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The NASA Science Information Systems Newsletter (SISN) is prepared for the Office of Space Science (OSS), Science Information Systems (SIS) Program through an agreement with the Jet Propulsion Laboratory. The newsletter, which has been an ongoing task for over ten years, is a forum for the space science and applications research community to report research and development activities, outreach activities, and technology transference. SISN offers a venue for articles that are not likely to appear elsewhere and provides the opportunity for information exchange within the science community, as well as a platform for accomplishments by that community. Related articles from other programs and agencies are also published.

Questions or comments regarding this newsletter task may be emailed to Sandi Beck at <sandi.beck@jpl.nasa.gov>.

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WHITE PAPER

Can We Avoid A Data Survivability Crisis?

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Executive Summary

This paper is in response to a request by the NASA Associate Administrator/OES to assess the long-term high-capacity data storage media and system-related issues of the ability of data storage systems to survive, be reliable, and adapt to changing needs. A preliminary review is presented of the potential impacts to agencies and the business sector, which, like NASA, have responsibilities for the management and preservation of long-term digital data in mass storage systems. Unlike the Y2K problem, where the clock is ticking and a crisis is set to go off at a specific time, large capacity storage systems face a crisis similar to the one faced by the social security system, in that the seriousness of the problem emerges after a decade or so. The longer one waits to take steps to address the problem, the more draconian become the required measures to save the data.

Over the last two decades, a number of anecdotal crises have occurred; vital scientific and business data were lost, or would have been lost had it not been for major expenditures of resources and funds to save this data. A prime example was the joint NASA/NSF/NOAA effort to rescue eight years worth of TOVS/AVHRR data from an obsolete system. The herculean and expensive effort to save the data resulted in the preservation of valuable 20-year-long satellite records documenting global warming.

Current storage systems solutions to long-term data survivability rely on scalable architectures having parallel paths for data migration. As a result, three factors add significantly to the complexity of storage management systems and their long-term evolvability:

(i) Hardware components become obsolete much sooner than the storage media, leaving behind massive volumes of data in legacy systems.

(ii) Software systems need to evolve maintaining backward compatibility in terms of device readability, portable file management databases, network connections, and other operability issues.

(iii) The reliability of the system can not be compromised either by inadvertent data corruption or deliberate penetration.

In addition, these systems need to be insulated from blackouts and brownouts similar to the telephone and internet system overloads. Technological growth across all these areas has not been impressive in relation to the data growth, since the return on investment by the industry in new technology is often based on incremental demand-supply relationships.

The data growth experienced in the recent past has been of staggering proportions. Over the past 10 years, tape data storage density (with the same form factor) has increased according to Moore's law, doubling every 18 months. However, during the same period, data transfer speeds have only increased at a rate of about 1.3 times every 18 months, and thus have fallen behind data density growth rates by a factor of at least 3. Coupled with data media density growth, data storage requirements have gone up significantly. According to a recent Computer Technology Review article (March 1998) the total storage at a typical Fortune 1000 site is projected to escalate from just 10 TB in 1997 to 1 PB by the year 2000. In the next 5 years, a typical large database system for U.S. government agencies is expected to accept 5 TB per day, maintain 300 TB on-line (within 15 seconds to 1 minute access time), and archive from 15 to 100 PB. Additionally, data intensive programs such as NASA's Earth Observation System (EOS) and the intelligence data archival systems at the Rome Air Development Center, and scientific laboratories such as Thomas Jefferson National Accelerator Facility will have enormously large scientific databases with very large storage requirements.

Meanwhile, the technology of mass storage systems, though impressive in some areas, has barely kept up with the growth requirements in others. Today a single cartridge can hold 10 GB on 128 tracks compared with the 1960 vintage tapes of less than 1 MB capacity, a 10,000 fold increase in 30 years. Magnetic tapes are now available for 1GB/$1 range with an expected life of 10 years. Optical tape holds forth the promise of very large capacity in a single media unit, fairly great information volume density, and very low cost per GB. One optical tape/cassette is equivalent to 250 to 500 magnetic tapes such as IBM 3480 cartridges. However, optical tape technology is only now beginning to show commercial potential. Although revolutionary media such as optical tape storage systems, holographic storage devices, and biological storage such as Halobacterium have not proved commercially viable yet, the prospects of tremendous capacity increases with retrieval and transfer speeds orders of magnitude faster than today appear to be within reach.

Considering the impact of mass storage technology in promoting information growth in global economies of the world, the United States needs to maintain its leadership position and technological edge in this field. This technology assessment leads to two sets of recommendations to achieve this goal. From a short-term perspective, the federal government should:

1. Develop a long-term strategic plan to maintain the technological edge of the United States in high-capacity storage systems.
2. Require agency CIOs to collect annual reports internally on data growth and related statistics (mounts, access, media, etc.) from all its internal organizations managing more than a TB of data. This information should be used to identify storage media at risk and estimate future requirements within the agencies but also across the government.
3. Encourage agency investment in hardware and software storage system migration to safeguard large volume data through effective, timely, lossless transfer of data from aging systems to the new dense media with minimum impact on the production systems. Encourage national exchanges of technical innovations and sharing of software performance by large repositories of data holders and support national storage standards.

In the long-term, the federal government should:

1. Establish a national goal and direct the next generation mass storage technologies towards building an affordable modular exabyte (1018 byte capacity) system. This system should be scalable, distributed, evolvable, and reliable.
2. Forge a strategic alliance of government agencies, industry and academia to maintain a vibrant research program in support of these critical storage technology goals.
3. Serve as a catalyst by promoting storage technology application demonstrations and test bed facilities that help vendors integrate software and hardware to stress end-to-end performance of their systems. The Government needs to develop opportunities for the industry to foster growth through vendor-clientele partnerships.

This technology assessment of long-term, high-capacity data storage systems identifies an emerging crisis of severe proportions related to preserving important historical data in science, health care, manufacturing, finance, and other fields. For the last 50 years, the information revolution, which has engulfed all major institutions of modern society, has centered itself on data - their collection, storage, retrieval, transmission, analysis, and presentation (P. Drucker, Forbes Magazine, 8/24/98). The transformation of long-term historical data records into information concepts, according to Drucker, is the next stage in this revolution towards building the new information-based scientific and business foundations

Central to the transformation of data into knowledge-based information is the understanding of how to preserve a long term archive of digital data that resides in mass storage systems. As these storage systems evolve through new software and hardware technologies of tomorrow, we need to ensure data survivability and reliability, as well as the evolvability of these systems, all of which pose technological challenges as formidable as the Y2K problem. However, unlike the Y2K problem, where a crisis is set to go off at a specific time, large capacity data storage repositories face a problem similar to the social security system in that the seriousness of the problem emerges after a decade or two. Briefly, the essence of the storage crisis can be stated as follows: since it could take a decade to migrate a peta-byte of data to a new media for preservation, while the life expectancy of the storage media itself is only a decade, it may not be possible to complete the transfer before a non-recoverable data loss occurs.

The information revolution has placed a great demand on the storage industry to develop media that can keep up with exponential growth at constant costs. Recent technology developments have given us the ability to store a peta-byte (8x1015 bits) of data into silos for under $1 million, about $1/GB for the media alone. This local capacity is large enough today to handle most of the demand for all known civilian systems except for a few large projects such as the Earth Observation System. However, the migration of a few petabytes of data to a new media for preservation or economy could take more than 10 years. Hence, the crux of the crisis: If it takes a decade to copy data to new denser media and the life expectancy of the new storage media itself is also a decade, then one may not have time to save all data on the new media.

Unless major breakthroughs in the speed of I/O transfers occur or new scalable transferring processes are developed, it may not be possible to permanently store all data collected in the future. Even if the process of migrating key information starts as soon as new storage media becomes available, the old storage media need to have a life expectancy of at least twice the time needed to transfer data in order to accommodate the explosive growth of our observational and computational systems.

This past decade has seen microprocessor speeds increase according to Moore's law from 10MHz to 1000 MHz, more than a 100-fold increase. Storage densities have also increased from 200 MB to 20 GB and to more compact 4 x 4 in. magnetic cartridges. Unfortunately, data transfer speeds have only increased from 3MB/s to 12MB/s in this same time frame, a four-fold increase. With the advent of high-speed robotic silos and software to manage these mass storage repositories, one would have expected the industry to have provided solutions to the data transfer rate problem as well. Unfortunately, data transfer rates are only one of the problems faced by the mass storage user community; other problems involving performance issues, information security, and portable database software methodologies offer other daunting challenges to pushing the technology envelope.

A storage crisis perspective

Over the last two decades, a number of situations have occurred where vital scientific and business data were lost or would have been lost if not for major expenditures of resources and funds to save this data, much like what is happening today to solve the Y2K problem. Data loss can be prevented with better data management and investment strategies by computing center managers. Unfortunately, computing centers and data repositories find it easier to obtain funding towards meeting their growing computing requirements than investing in newer storage technologies. A number of anecdotal examples can be cited to demonstrate the significance of data losses that could have been prevented with timely investment in the mass storage technology industry.

One such crisis was experienced in the mid-eighties, resulting from technology decisions made earlier with respect to the storage of National Oceanic and Atmospheric Administration (NOAA) operational weather satellite data from TIROS N. This satellite carried two major data producing instruments, the Advanced Very High Resolution Radiometer (AVHRR) and TIROS Operational Vertical Sounder (TOVS). After nearly seven years of continuous operation, these data would have been lost but for a dedicated NASA/NOAA/Nationa Science Foundation (NSF) reclamation project at considerable inter-agency expense. The inter-agency project involved migration of the data from the terabit mass storage system (TBM) developed by Ampex Corporation, an industry leader in the 1970s. Ampex entered the large scale, high performance systems market in the early 1970s with a high speed tape system designed to hold one terabit of data and rapidly locate and transfer the data to supercomputing systems. Five systems were sold to the community, principally in the atmospheric modeling arena. The largest system was installed at NCAR, at a cost of between $1 million and $2 million, over a period of several years; another system was installed at NOAA for archival of TIROS N and future NOAA weather satellite data.

