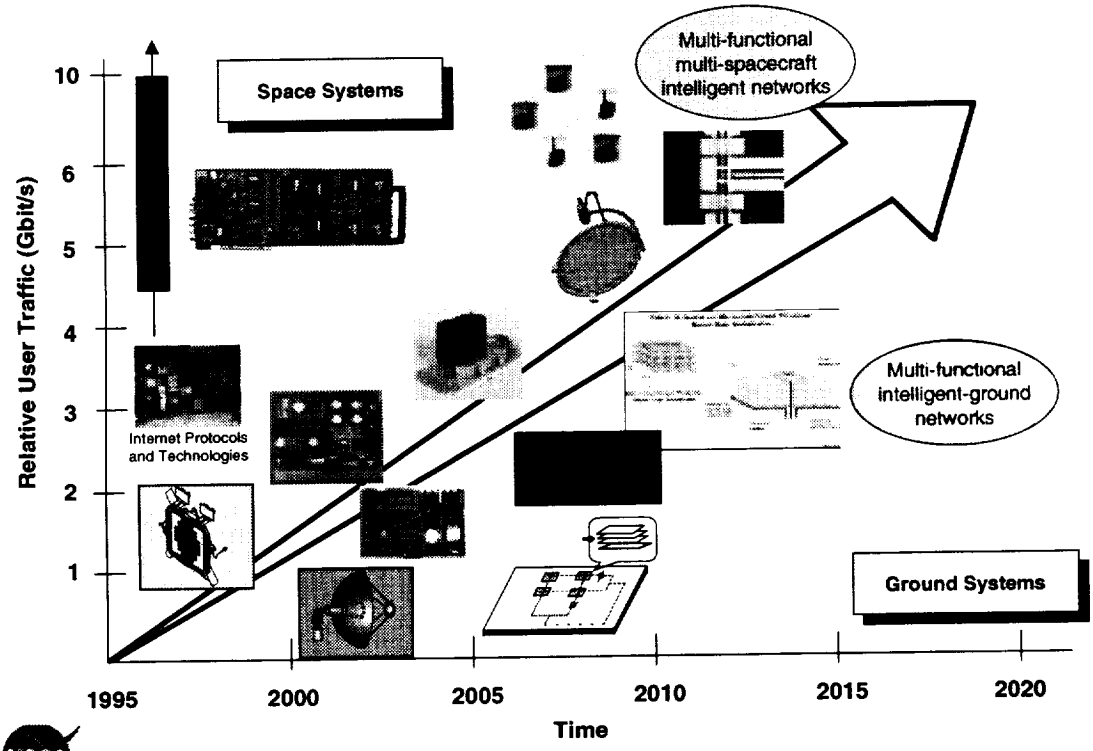
High Rate Communication Network Technologies



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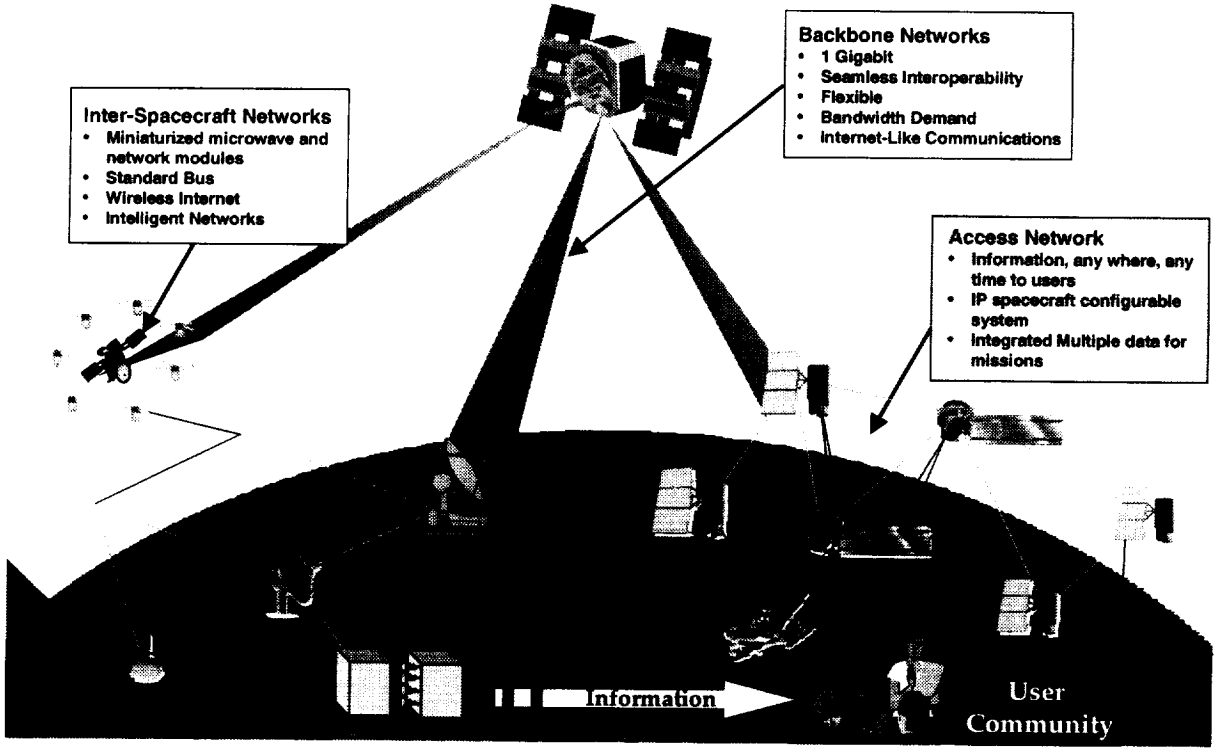