Ampex did not have a market for the product and eventually dropped support. The agencies that had purchased this equipment were left with their only copy of satellite data on this media with no operational backup. NCAR had the biggest system and was able to keep the tape drive hardware operational for the longest period. Later, NOAA shipped its system to NCAR for spare parts to maintain the archive. This provided NCAR the capability to recover critical satellite data when its systems failed. As a result, after 19 months, 88 percent of the AVHRR data and 49 percent of the TOVS data were rescued at a cost of more than $500,000. Despite the fact that some data were lost, the rescued data for the period 1979-1986 have enabled the preservation of a continuous 20-year data record for the study of global warming issues. Some of the notable scientific achievements that would have not been possible but for this effort include: the microwave sounder global warming studies by R. Spencer at Marshall Space Flight Center, a unique set of TOVS decade long sounding products by J. Susskind at Goddard Space Flight Center (GSFC), changing desert boundaries studies by C. Tucker also at GSFC, and many other such valuable studies.

Another prime example is the experience at CERN (European Laboratory for Particle Physics). According to a January 1998 article written by Mark Ferelli, one of the largest data collection efforts ongoing today is at CERN, the world's largest high-energy particle physics laboratory, occupying a 30,000 square meter facility in Geneva, Switzerland. One of the main problems faced by CERN is a Commercial-Off-The-Shelf storage management software solution. The solution must be scalable because their upcoming Large Haldron Collider will be generating petabytes of data along several paths at an average of 100 MBps. CERN generates one "event" per second, which creates either 2 or 0.5 MBps at each of the four large experiment sites. Total data collection from these four experiments is over 20 TB per year. The total data generation rate on all experiments in the facility may soon reach 200 TB per year, with a potential to attain a peak rate of 1 petabyte a year. All this data is captured on disk and moved off to tape cartridges. The scientists there are working to capture data they have on old tape formats. For six months, they have been copying 200 MB 3480 tapes onto the D3 (Redwood) media. They expect that at the end of four to six months, they will have migrated over about 150,000 tape images. At peak performance, they can copy over 1,000 tapes per day. When this is done, they plan to begin copying the 3490 tapes with over 20,000 tapes of 800MB capacity in the archive. CERN is faced with an endless task and has bought a variety of systems with no viable long-term solution in sight.

Finally, from our own experience gained at the NASA Center for Computational Sciences (NCCS) we can relate migration challenges faced at GSFC. Acquisition and introduction of an IBM 3494 robotic mass storage system into its production mass data storage and delivery system was completed in November, 1996. It had already reached the saturation point with its StorageTek subsystem, comprised of six robotic 4400 silos holding nearly 33,000 800 MB tapes. A major repacking effort of copying 200 MB tapes onto 36-track 400 MB capacity tapes, and later again onto 800 MB tapes had already been completed. With the indefinite delay in StorageTek delivery of its new "eagle" technology (20 GB tapes with a transfer rate of 12 MB/second), the NCCS had no choice but to purchase yet another robotic device, this time the IBM technology solution.

The NCCS began writing all new data to the IBM Magstar robotic subsystem in November, 1996. For a cost of nearly $250,000 the NCCS upgraded the remaining five StorageTek silos to faster robotics (2.5x), in preparation for mounting more than 33,000 800 MB tapes for repacking onto the more dense 10 GB tapes. Requiring more tape mounts to support an average monthly rate of 1.5 TB of new data into the system, the NCCS installed IBM Magstar tape drives in its StorageTek silos in August, 1997, Increasing the amount of data a silo can store twelve-fold.

In March of 1998, with the creation of a specialized software function for making a duplicate copy of existing data on a remote backup silo while simultaneously repacking that same data on the 10 GB Magstar tapes, the NCCS began in earnest to migrate off the 800 MB tapes. This migration/repacking and duplication effort is taking place simultaneously on the same production system that is still acquiring data at the rate of over 1.5 terabytes of new data a month and transferring over 200 GB of data into and out of the system daily. After four months of concentrated effort, the NCCS has been able to free up 3,500 800 MB tapes with nearly 3 TBs worth of data. To complete this migration effort of 35,000 800 MB tapes will require over three and one half year's worth of processing. The life expectancy of the IBM Magstar 10 GB tapes is 10 years; the NCCS will finish migrating 35,000 800 MB tapes by the year 2002, only to begin again the process of migrating off the 10 GB media at that point.

Storage growth

When we think of large storage requirements, we tend to think of large repositories at NASA, the Internal Revenue Service (IRS),the Central Intelligence Agency (CIA), or the National Security Agency (NSA). Other major users are associated with agriculture, forestry, banking, medicine, weather, surveillance, military, and entertainment. Mass storage requirements for many of these applications have grown dramatically for two major reasons. First, with doubling of clock speeds in chip technology and computer upgrades, there is an ever-growing demand for mass storage. Second, for many applications - particularly in earth sciences - ever-increasing refinement of spatial and spectral resolutions increases storage requirements in a cubic fashion. For example, at the NCCS facility, currently we have been experiencing a growth of 1.5 to 2 TB every month, with an acceleration factor of two for every instrument mission increasing in data resolution. Such stories of increasing demand are becoming common across a variety of applications.

Satellite remote sensing

Geospacial Information Systems (GIS) are the new horizon in Earth exploration (Reported at AFCEA TechNet 96 panel entitled, "Space Segment Data Providers - US Private Sector Sources" will have 10,000 commercial remote sensing systems in 95 countries (reported by L. E. Jordan III, president of ERDAS Inc.). Timeliness is critical because old information is bad information. Products set to launch in the next three years will downlink intelligent information of two-, three-, or four-dimensional images that a person can fly through, navigate through, query via the television, telephone, or computer in real-time to stations world wide. Data storage requirements for this kind of applications will be on the order of close to a terabyte per day.

Banking and finance industry

The government will be forced by an unnoticed provision of the recent budget compromise to abandon paper checks almost entirely before 1999. All one billion government checks written each year including Social Security, Medicare, and Medicaid, will have to be made through electronic transfers. Comparing this to the check processing volume load at Chase-Manhattan, which processes 150,000 checks daily, we can see that this will place an enormous burden on the imaging system for storing the checks digitally. A recent study predicts that the number of consumers who bank on-line will reach nearly two million by the end of 1998, up from 754,000 in 1995. By the year 2000, estimates are that there will be some 13 million on-line banking customers (A study by Jupiter Communications LLC in New York reported in Investor's Business Daily 10 Sep 96). The recent announcement that 15 banks will team with IBM to offer electronic services is the first signal that banks are ready to change the way they do business. The primary impetus for this shift is an aggressive move by the banking industry to reduce operating costs.

Civilian government applications

The National Archives and Records Administration (NARA) is in an unenviable plight. The cost of space alone to store the government's paper records required nearly half the agency's 1997 budget. NARA suffers from being caught in the middle of the transition from paper-based to electronic-based information. To further complicate this issue, in the fall of 1997, NARA was directed by Congress to implement their recommendations for the storage of electronically created documents. The policy had been to have agencies create a hard copy of the documents to store them for archival purposes until now. The new directive is to develop a plan to quickly migrate the archives to a digital media.

Military applications

The Pentagon established the Advanced Concept Technology Demonstration (ACTD) candidates for fiscal 1997, with information technologies for the battlefield leading the list. The ACTD program is designed to field advanced technologies quickly. For FY 1997, Rapid Battlefield Visualization with a 3-D view of the battlefield is the most important of the 18 projects. Commensurably, 3-D graphics performance will be increased 10 times over the next three years. Other military applications will develop as the data begins to accumulate from the effort in place to care for the nuclear test stockpile. For example, the Air Force Rome Labs has 350 TB on line and 20,000 TB (20 petabytes), of intelligence and imagery data off line. Since nuclear weapons can no longer be tested above or below ground, the explosions will be simulated on a Teraflop machine being built by Sandia, Los Alamos, and Lawrence Livermore. The data will be a national resource. One of the agencies involved is the Department of Energy. In concert with the support of this project, DOE has been a contributor to the development of the 1 TB cartridge optical tape system coming from LOTS Technology.

Medical informatics

The emergence of medical informatics as a new discipline is due in large part to advances in computing and communications technology, and to an increasing awareness that the knowledge base of medicine is essentially unmanageable by traditional paper-based methods. Tele-radiology is a clear example of strong growth in this direction. For instance, the typical mammogram results in a 2048 X 2048 image with 16-bit resolution; a typical hospital incurs a data rate of 10 Gbytes per day for mammograms alone. The FDA stipulates that the data can only be compressed using compression techniques with no loss of information, which hardly provide a compression level of five to six for mammograms. A quick analysis shows that a typical hospital attempting to store MRI, PET scan, mammograms and X-Rays can potentially experience a data growth rate of 1 TB a month. Unlike other fields in which data can eventually be discarded as duplicative or obsolete, medical data needs to be at least near-line and should be preserved forever for clinical experimentation.

World wide web: E-commerce

The emergence of the World Wide Web as the corporate and consumer information access medium of choice will combine with enhanced database software and new server and browser technologies to enable powerful data management services. Millions of people are traveling the Internet and using web browsers to retrieve information. The Internet soon will be the de facto medium through which people retrieve information. Over 60 million PCs are already Internet-ready and that number will grow to 265 million by 2000. Three years from now, over 82 percent of corporations expect to support fully connected internal networks.

How does this translate into data storage? First, consider that data files of the future will contain images and probably audio or video clips. This will translate into files that range from 1 to 1,000 MB in size. Second, assume that by 2000 we have 10 Mbps service to the home. Third, assume that a user wishes to retain the content of some information. Internet traffic through the five largest network providers and metropolitan-area exchanges exceeded 250 TB per month in 1997. Estimates put the Web at 50 million pages on 475,000 sites and the entire Internet at anywhere from 1 to 10 TB of data with typical Web sites averaging 10 to 20 MB of data. Will the choice be to store the data on-site or to leave the data at the web site? The question is: how much storage is available locally versus how long it takes to download the data. Add to this the most commonly cited problems associated with the Internet: speed (80.9 percent of users), organizing retrieved information (33.6 percent), and finding information (32.4 percent). Solving this equation will be an individual matter (user-pull) contingent on affordable systems (technology-pull). The eventual impact the Internet will have on data storage will depend upon the size of individual data files being transferred, the speed with which those files are transferred, and the cost of data storage.

The scientific community

Several scientific applications have experienced tremendous data growth. For instance, at the Thomas Jefferson National Accelerator Facility, on-line data increased in 1997 by a factor of five from 100 to 500 GB; this amount should double in 1998 to 1 TB and double again in 1999 to 2 TB. Over the same time period, near-line data increased by a factor of 30 from five to 150 TB; it should double in 1998 to 300 TB and quadruple in 1999 to 1.2 PB. At the same time, on-line data should increase by a factor of 20 from 1996 to 1999, and near-line data should increase by a factor of 240. This represents just one of the hundreds of national and international laboratories and research institutions which will be storing their data electronically.

In addition to the increase of total overall data storage requirements, there is an upward shift in the hierarchy of currently stored data. More data is being stored, and more data is moving from off-line to near-line; and from near-line to on-line. Some data bases will grow by gigabytes while others will grow 1 to 3 terabytes daily. Some data bases will grow to petabytes over time and data bases with 30 year retention requirements could grow to hundreds of petabytes. All of these data bases will demand a user-friendly software to accommodate potentially hundreds, thousands, or tens of thousands of user transactions per day without heavy operator interaction

Overall market growth

The worldwide data storage market in 1996 is approximately $100 billion including media and devices. This includes data, audio, and video applications, 40 percent of which are in the US. The computer data storage portion in 1996 is about $65 billion. The digital magnetic tape storage system market was about $7 billion in 1996. The magnetic hard disk market has been growing at the 25-percent level for several years despite large increases in bytes per drive and modest increases in unit volume (price per byte is declining rapidly).

There were 6,454 large tape libraries in 1994. With the rapid introduction of many smaller libraries, the total number of libraries is expected to increase to about 90,050 by the year 2000 for a compounded growth rate of 55 percent (1995 Freeman Associates Report). According to Fred Moore of STK in the 1995 yearly STK market report, over 600 petabytes will be stored on-line in computer-readable formats by the year 2000. Although this sounds impressive, it accounts for only five percent of the expected world's data by that time. According to LargeStorage Configurations, by the year 2000, each of the Fortune 500 will have over a petabyte of data. From Network Computing magazine**, the total storage at a typical Fortune 1000 site is projected to escalate from just 10 TB last year to 1 PB by the year 2000.

Only a decade or so ago, megabytes of storage were considered more than adequate for most large data centers. Then for several years gigabyte sized systems offered apparently unlimited storage capacity for almost any conceivable project. More recently, terabyte systems have become available for large data requirements. The growth of data storage needs has outstripped the impressive advancements in computer system performance and appears to require even larger and faster data storage systems. Recent articles in Defense Electronics and the Journal of Electronic Defense describe the growing need for petabyte storage capacities. A typical large data base system for U.S. government agencies is expected in the next five years to accept 5 terabytes per day, be able to maintain 300 terabytes on-line (within 15 seconds to one minute access time), and be able to archive from 15 to 100 petabytes. These large government systems are expected to presage an analogous requirement in the commercial sectors.

Assessment of technology

Undoubtedly the mass storage systems have been experiencing impressive growth in technology in many areas including storage density new forms of storage media, though relatively a smaller level of progress has been noticed in other areas such as access speeds. To provide a comprehensive perspective, we begin with the storage technology of the past.

Storage media in the past:

GSFC opened its first science computing center in the basement of building 1 in July of 1960 with a IBM 7090 using 200/556 bits per inch 7-track tape drives. These tape drives were upgraded to 200/556/800 BPI capability. In 1965, the IBM 360 systems were introduced to the GSFC Community. Tape compatibility was maintained; both the 7-track tapes and 9-track 800/1600 bits (or bytes) per inch tape were used. Toward the end of 1960, it was noticed that tapes which had not been used for several years had deteriorated significantly to the point where, in the worst case, the media was dissolving into its original components. This process resulted in damaged tape drives, as well as the loss of science data that, in many cases, had not been backed up. In the 1970s, the tape subsystems were upgraded to STK 1600/6250 BPI drives with much higher reliability. The computing center, in conjunction with the NASA Science Systems Data Center (NSSDC), led an effort to have the science community voluntarily move the data off of the older media to the new tape system, an effort that met with mixed response. Much was saved in this process; other data were lost.

Magnetic tapes have been around for about 50 years and still are the preferred digital storage media for long-term archiving. In the last decade, removable disk storage has become another contender for long-term storage as their costs have come down with increasing capacities. The three probable governing factors for the choice of magnetic tapes are (i) cost in terms of bytes per dollar, (ii) survivability and (iii) technological evolvability to increased storage density per unit volume. Its major deficiencies result from imposing sequential access thereby limiting scaleable I/O transfer rate increasing in performance as density increases. Magnetic disks of varying size, optical disk, CD- ROMs, optical tapes and other media have been tried by various communities but have not yet gained wide acceptance over magnetic tapes. For the last 25 years of electronic computing, 7- track magnetic tapes of 800 bits per inch and 2400 feet of length were the standard format for the data storage industry. Standards have been put into place by most major manufacturers that built tape controllers. The tape media has evolved over time to 9-tracks with 1600 BPI and then to cartridges with more tracks and denser storage. Today a single cartridge can hold 10 GB on 128 tracks compared with the 1960 vintage tapes of less than 1 MB capacity, a 10,000 fold increase in 30 years.

Current storage media

The NCCS is currently using 3480/3490, Magstar, and Redwood tape storage media in climate-controlled autonomous access silos. This system eliminated human errors (i.e: mishandling; tape label errors) from the media managing process, and it was believed that this would eliminate the largest source of error from our mass storage system. Operationally, active long term data storage systems have a number of challenges that can introduce some potentially catastrophic errors. The initial 3480/3490 technologies were designed to be used on IBM mainframes using the IBM flagship operating system, MVS. This system has capabilities not currently available on the more cost effective Unix systems, such as tracking temporary failures and notifying operations when a tape needed to be replaced before it failed permanently. We now experience as many as two hard failures a month with a total activity of 30,000 tape mounts per month on average. Depending on the needs of the community, some tape media may be much more active than others. This also is harder to track on the present operating system. Tape drive maintenance is critical, a failing or out-of-adjustment drive can introduce permanent failure to new data or destroy existing data media. Good environmental control and protection from physical damage such as leaking roofs or failing sprinkler pipes is critical. Coordinating multi-vendor shops to assure that IEEE standards are met and interpreted in the same way is necessary to maintain data integrity. Instances of differing interpretation, while not common, can be problematic. The process of unobtrusive (to the science community) upgrades introduces a new level of complexity necessary to meet the growing, near exponential demand for storage. The NCCS presently has three types of media - 3480/3490, MAGSTAR, and Redwood - each with several densities or size of tape available. The 3480/3490 has the capacity of 200 MB, 400 MB, or 800 MB on a tape, presently most are 800 MB. The Magstar is 10 GB. The Redwood is 25GB or 50 GB per tape. The age of the media and activity is:

Type	Age	Percent of Mounts
3489/3490	4-5 years	45
Magstar	1-2 years	45
Redwood	1 year	10

The NCCS computing facility is backing up the active data on the Redwood equipment located in the EOS Building 32, a half a mile from the main computer center in building 28.

The NCCS has the problem of replacing the HP/Convex 3830, a Y2K non-compliant system now five years old, to assure that members of the user community do not experience any impact on their work. The NCCS is evaluating four other vendors' data servers and will be evaluating several alternative operating systems to replace the Unitree system that currently manages the data. Computing center management has a good track record for benchmarking upgrades. Because other computing facilities are in the process of doing similar changes the possibility of problems is reduced greatly. For active growing data storage facilities the evolution of media, supporting hardware and software has to continue in order to support the community dependent on it. The facility must maintain its inventory of people skills to enable this process.

Future storage media

Data storage technology is now allowing higher density storage with faster speeds and lower costs than ever before. At the same time, more data storage technologies options exist now than ever before. Types of media technology can now be chosen to best suit the applications for which they are intended. The choices are exciting, but for our purpose we will focus on magnetic tapes and optical media. As pointed out earlier, magnetic discs would be a viable option for long-term storage if the costs were to come down a factor of 10 or more. It is conceivable that this will occur in the next few years, since this technology benefits from leveraging the mass market for PCs.

Short-term technology outlook

The infusion of new technology into linear tape systems provides new life and a continued migration path to higher area density and capacity. Track-follow servos and MR (thin film magneto-resistive) read head technology are easily applicable to all forms of linear tape technology. The 3480 was the first to introduce MR head technology to any magnetic data storage system, nearly a decade ago.

Choosing a magnetic disk drive (MDD) has never been easy. There is a constantly changing product line brought on by rapid technological advantages. And while the dizzying pace of MDD technology makes products "obsolete" sooner, it also provides a myriad of choices. You will always wish you had more storage space. We expect these technology improvements to continue for the next commercial market.

Optical tape holds the promise of very large capacity in a single media unit (cassette or reel), fairly great information volume density, and very low cost per MB. The generally long access times have been improved and are really not a problem in some sequential types of applications, such as entertainment presentation (audio and video) and data archiving.