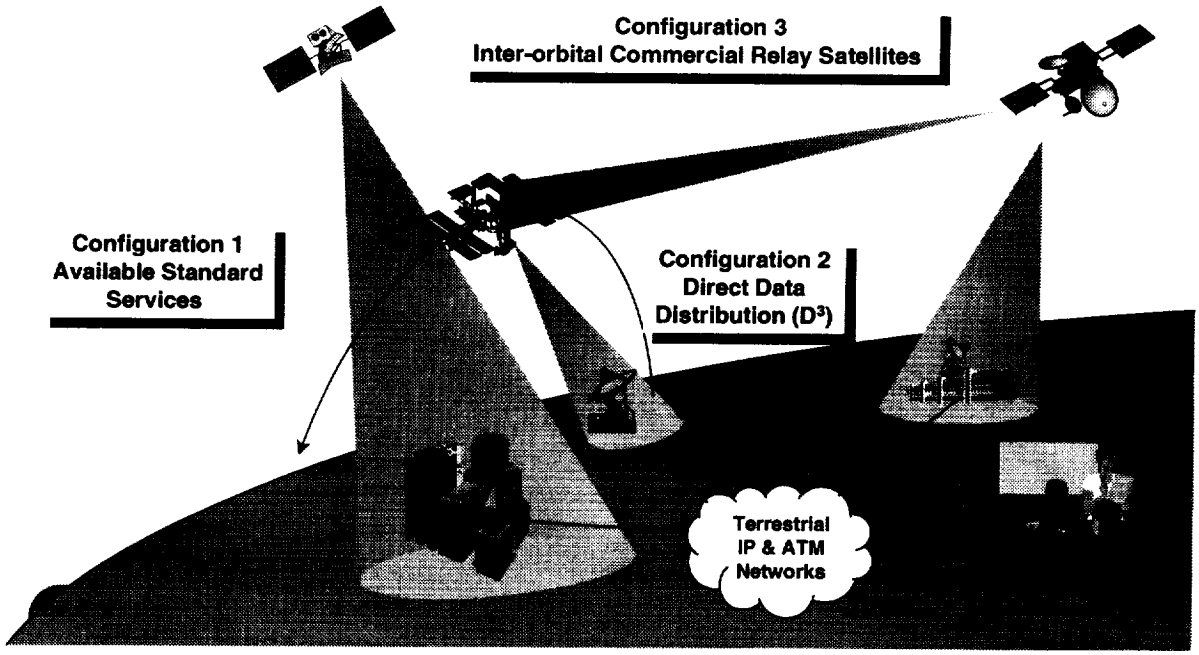
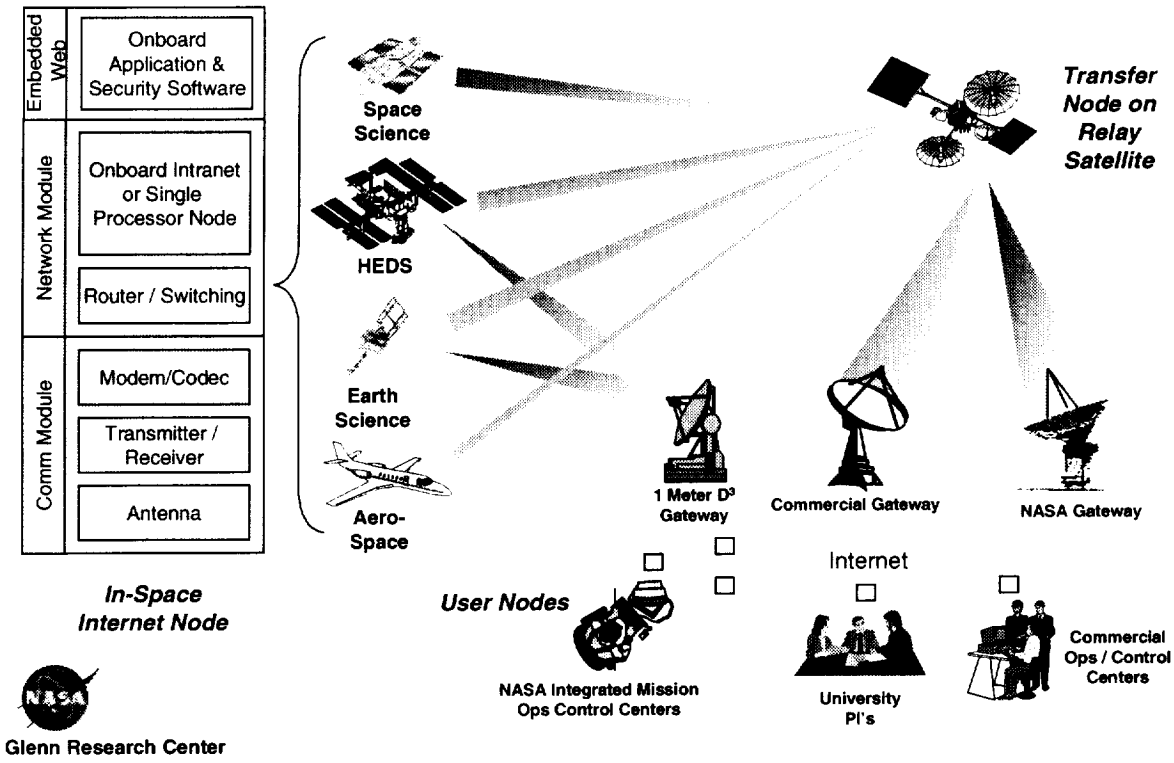
Future Directions