Compared to magnetic tape, optical tape offers orders of magnitude greater capacity per media unit. In fact, capacity comparisons with virtually all other storage media are impressive. One DOT cassette is equivalent to 250 to 500 3480 cartridges. One reel of tape for one system holds the data of 5000 conventional computer tapes, 100 12-inch instrumentation tapes, or 2000 5.25-inch optical disks. Optical proponents also feel that their media will last much longer in archives. Tests appear to confirm advantages of optical over magnetic tape with regard to aging and sensitivity to environmental deterioration. Use of the popular 3480/3490 format for the LaserTape system will certainly be advantageous for both users and manufacturers trying to establish a marketplace. Because the manufacturing cost for optical tape should approximate that for magnetic, whereas the optical storage density is far greater, the media cost per capacity unit will be far lower. In fact, optical tape media cost appears to be lower than that for any storage competitor at this time.

Optical tape technology is not yet demonstrated to be commercially competitive for our purpose. It is worth sharing some previous experiences in waiting for new technology to arrive. In 1984, large scale government systems managers waiting for new technology but under pressure to provide more storage space immediately for use by their high speed processor customers received a gift in terms of an announcement several days before Christmas. A major manufacturer of storage devices withdrew from the optical disk market after promising for years the delivery of these optical disc storage systems. These systems had been undergoing beta testing at supercomputer centers such as NCAR for several months when the vendor withdrew the technology from the marketplace because of the difficulty in manufacturing the large 14-inch media platters. The failure of this promised upgrade path delayed the introduction of optical disk systems for large-scale use by five or more years. However, optical disk drives find their biggest success in the international industry. For the sake of comparison, not all the numbers provided by the manufacturers are credible, and commercial success at this point is at the PC level and not applicable to our purpose.

Generally speaking, the 12-inch optical disks should hold 60 GB in a dual-head format while the single-head 5.25-inch are scheduled to reach 10.2 GB. On the small end, the 2.5-inch optical has caught up with the 3.5-inch optical and each hold 640 MB. Pit depth modulation technology will triple the DVD technology after it tops out at the turn of the century. Tapes will reach 1 TB in a 3480-type format using laser optical media. Magnetic tapes can reach 660 GB in a single large-format cassette, while the small 4 mm may find a comfortable market niche at the 12 GB level. The 8 mm from Sony and Exabyte will top out at 100 GB and 300 GB respectively. Other improvements include partitioning and the addition of the MIC chip.

Long-term technology leaps

Over the next 15 years, scientists will narrow the width of lines etched into semiconductors to less than one-tenth of a micron, meaning that electrical signals running through those circuits will contain so few electrons that adding or subtracting a single one could make a difference in the computer's functions. To control the movements of very small groups of electrons, researchers are developing quantum dots that can corral rambunctious electrons, allowing them to escape only when zapped by a precisely sized boost of energy from outside. Such "quantum confinement" could lead to tiny, very high-powered lasers that could make it possible to store 15,000 times more data on a computer chip the same size as those produced today.

Current nano-technology storage capacities available are 125 MB/in2. The National Storage Industry Consortium (NISC) is hoping to have production units at a level of 1.25 GB/in2 by 2000. This should be reachable because there has been a 60 percent growth per year for the last 5 years and if the trend continues, by 2005, the capacities will reach 12.5 GB/in3 and 125 GB/in3 by 2010.

Holographic storage could reach 125 GB/cm3. In principle, this technology is fairly established. Unfortunately, there are no good recording mediums, the holograms are hard to stabilize, and the laser beam is hard to steer. The file maintenance system is difficult, and as more holograms are added to the system, the older ones fade. Finally, holographic materials offer a low defraction efficiency. Emerging 3-D two-photon photochromatic storage technologies are being funded by Rome Laboratories and developed by the University of Southern California - San Diego that will read pages of data stored in a cube format. 3-D storage cube technology cannot be realized until some of the components reach maturity. The impediment to implementation has been that no one has found a suitable medium that is sensitive to light so that it does not require a high powered laser to etch the hologram, yet stable enough that it does not deteriorate. In addition, the medium should also have a high signal-to-noise ratio. In short, the medium material for holographic storage is a physics and chemistry problem yet to be solved.

Presently, the Earth and Space Data Computing Division (ESDCD) at GSFC is sponsoring research in this area at the University of Maryland - Baltimore County (UMBC). Specifically, UMBC Professor M. Hayden has recently been successful in storing a rather permanent hologram in a polymer matrix that he designed. This arrangement yields a permanent storage because the 675 nm recording light beam actually breaks some molecular bonds in the dye. The medium is said to be photochomic. Subsequent illumination with the same beam for many hours does not alter the hologram, and, in this sense, the image is termed permanent. Hayden has also been successful in temporarily storing a hologram in the same polymer matrix which is sensitive to a longer wavelength of 800 to 900 nm. This medium is said to be photorefractive, and the recording light will erase an image in a few tens of minutes. Thus, by virtue of this polymer research, he is now able to permanently store images at the shorter wavelength and also storeerasable images at the longer wavelength in the same medium.

Another holographic storage solution sponsored by the ESDCD is that of multiplexing data in the medium. This is a systems engineering and data encoding problem; we know we can do it, but we much search for the best method to optimize the process and achieve an acceptable bit error rate. In this area we are using the NASA Small Business Innovative Research (SBIR) program to fund Optitek, Inc., which is exploring an innovative, proprietary parallel optical architecture to multiplex holograms angularly into the same photorefractive crystal volume - a design breakthrough if successful. Optitek will be delivering a holographic storage device to the ESDCD for evaluation inthe near future. Additionally, with SBIR funding, both Optitek and Arizona State University are studying how to optimize multiplexing schemes with regard to output signal-to-noise by a global encoding of the stored data. Another important area of research of critical components necessary to holographic storage is that of advancing the technologies associated with input/output devices such as spatial light modulator and charge coupled devices (CCDs). This technology development is already well funded by industry, which will use these devices for other purposes. For example, spatial light modulators are the basis for flat-screened TVs and CCDs are used in CamCorders and all sorts of scientific instruments.

Electron etching on HD-ROM (High Density - Read Only Memory) storage media was demonstrated by Los Alamos National Laboratory (LANL). The technology incorporates the ability of liquid-metal focused electron-beam milling in an ultrahigh vacuum to achieve feature and hole aspect ratios on the sub-micron (nanometer) scale. The method developed by LANL uses a Focus Ion Beam (FIB) micromilling process for storing data in one of three different formats: 1) binary (image) at densities of 2.9 GB/in2, 2) alphanumeric (ASCII) at optical or non-optical densities, and 3) graphical (video) at optical and non-optical densities. This media may carry all three formats and thus increase the utility of the recorded media. Using an electron beam that is 150 billionths of an inch wide to record on a 10 micron-thick steel tape could result in a storage capacity of 50 TB/in3. If a 3 µm tape were used, the capacity goes to 190 TB/in3. The projected migration path is 100 GB/in2 by 1999 and 400 GB/in2 by 2003. The practical limit is reported to be 1.4 TB/in2. Read and write speeds are 2 GB/sec and 4 MB/sec respectively with 200 millisecond access time. This technology is now being promoted by Norsam Technologies, and the first demonstrated product was shown at the AIIM show in May 1998. A 2-inch metal disk had been etched with 90,000 analog images. Each page was 100 x 200 microns and each letter was 1.5 x 2 microns. The image could be viewed through a powerful microscope developed by IBM, and viewed on a computer screen, printed or transmitted. This shrunken version of microfilm represent 9 four-drawer file cabinets or 4.5 GB. The next product should be ready by 2000 and offer 165 GB on a single 5.25-inch platter.

Biological solutions are on the horizon as well. Researchers are considering storage mediums based on the phosphorescent properties of Halobacterium found in the lagoons off of San Francisco Bay or in the iridescent covering of jelly fish. Much like promises of organic computing, it remains to be seen how far these promising technologies are commercially viable.

Recommendations

The mass storage arena is facing a crisis of severe proportions that merits attention at the national level. Considering the impact of mass storage technology in promoting information growth in globalized economies of the world, U.S. needs to maintain its leadership and technological edge in this field. A compromise in its investment on mass storage technologies could spell disaster not only for the scientific community but also could result in loss of critical information to the commercial sector. Industry invests in new technology based on incremental demand-supply relationships and the promise of high returns in relation to the investment. The Government has a clear near-term need that could lead to a long-term demand and thus should play a critical role similar to that played in high performance computing, i.e., of a catalyst and a ready buyer to stimulate growth.

Short term recommendations

Considering the impact of mass storage technology in promoting information growth in global economies of the world, the US needs to maintain its leadership and technological edge in this field. This technology assessment leads to two sets of recommendations to achieve this goal. From a short-term perspective, the Government should:

Develop a long-term strategic plan to maintain the US technological edge in high capacity storage systems.

Require agency CIOs to collect annual reports internally on data growth and related statistics (mounts, access, media, etc.) from all its internal organizations managing more than a TB of data. This information should be used to identify storage media at risk and estimate future requirements within the agencies but also across the government.

Encourage agency investment in hardware and software storage system migration to safeguard large volume data through effective, timely, lossless transfer of data from aging systems to the new dense media with minimum impact on the production systems. Encourage national exchanges of technical innovations and sharing of software performance by large repositories of data holders and support national storage standards.

Long term recommendations

From the long-term perspective, the government should:

- Establish a national goal to develop the next generation mass storage technologies towards building an affordable modular exabyte (1018 byte capacity) system. This system should be scalable, distributed, evolvable, and reliable.
- Forge a strategic alliance of government agencies, industry and academia to maintain a vibrant research program in support of these critical storage technology goals.
- Serve as a catalyst by promoting storage technology application demonstrations and test bed facilities that help vendors integrate software and hardware to stress end-to-end performance of their systems. The Government needs to develop opportunities for the industry to foster growth through vendor-clientele partnerships.

In summary, the untamed growth in information storage and exchange is a harbinger of a looming crisis similar to the Y2K problem. This problem deserves early attention to preserve all the valuable historic data sets in science, medicine, commerce, and industry.

This paper is in response to a request by the NASA Associate Administrator/OES to assess the long-term high-capacity data storage media and system-related issues of the ability of data storage systems to survive, be reliable, and adapt to changing needs.

*Raytheon ITSS Corporation

** Fred Richardson, "Windows NT Storage Management," Computer Technology Review, Vol. XVI, Number 11

Questions or comments on this white paper should be addressed to Milt Halem at <milton.halem.1@gsfc.nasa.gov>.

Learn more about the ESDCD at <http://esdcd.gsfc.nasa.gov/ESDCD/>. ■

The Astrophysics Multispectral Archive Search Engine

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The importance of multi-spectral research in solving fundamental problems in astrophysics is undeniable. It is generally advantageous, for example, to use multi-wavelength observations to interpret a class of celestial objects. However, NASA archival data are usually not organized to support multi-spectral research. The data are products of space missions and are stored in the archives according to mission-specific parameters, in disparate mass storage systems and in different formats. This makes it quite challenging to locate data for research that cut across mission or spectral boundaries. The Astrophysics Multispectral Archive Search Engine (AMASE) aims at providing a uniform multi-mission and multi-spectral interface, enabling global searches of these heterogeneous, distributed data holdings using astronomical classification and complex spatial queries. You are able to locate relevant mission data for research without detailed knowledge of the missions beforehand.

Design and implementation

AMASE uses object-oriented data base (OODB) techniques to "merge" astronomical data from heterogeneous sources. These techniques encapsulate the existing data, metadata, and associated documentation and bibliography into an abstract Astronomical_Object. The flexibility and modeling capability of OODB allow for diversity and complexity within a common framework. The relationship between objects can be captured in the database schema and implemented at the time of data loading. The Astronomical_Object can be characterized by very complex and rich data types, and can take on multiple classification to reflect both its intrinsic scientific nature and the instrument parameters connected with scientific data acquisition. The Astronomical_Object acts as a `directory' pointing users to, for example, the catalogs in the Astronomical Data Center containing information about the celestial object and the mission data in the distributed archives with different observatory-instrument settings. When you query for science data, the search criteria are issued against the scientific parameters of the Astronomical_Object while the response is given in terms of mission data descriptors. The mission data descriptors identify the relevant mission data sets and give the archive location and retrieval information. In this way, AMASE provides a scientific view into the distributed data archives without changing the existing underlying mission-oriented structure.

AMASE is implemented using the commercial object-relational product Informix-Illustra DBMS. It offers the dual advantages of an OODB and a relational database, with complex and user-defined data types that are not normally supported in a relational database, a standard SQL non-procedural query language, the robustness of a storage manager, a query optimizer, and the maturity of the technology provided by relational systems.

Building the knowledge base

To support queries using scientific parameters, AMASE must first build an astronomical "knowledge base." The domain knowledge needed to describe modern astronomical classification structure is captured from experts in the different disciplines. The heritage and relationships of different mission data products are likewise captured from the appropriate mission scientists. Once the basic classification schema is defined, the knowledge base is populated with valid astronomical measurements. These are generally available in published astronomical catalogs and can be captured by automated procedures. But, naturally, the data in the knowledge base will be subject to revision in the course of scientific inquiry: new data will be acquired from future missions, new object cross--identifications will be made, resulting in a better understanding of physical phenomena, and possibly, a new object classification scheme. So a mechanism for incremental buildup of knowledge and subsequent knowledge evolution is built into the AMASE architecture, enabling it to become a true search and discovery engine.

Loading an OODB is much more involved than loading a relational database. Correlations between objects are created and maintained by the database at load time. Linkages are represented by object identifiers (OIDs) in the database. The team choose to use common astronomical names as the cross-catalog and cross-mission OIDs in AMASE. The dual use of astronomical names to refer to celestial objects as well as database objects provides a friendly user query mechanism. The OIDs are often not available when the load file is written, because the detected sources of an observation are not yet identified. In such cases, the semi-automated bulk loading procedure will create incomplete objects with surrogate identifier when observations are first loaded, then complete the object by adding correct pointers to the relevant astronomical characteristics when the target is identified. The team is building incremental bulk loading utilities and user utilities to support updates of object characteristics, to "merge" objects upon positive cross-identification, and to separate objects into components when they are resolved by high-resolution observations.

Accessing remote databases

The major archive sites of the NASA astrophysics missions are geographically distributed. Their data holdings are frequently updated as new observations are taken and new data are released to the public archive. AMASE must provide access to data at these archive sites and maintain current information about their data holdings. The schema of each remote archive database is first mapped to the AMASE schema. Then a small but sufficient amount of metadata is ingested to create a "partially materialized" view (Roussopoulos et al.1993) in the AMASE database. An alternative is to create "virtual" object in AMASE that is "pointer-based" and populated with references to the data values and locations in the remote archives (Roussopoulos 1982). Batch updates of these derived views are carried out by a special utility built using the Sybase Gateway of the Informix-Illustra DBMS.

Query capabilities

There are two main ways to query the AMASE database: by object name and by position. The query by astronomical name illustrates the advantage of an OODB implementation. Since all information that pertains to a requested object is linked at load time, the execution is very efficient. The positional information is returned as part of the search result and is not used at all during the search.

To efficiently process queries based on spatial position, spatial indexes are built on every database object that contains spatial attributes. Packed R-trees (Roussopoulos & Leifker 1985) are used to significantly reduce the search selection set and the team is extending their use to support the spatial ordering of objects and data discovery based on object position.

Since there is no "natural" ordering of multi-attribute data, especially spatial data, results are returned in the order they are retrieved from the index. To obtain the result based on "closeness" to the query object, most query implementation will select the data first, write the results to a temporary object, then sort them for presentation. But the cost in time and space for this approach will be prohibitive for queries with a large number of results. To address this issue, a "K-Nearest Neighbor" access method is being developed that will generate and return the K objects closest to a given spatial position in order (Roussopoulos et al. 1995).

Future work - data discovery utilities

A principal goal of AMASE is to support astrophysics research by providing a position-based "data mining" facility. The first implementation of this facility will support field-of-view (FOV) correlation.The team would use an instrument FOV to scan through the AMASE database to extract information for off-target objects, correlate them to other data (from other catalogs/observations) via spatial (primary) and other attributes, then present the results to a scientist for review.

Other data discovery utilities include view-caching and user-defined types. Query results can be cached into the database and used for repetitive queries and/or refinement. An astronomer can build his/her own profile of interested objects from the database. Results cached in views can be accessed much more rapidly as they are compact and require a much narrower search. To support user-defined classes, the system must have a utility to rearrange the class hierarchy and its implied inheritance, and to assign object identifiers to newly derived class object. The team plans to use "materialized views" as the mechanism for supporting user-defined types (Roussopoulos 1991, Roussopoulos et al. 1993). Part of this work was funded by an earlier NASA AISR grant.

Summary

The AMASE prototype is currently populated with selected data products from six NASA astrophysics missions, as well as various astronomical catalogs. Users can search for information by specifying either object name and/or various positional information. The search can be further qualified by selecting the object type, the spectral region and the mission. Sorting and visualization capabilities will soon be available through the ADC Data Viewer <http://tarantella.gsfc.nasa.gov/viewer>.

In the coming year, the team shall provide the capabilities to interoperate with other data archives and develop utilities for user-defined views, positional data mining, and object cross identification.

AMASE is funded by the NASA Applied Information System Research Program. It is developed jointly by the NASA GSFC's Astrophysics Data Facility and the University of Maryland Institute of Advanced Computer Science.

This article was originally presented as a paper at ADASS'98 on November 4, 1998.

Learn more about AMASE <http://amase.gsfc.nasa.gov/>.

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NISN's Fourth Customer Forum

NASA Internet Science Network (NISN) recently held its fourth customers' conference to report current status, present new and future technology, and provide users with a forum for feedback. Discussions, presentations, and demonstrations included topics on web caching, high performance peering, voice and video technology investigations, ATM QoS, mission high rate data, technology flow, network security, and NISN policy, management, and service.

Beth Paschall, Customer Interface Group (CIG) team member, began the opening session with welcoming remarks, after which the NISN Project Office Manager, Rick Helmick, presented NISN's highlights (support for space flight, conferences, Russian requirements, space sciences, and NASA's education projects), general accomplishments (the transitioning of the IP backbone to ATM, the elimination of the mission x.25, metrics development, and consolidated circuit procurement via PrISMS), and current challenges. Following Helmick, Deputy Manager, Brad Torain, explained the NISN organizational hierarchy, Kathy Hatley, of the Network Services Group, provided an overview of network management and operations, and Matthew Kirichok, Special Staff-Security, spoke on NISN security policies.

About NISN

NISN is the result of the consolidation of the management responsibility for the various NASA wide-area telecommunications networks under a single organization. These networks were formerly known as:

- PSCN - Program Support Communications Network
- Nascom - NASA Communications Network
- NI - NASA Internet (formerly NSI - NASA Science Internet)
- AEROnet - Aeronautics Network
- EBnet - Earth Observation Data Information System (EOSDIS) Backbone Network

There are currently two Network Operations centers: Marshall Space Flight Centers NASA Information Support Center (NISC) and Goddard Space Flight Center's Network Operations Management Center (NOMC). NISC is the overall operations center and is primarily responsible for voice, fax, routed data, international services (including Russian services), video, and COMSEC. NOMC is the day-to-day interface for mission-related services. Trouble calls are accepted at either center, where they are assigned appropriately by a tracking system that is shared by both NISC and NOMC. The center with primary responsibility then interfaces with the customer. Activity requests and outages are worked through the two centers and are acknowledged and handled according to policy. Standard Operating Procedures (SOP) to formalize these processes are currently in internal review.