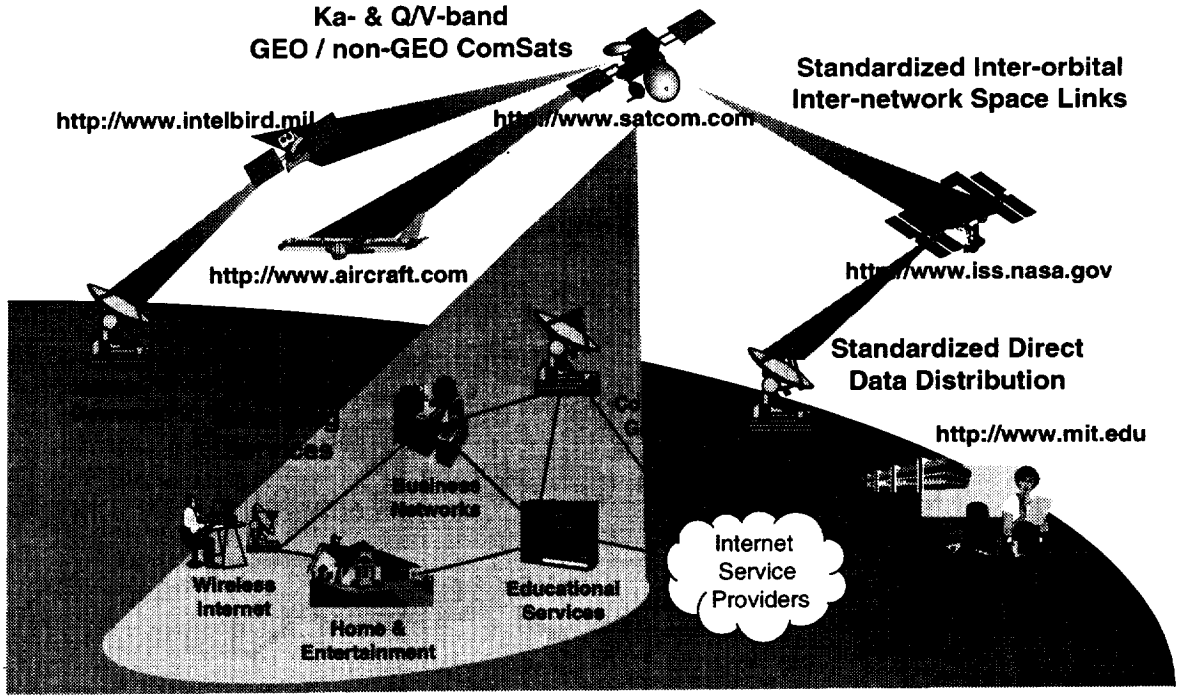
Commercial Utilization Configurations



Common Interface Architecture



Space Internet Vision
For Commercial Space & Ground Interoperability



The Aviation Capacity and Safety Challenge

Air Traffic to Triple in Next 20 Years

NASA Technology Goals

- **While maintaining safety, triple the aviation system throughput, in all weather conditions, within 10 years**
- **Reduce the aircraft accident rate by a factor of five within 10 years, and by a factor of ten within 25 years**

The current air traffic management system is near its capacity limits with extensive system delays and inefficiencies resulting in annual losses to users estimated at over $3.5B.

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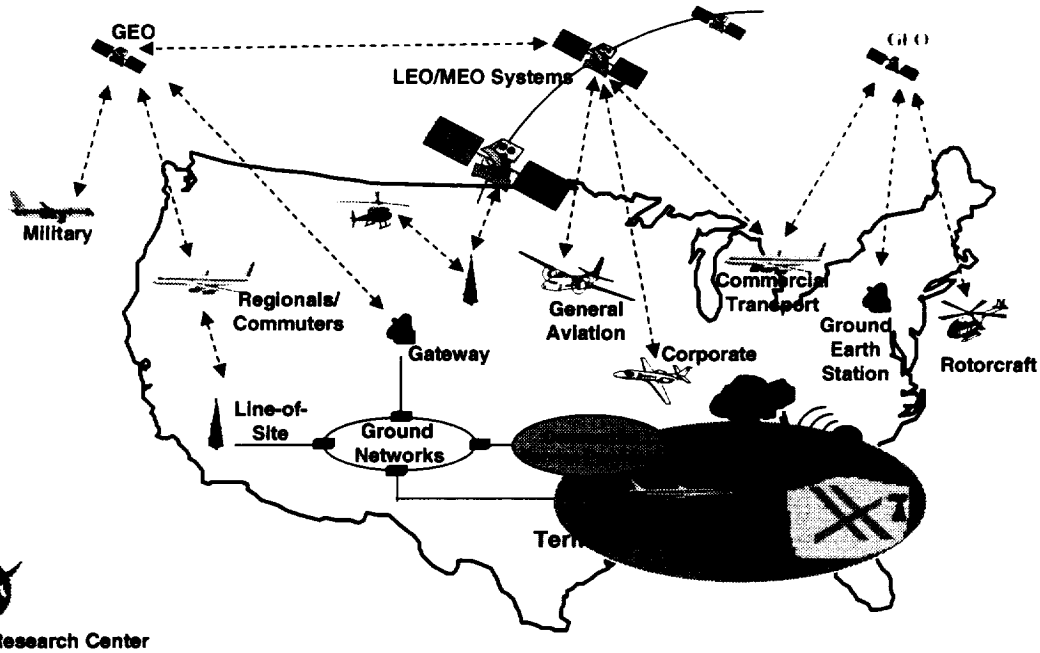
Next-Generation NAS Communications