NISN security is ensured by technical and administrative security teams. The technical team is responsible for day-to-day operational backbone security, providing network traffic monitoring, incident summaries, and metrics for trend analysis. The team also monitors "hacker" newsgroups for the latest developments in hacking and security issues. The administrative team performs network design and provides engineering security support by preparing and maintaining policies and procedures, conducting audits, and collaborating with other government agencies. NISN security teams work with customers to install detection systems and to correct problem areas.

Services update

The following is a synopsis, as presented by Scott Douglas, of the Network Services Group, of current services:

Mission voice

The Voice Switching System (VSS), located at GSFC, is the network hub for all mission voice conferences, and is Y2K compliant. Metrics taken over a three-month period show the system handles 67 full-period conferences on any given day.

Mission routed data

The IP Operational Network (IOnet), is managed out of GSFC's NOMC, supports Mission Critical and Real Time Mission Critical Routed Data Services. Its IP Transition Segment also supports Multicasting.

The SN cutover to UDP/IP Packets (which allows multicasting) was October 7th and the GN cutover was from October 8th through November 30th.

Note: The Space Network MDM Broadcast and the Message Switching System were both taken out of service on 1/4/99, completing the Transition to IP.

Mission support routed data

A permanent router is being installed to support peering with BNS (a Department of Energy program) at Ameritech in Chicago. This allows NISN access to a variety of universities without having to provide direct lines to them. Peering with Sprint helped establish 10Mbps Virtual Circuits to MSFC, GSFC, and ARC.

Standard and premium routers were transitioned to ATM service at NASA HQ. ATM at KSC will be rolled into a single SONET ring, and rolled directly into the Sprint Backbone at ARC. EBnet has also been transitioned to ATM. Upcoming ATM locations are at DFRC and the University of Colorado (in Boulder, Colorado). A ROM study to establish ATM at SSC has also been conducted.

Ordered Telecommunications Service Priority (TSP) will result in higher priority in service restoration, and will apply to all existing and future ATM services.

"Best Effort" routed data services are being considered, which would allow NISN the option to contract out for standard data services (via commercial ISPís or through a collaborative effort). This would be offered as a cost option (with an appropriate service description) for all networking requirements. It would cost less and be less complex to implement, but a higher risk factor is involved due to lack of service guarantees, increased difficulty in trouble reporting, and lack of performance management metrics. This most definitely would not be used for mission critical data.

Facsimile service

The current fax contract with Pitney Bowes is the lowest cost contract in the US and has a four hour nationwide response time. NISN provides service management and trouble resolution expertise, and maintains interoperability standards and software upgrades.

The current standard being offered is the model 9920, with a 9930 model with a high-speed 33.6k modem also available. PB confirmed they will continue maintenance support for all existing 9300 models, and they are discussing replacement costs and methods much as they did earlier with the 9200 models.

Broadcast Fax service has been successfully outsourced to MCI. NISN provides billing management, metrics, and problem resolution. Broadcast fax is still heavily used, particularly by the Shuttle and Public Affairs offices.

Limits on facsimile machines are set by the individual centers. The industry standard is for one fax per 20 people in an office. Currently, NASAís ratio is one fax to every 12 people.

Voice teleconferencing

NISN has contracted with MCI to begin offering "Meet-Me" Voice Teleconferencing, where users would be given a toll-free number and password to access a teleconference. The conference leader, who notifies all participants, arranges scheduling. To arrange a teleconference, call toll-free 1-888-707-NASA (1-888-707-6272). NISN will need to know how many ports are needed for each conference, but charges will only be on ports utilized. An MCI trouble number for trouble resolution will be provided in the conference confirmation.

Reserved Voice Conferencing will continue to be offered. All reserved teleconferences with five or more participants will be arranged by the NASA Teleconference Center, which will send e-mail validations as reservations are made. Trouble resolution for reserved conferences is via the MSFC NISC at (256) 544-1771.

Video teleconferencing

Improvements to the ViTS system have been made in the form of audio quality and switching, and upgrades of room controller systems (which are complete at rooms MSFC1 and KSC1, and will be scheduled for others).

The new Video Conference Room Scheduler (VCRS) was deployed to the web on November 2, 1998. VCRS includes not only ViTS but also Low Bandwidth Video sites, including the Russian sites. Use this system to schedule a room first, then, if necessary, call FTS2000 for network resources.

A trial video user survey will be set up on the web.

Ongoing Video Conference activities include the evaluation of other vendors (MCI, InView, and FTS2001), as well as a draft study of bridges with advanced features.

Advanced technology

The goals of the NISN Technology Program are to ensure NISN is positioned to meet all requirements; investigate new technologies, work to infuse NISN services with new capabilities, and collaborate with other advanced networking initiatives. The following is a synopsis, as presented by Chief Engineer, Dan Scott, of new technology. NISN has formed relationships with the following:

Next Generation Internet (NGI)

NGI is a multi-agency federal R&D program to develop new networking technologies in partnership with academia and industry. Its goals are to promote experimentation with new networking technologies, develop new applications to meet important national goals and help move them from the research to the operational arena.

NASA Research and Education Network (NREN)

NREN is the NASA component of NGI, and the primary networking technology group in NASA. NISN is the recipient in the technology transfer partnership. Two charts were shown, broken down by Enterprise and Program/Project: one with NREN applications currently in active research, and one with those applications still in concept definition, where users are being consulted and goals defined.

Space Operations Management Office (SOMO)

NISN supports various elements of the SOMO Technology Plan, including providing data and mission services to the NASA Enterprises (via High Performance Communications) and advancing US industry leadership in commercial satellite communications.

NISN is involved in several technology initiatives with other organizations and programs.

- With NREN, it has supported the ATM Quality of Service project, and studies for OhioView (data archive center), TReK (desktop videoconferencing) and Autogenics (Biofeedback).
- With NGI, it has submitted a proposal to host the NGI Exchange - East, and improved peering with NGI-Class Networks for both official and International Research.
- With Internet2, it has entered into peering arrangements with vBNS and potential participation in several GigaPOP's.
- With PCCA, it has done network modeling and collaboration on standards development and network impacts.
- With DTV, it has established schedules and standards for NASA migration to DTV. The DTV Working Group was also instrumental in determining user acceptability criteria for use of MPEG2 to support NASA video distribution requirements.

Internet 2

There are differences in NGI and Internet 2. NGI is funded by the Federal Government and uses state-of-the-art technology, while Internet 2 is funded by research universities and employs current practice technology. Both, however, will work together to ensure advanced services are available interoperably.

Overview presentations were provided addressing the following specific technology areas NISN has been involved in:

Web caching

- High Performance Peering
- Video Technology Investigations
- Voice Technology Investigations
- ATM Quality of Service
- Mission High Rate Data Studies
- Customer Interface Group

The Customer Interface Group (CIG) activities for FY98 included outsourcing the FAX Broadcast service, the introduction of "meet-me" voice teleconferencing, publishing standard service delivery intervals, support for the last NISN user form in Atlanta, and "best-effort" IP routed data service, currently under consideration via peering and ISPs. Future plans include maintaining customer focus during contract and service transitions, integration of NISN database systems, automation of NISN Service Request (NSR) tracking, support for existing programs, support of Full-Cost Accounting in FY01, automation of PSLA generation, and preparation for the next Customers' Forum in the summer of '99. The next generation of the NSR system is currently being tested. The customer satisfaction survey identified areas of concern, which were reviewed and discussed during the Forum. Also reviewed was the standard implementation process for both mission and non-mission Network Service Requests. An SOP for service implementation is being developed.

Breakout sessions

A variety of breakout sessions were arranged: mission ops, Earth Observing System (EOS), network ops and trouble resolutions, collaborative technologies, Canadian Space Agency, EOS/NASDA, CNES, NREN, and FY2000 Budget. During these sessions participants had the opportunity to exchange information and express concerns. Here are just some highlights from these sessions:

Collaborative Engineering Rooms, also known as Interactive Engineering Rooms, have three levels of functionality. The simplest, Level 3, is a computer and monitor with Net Meeting installed and a Smart Board attached. In the future this low-end configuration may be implemented in all standard conference rooms. Level 2 has the functionality of Level 3 with an added Venue 2000 PictureTel system, surround sound, and two room cameras. Level 1, which is still being researched and developed, has a Silicon Graphics workstation with a direct connection to a Cray, and is used for high-end projects. Five of these Level 1 rooms are planned for MSFC, Johnson Space Center, Kennedy Space Center, Lewis Research Center, and Langley Research Center. Recently during a visit to MSFC, NASA's Director, Dan Goldin, commented that this was the direction in videoconferencing the Agency should pursue.

On the telemedicine issue, Canada will provide its own flight surgeon for the Canadian space crews. During the ICD teleconference, CSA will discern the medical requirements needed for the Crew Health Care System.

Current data configuration between the US and NASDA contains 1.152Mbps for mission support (Ebnet), 576kbps for user services, 192kbps for Space Station, and 19.2kbps for voice service. Future mission requirements will necessitate increasing the mission essential data flow to about 3.1Mbps. Three scenarios have been developed to satisfy these requirements:

Move the standard routed data flows to TransPac, which would free that bandwidth on the T1

- increase the amount of bandwidth available
- use of the ATM Cloud

NISN is considering establishing a 128kbps IP connection to CNES to support the JASON mission from June 1999 through 2000. The next mission support requirement for the French is for the Mars Sample and Return mission in 2005. To handle the "worst case" scenario, one proposal is to upgrade the current connection from 512kbps to 768kbps.

To allow International Space Station science users to conduct their experiments from their home bases, the MSFC Mission Operations Laboratory is developing the Telescience Resource Kit (TreK), a low cost remote operational approach. This approach will provide to the end-user location: telemetry receipt and display, commanding, payload operational voice, planning video teleconferencing and down link video capabilities for a workstation cost, including hardware and software of less than $10k.