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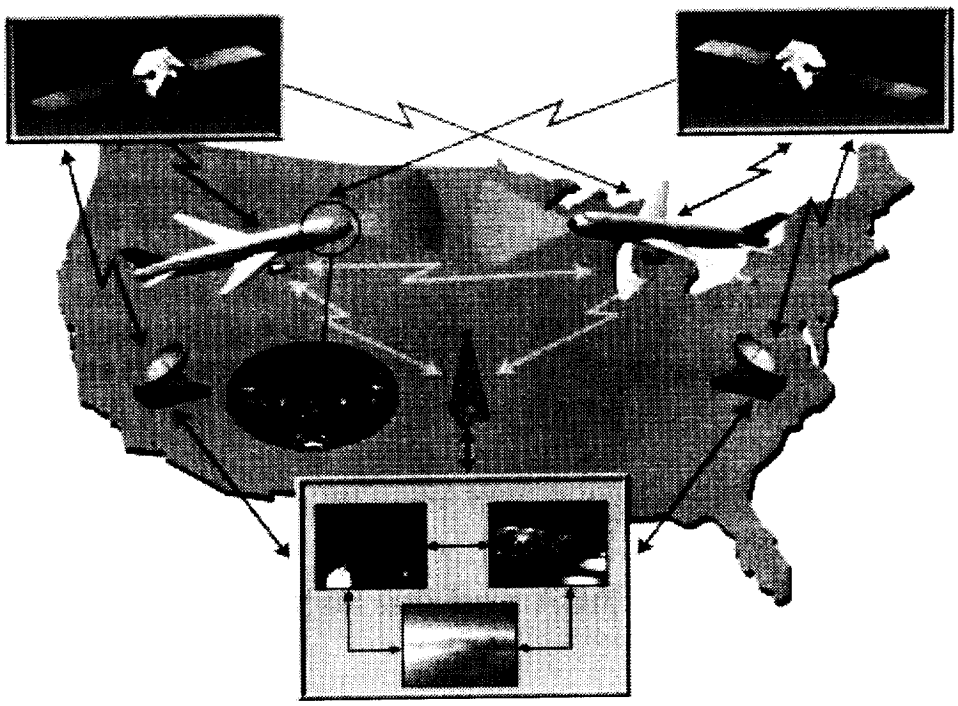
Weather Information Communication



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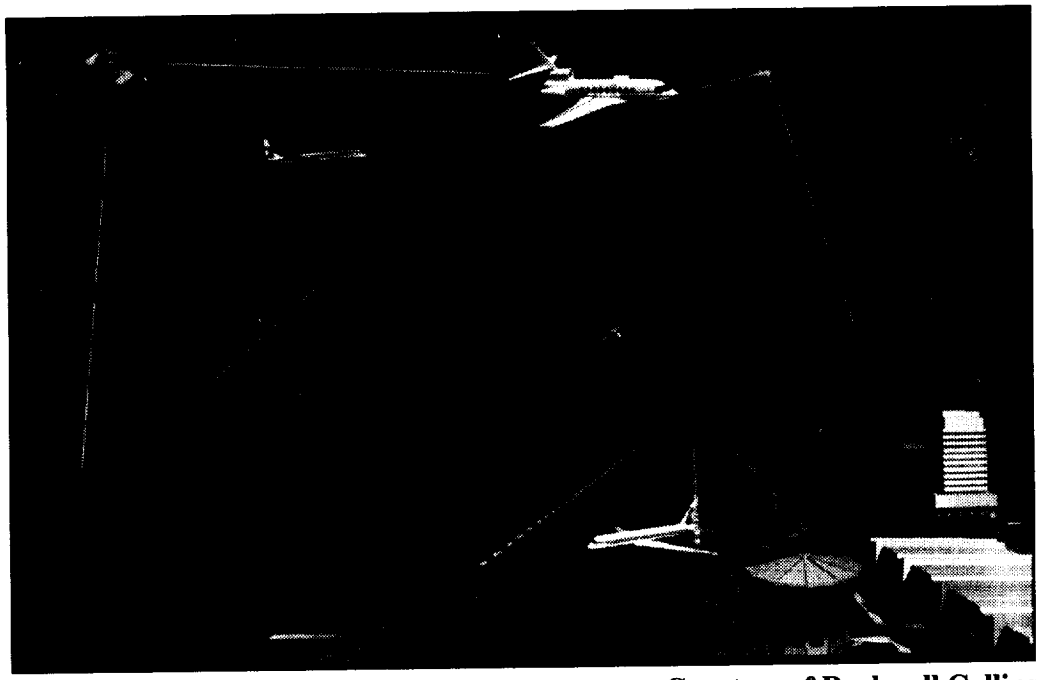

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Partnering with Industry

- **NASA**
  - Ka-band research & technologies
  - Propagation research
  - Communications R&D
  - Use of Commercial sys & services
  - ACTS follow on netw experimentation

- **INDUSTRY**
  - Global competition
  - Interoperability with terrestrial systems
  - Ka-band technologies and services
  - Satellite-delivered spacecraft and aircraft services

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