Excerpted from the NISN Web site report on the Fourth Users Forum. Images courtesy of the NISN Web site.

Learn more about NISN <http://www.nisn.nasa.gov/> and the Fourth User's Forum <http://www.nisn.nasa.gov/Forum4/HOME.html> and read the results of the customer survey <http://www.nisn.nasa.gov/metrics/metrics.htm>. ■

Frontiers '99: A Report

Jarrett Cohen, Science Writer, Raytheon ITSS, Goddard Space Flight Center

Editor's Note: Excerpts of several cited papers presented at Frontiers '99 will appear in future issues of the Science Information Systems Newsletter.

The Frontiers of Massively Parallel Computation symposia have surveyed high-end computing technologies since 1986. Seventh in this series, Frontiers '99, took place February 21—25 in Annapolis, Maryland.

According to Program Chair Ian Foster, senior scientist at Argonne National Laboratory and professor of computer science at the University of Chicago, it was "an occasion to explore the major themes that are going to be important in the next 10 years."

A highlight was a keynote address by Rice University's Ken Kennedy, co-chair of the President's Information Technology Advisory Committee. The Committee released their report "Information Technology Research: Investing in Our Future" the week of Frontiers '99, and Kennedy covered its major points. Among their recommendations is that the Federal government increase its support for information technology research by $1 billion per year by Fiscal Year 2004, doubling current investment. They also made software the top research priority, with productivity, reliability and security, and usability areas of greatest concern.

Observers view Frontiers ‘99 as having covered the "waterfront" of high-end computing. Two workshops delved into technologies that seek to make major performance gains over computers based solely on electronics.

Quantum Computational Science Workshop 1999 discussed applying ideas from quantum physics to the computational sciences, with the goal of "enabling new forms of communication, computing devices, and computational algorithms."

The Third Petaflops Workshop presented research on developing hardware and software capable of one million billion floating-point operations per second. Among the most promising efforts is the Hybrid Technology MultiThreaded (HTMT) architecture, which combines superconducting processors, memory chips with internal processing capabilities, optical communications, and holographic storage.

Petaflops also was the subject of a Technical Program panel, while a University of Delaware and Jet Propulsion Laboratory-Caltech paper addressed HTMT's superconducting processors.

Technical Program sessions touched on such topics as designing and optimizing software for Grand Challenge applications, detailing the progress of the Department of Energy's Accelerated Strategic Computing Initiative (ASCI), and comparing performance on vendor supercomputers versus parallel computers built from commercial off-the-shelf parts. There were two Goddard Space Flight Center papers about performance comparison, one on satellite image segmentation and the other on a regional climate model.

"Since our last gathering at Frontiers '96, there have been many applications successes on highly scalable systems, which bring up the issue of software complexity," said Frontiers Steering Committee Chair Jim Fischer, manager, NASA's Earth and Space Sciences (ESS) Project. New ways of managing this complexity are cropping up, and several were described.

Innovations in software engineering and programming languages are having an impact on high-performance computing usage. One software engineering approach is the framework, where large software codes are divided into collections of objects having flexible and well-defined interfaces. Researchers can then independently develop and improve modules for particular tasks or applications. In a paper, researchers from a NASA ESS Project-funded Grand Challenge team described their Cactus code for studying relativistic astrophysical phenomena. Among the code's uses is simulating neutron star mergers.

Modularity is a key feature of the Java programming language, which is gaining ground as an efficient way of developing large-scale scientific and engineering codes. As related by one presenter, a Java Grande Forum is working on these issues towards the goal of building a better programming environment than the more popular Fortran and C++ can provide.

"Java shows a lot of promise," Foster said. "Performance and numerical issues are being overcome to an extent."

General application complexity is another challenge being met with a variety of approaches. Procuring and using supercomputers linking thousands of processors for multiple teraflops (one trillion flops) performance, ASCI researchers have found they need larger research teams, upwards of 50 people to tackle a single problem. ASCI also has begun deploying data visualization corridors–collections of mass storage, visualization, and display technologies linked by high-speed networks–to help scientists better understand the huge datasets produced by their simulations.

Related to the corridor concept is the grid, automating distribution of computation to geographically separated supercomputers with available cycles. Among the grid-building efforts is NASA's Information Power Grid. Ames Research Center and Argonne National Laboratory scientists discussed how they maintained good performance on a computatio nal fluid dynamics application running on two supercomputers nearly 2,000 miles apart.

Frontiers 2000 is tentatively scheduled for October in Annapolis.

Learn more about Frontiers '99
<http://cesdis.gsfc.nasa.gov/frontiers/front99.html>. ■

Planetary Scientists Meet the Press

The "Planetary Scientists Meet the Press" workshop kicked off the activities at the 30th Lunar and Planetary Science Conference (LPSC) held at the Lunar and Planetary Institute (LPI) in Houston, Texas, the week of March 14th. Because scientists and journalists are key partners in informing the public about scientific discoveries and technical innovations, the workshop's goal was to foster more effective communication of scientific information to the public. Following this initial workshop, the conference focused on various topics of interest, such as the new evidence regarding the possibility that an ocean once existed on Mars. The conference, which was chaired by Carl Agee and David Black, was held at Gilruth Center and the University of Houston - Clear Lake (UHCL).

Technical sessions, held at Johnson Space Center's Gilruth Center, included oral presentations on continuing investigations of the Martian meteorites, results from the Mars Global Surveyor mission, discussions about astrobiology and origins of life in the Universe, findings about Jupiter's moon Europa, and goals for near-future Mars missions (the Mars Surveyor 2001 orbiter, lander and rover, and the European Space AgencyÌs Mars Express). A special plenary session featuring the Masursky Lectures highlighted the scientific and technical accomplishments made during the Galileo mission to the Jovian system. Scientists also previewed Cassini's exploration of the Saturnian system.

Special sessions included the Near Earth Asteroid Rendezvous (NEAR) flyby of the asteroid Eros, new views of our Moon by the Clementine probe, and Lunar Prospector's mapping and measurements of the magnetic and gravity fields of the Moon's surface. New perspectives on Mars Global Surveyor results regarding Martian volcanism, possible lakes and oceans, the planet's polar regions and other terrain were discussed, as well as future missions to understand how Earth-like planets form and evolve to become habitable. Poster presentations were held Tuesday and Thursday evenings at UHCL's Bayou Building.

Excerpted from NASA press release J99-6, written by Laura Rochon Johnson Space Center. Image courtesy of the LPI 30th web site. ■

"Images of Earth and Space II" tours the Solar System and outer space using scientific visualizations from Goddard Space Flight Center, Jet Propulsion Laboratory, and NASA HPCC's Earth and Space Sciences Project (ESS).

New Videotape Explores Earth and Space With Visualizations

Jarrett Cohen, Raytheon ITSS/Goddard Space Flight Center

At the Sun, simulations investigate processes that create magnetic fields and release energetic particles. Earth science begins with the Pacific Ocean, studying the 1997-98 El Niño and Cyclone Susan. Crossing the globe, visualizations trace North America's East Coast and ocean currents in the North Atlantic Ocean. The night light from the world's cities then shows human impact. Next, two models probe nearby space phenomena, fluid behavior in microgravity conditions, and an asteroid collision. A jaunt to Mars explores the mountains and trenches of its dry, rocky exterior. The video concludes a a binary neutron star system, where two city-sized objects with the Sun's mass merge in a titanic explosion.

Learn more about the HPCC/ESS <http://esdcd.gsfc.nasa.gov/ESS/> Project. See a preview of the video <http://esdcd.gsfc.nasa.gov/ESS/images2/images2.html> with narrative text and QuickTime movies. To obtain VHS copies of the video with its accompanying booklet email Jarrett Cohen <jarrett.cohen@gsfc.nasa.gov>. ■

Advances in Digital Libraries '99 -

Digital Earth / Digital Sky Themes at Premier ADL Exhibition

Exhibits on the themes Digital Earth and Digital Sky will be shown May 19-20 in Baltimore as part of Advances in Digital Libraries (ADL '99), the premier digital library conference. Conference sponsors include NASA/CESDIS and IEEE. Admission to the exhibit sessions is free to NASA employees and contractors, but advance registration is required at the website given below.

The Exhibits include commercial exhibits from digital library hardware and technology vendors such as Oracle, Sun, SGI, IBM, ERDAS (a geographic imaging solutions company) and KTI (developing large information based applications). Research projects include the United States Geological Survey; TerraVision, an interactive terrain visualization system from SRI; Profiles in Science and the Visible Human from the NIH/NLM; the National Engineering Education Delivery System (NEEDS) from UC Berkeley; the Informedia Digital Video Library from Carnegie Mellon University; the Art Museum Image Consortium; Digital Meadowlands: An Environmental Digital Library from CIMIC, Rutgers University; the Global Legal Information Network from the Library of Congress.

Learn more about ADL '99 <http://cimic.rutgers.edu/~adl/>, which will be held at the Renaissance Harborplace Hotel, 202 East Pratt Street, Baltimore, MD 21202. Exhibits are May 19 and 20, from 10 AM - 5 PM (closed 1-2 PM). ■

The goal of NASA's many outreach programs is to promote to the general public an understanding of how NASA makes significant contributions to American education systems and to institutions dedicated to improving science literacy. This newsletter provides one vehicle for reporting how applications and hardware used for space science and other NASA research and development can be adapted for use by teachers and their students and by non-NASA organizations.

Science Teachers "Capture" NASA's Vision at Conference

Capture the Vision...Make it Real, was the theme of this year's annual National Science Teachers Association (NSTA) conference, held in Boston, Massachusetts. The NSTA's mission is to promote excellence and innovation in science teaching and learning for all, a mission statement put to music by this year's association President, Steven Rakow.

Capture the vision and make it real,
The sense of wonder that you will feel,
If you reach out, your quest will reveal
The beauty of science and its appeal,
When you capture the vision and make it real.
First verse - Steven J. Rakow

The "Capture the Vision" theme also incorporated the sub theme of "...Navigating the Standards," which reflects the challenge now before the educational community to make national education standards a reality in instructional materials and classrooms across the nation.

Over twenty thousand teachers, administrators, and other education-related attendees (the largest attendance to date) thronged to the Hynes convention center and nearby hotel venues to glean the wealth of information offered during the five days of workshops and seminars, stimulating field trips, lectures, talks by guest speakers, and the ever-popular exposition of science materials. Additionally, the NSTA hosted an evening at Boston's New England Aquarium, and introduced a new event - "Family Science Day" - which was engineered to bring together students and their parents with science educators for a fun-filled day of science-centered activities.

NASA at NSTA

Once again, NASA hosted the largest of the exposition arenas, with exhibit booths from several of its centers and research facilities. The NASA venue offered attendees free materials on Earth and space science, technology and hands-on demonstrations, and on-site researchers to answer questions.

The Office of Space Science (OSS), in partnership with the Jet Propulsion Laboratory, Goddard Space Flight Center (GSFC), Ames Research Center, Johnson Space Center (JSC), Space Telescope Science Institute, Lunar Planetary Institute, and Space Science Institute, offered a variety of free posters, education briefs, hands-on activity packets, lithographs, CD-ROMs, brochures, and other educational materials. OSS seeks to solve mysteries of the Universe, explore the solar system, and discover planets around other stars and search for life beyond Earth. From origins to destiny, OSS will chart the evolution of the Universe and understands its galaxies, stars, planets, and life.

NASA's space science booth

The NASA Education Program distributed free teaching materials for studying Earth, life, physical, and space sciences for grades Kindergarten through graduate school. Additionally, materials for learning about NASA's past accomplishments, recent discoveries, and future missions were available.

Teachers “capture” NASA handouts

The Earth Science Enterprise provided classroom materials, teacher guides, lithographs, and posters of the latest news about NASA's mission to understand our changing planet. Scientists were on hand to talk about research results and new education programs. Earth science that is available on the Internet and on CD-ROM was demonstrated.

The Aerospace Technology Enterprise displayed materials that outline its ten far-reaching goals. Posters and glider kits were distributed. Researchers were on hand to discuss the upcoming launch of the X-34.

The Human Exploration and Development of Space Enterprise exhibit highlighted exploring space to enrich life on Earth through people living and working in space. The main feature of this exhibit was the Space Station depicting the research to be conducted in the lab. The research focuses on two key areas: life sciences and materials sciences. Other featured areas were SAREX, BioBlast, and Data Archive. There were also hourly demonstrations of astronauts space gear, as well as a hands-on demo area and a drop tower simulating microgravity research. Literature and various educational products were distributed.

Demonstrating space gear

Besides participating in the exposition, NASA presented numerous workshops and lecture sessions on using Earth and space research in the classroom. A short course entitled "Get A Grip on Robotics" was led by Greg Vogt of JSC. Hands-on workshop sessions included:

<u>Space Science</u>

Small Bodies with Big Impact: Activities on Asteroids, Comets, and Meteorites

- NASA Solar Resources That Meet Your Classroom Needs
- The Hottest Ideas Under the Sun
- How to Fit the Universe into Your Classroom in an Age When "Less Is More"
- The Solar System at Your Fingertips
- On-line Resources for Educators From NASA's Origins Program
- NASA's Sun-Earth Connection Forum - Teacher Involvement & Response to Teaching Needs
- Cosmic Quest: The NASA-SAO Education Forum on the Structure and Evolution of the Sun

<u>Human Exploration & Development of Space</u>

- Training Astronauts in the Classroom
- Living and Working on the International Space Station
- Have a Blast in Your Classroom: Rocket Building and Launching
- Why Thing Don't Float in Space: Taking Gravity Out of the Situation
- Neuron Explosions!
- The Ultimate Challenge: Defy Gravity!
- How to Live in Space: Defy Gravity!
- SEEDS II: Tomato Seeds From Space
- Recycling in Space
- An Inquiry-Based Approach to Biology Using Computer Simulations & NASA Data: BioBlast

<u>Educational Technology</u>

- Composites: A Less Weighty subject
- From Cyberspace to Satellites - Linking to NASA
- Making the Most of NASA Multimedia Products
- College SMET Courses for the Next Millenium: Innovative NASA/NOVA Models

<u>Aerospace Technology</u>

- Why Were the Wright Brothers Right
- Using NASA Wind Tunnel Data from the Internet
- New Approach to Self Achievement (N.A.S.A.) Project
- Aeronautics for Primary Grades

<u>Earth Science</u>

- Talking to Satellites
- Discover Earth
- Using NASA Materials to Design a Standards-Based Lesson Plan
- Get Global: NASA Langley/NSU Project eSS
- Using Remote Sensing to Study Weather Patterns
- Promoting Interdisciplinary Education Within the Earth Sciences
- Using Space Data in the Classroom; Some Examples
- A Walk Through the PUMAS Web Site
- Earth System Science: Professional Development and Student Engagement

Featured speakers for NASA were:

- Jeanne Sauber, lead investigator at the Laboratory for Terrestrial Physics, GSFC, speaking on behalf of the American Geophysical Union, talked about the "Earthquake Hazard in Alaska: Studying Subduction From Space."
- Brian Behnam Hashemi, NSBRI Research Associate at JSC, speaking on"Space Life Science Research: How Would Your T-Cells Behave in Microgravity?"
- Space Shuttle crew member, Al Sacco, JR., who conducted a workshop on "The Ultimate Challenge - Defy Gravity." Sacco, a payload specialist, shared his personal experiences during the 1995 Spacelab science mission aboard Columbia, where he performed a variety of research in life and microgravity science, including a crystal growth experiment that he devised. Sacco talked about future microgravity experiments planned for the International Space Station and answered questions at the conclusion of the workshop.
- Ann Druyan, author, lecturer, co-author and co-producer of the hit movie "Contact," and wife of Carl Sagan, who lectured on NASA's Voyager mission ("The Voyager Record - Earth's Extraterrestrial Ambassador"). 1999 marks the 20th anniversary of Voyager's first encounter, which was with the planet Jupiter. The two Voyager spacecraft are now speeding toward the edge of the solar system into interstellar space. Each spacecraft carries a record - an archive - containing Earth's music, sights, and sounds. Druyan spoke on the messages these records carry from Earth.
- NASA partners, the National Oceanic and Atmospheric Administration, the National Science Foundation, Global Learning to Benefit the Earth, and the Evironmental Systems Research Institute, Inc. also participated in the conference as exhibitors, presenters, and demonstrators.

Live webcasts: John Glenn and Richard Riley

This year NSTA arranged live webcasts during the two very special sessions featuring speakers astronaut John Glenn and US Secretary of Education, Richard Riley. These webcasts are archived on the NSTA web site.

John Glenn was the honored guest speaker at the Aerospace Educators Luncheon. In his informative and often humorous speech, Glenn stated that there is no truth to the rumor that NASA was afraid to have him on the Friendship 7 flight because at his age he might wander off, or to the rumor that he was the first 77 year old to leave Florida in something other than a Winnebago.

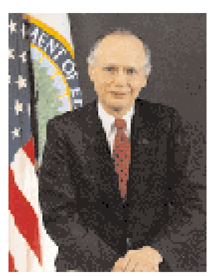
Glenn lobbied to participate once again in space flight to promote studies of changes in the aging human body in space versus Earth. He became a "guinea pig" during his flight, where experiments on osteoporosis, muscle system changes, sleep alteration, balance and coordination, immune system changes, and drug and nutrient tolerances were made. The results of these experiments are still being analyzed, he said.

Astronaut John Glenn

For the major portion of his presentation, Glenn narrated a film of the shuttle flight, Friendship 7: flight readiness, the launch, the craft interior and exterior, crew activities, images of space, and the subsequent re-entry. Friendship 7 orbited the Earth 134 times. During the flight 2500 images of Earth and its atmosphere were taken. Glenn commented that it doesn't matter if you have trouble going to sleep at night because, on the shuttle, another nighttime will be around in 45 minutes.

At the conclusion of his talk, Glenn stated that science educators play a key role in the future of our country. He encouraged teachers to participate in Space Day, promoted by Lockheed Martin, of which he is the official spokesperson. US Secretary of Education, Riley, has asked Glenn to participate in researching national education standards, and Glenn is the chairman of the National Commission of Mathematics and Science Education.

The Honorable Richard Riley has demonstrated his passion for education during his first and current terms of leadership. Riley first won national recognition for his successful effort to improve education in South Carolina. Riley has helped launch historic initiatives to raise academic standards, improve instruction for the poor and disadvantaged, expand grants and loan programs, give schools and libraries deep discounts for Internet access and telecommunications services.



Honorable Richard Riley

At a general session gathering Riley discussed the administration's education initiatives and outlined recent findings from a Department of Education report on teacher quality. He also gave an update on the reauthorization of the Elementary and Secondary Education Act.

Riley then presented the latest information on the Mars Millennium Project, an official White House Millennium Council Youth Initiative that challenges school children to develop futuristic plans for a colony on Mars. The project was unveiled on January 14 at a ceremony in the Smithsonian Air and Space Museum. The US Department of Education, NASA and the Jet Propulsion Laboratory, the National Endowment for the Arts, and the J. Paul Getty Trust are guiding the project, and a host of public and private organizations, corporations, and businesses are also taking part in advancing the effort to " Picture the Future."

Imagine creating a village for 100 transplanted earthlings on Mars in the year 2030. This national Mars Millennium Project will inspire debate, in-depth research and the quest for new ideas revolving around the White House Millennium Council's central theme, "Honor the Past - Imagine the Future." Throughout the course of the project, students will pose questions and find solutions to important issues that affect our lives now and for generations to come.

- excerpted from the Mars Millennium Project web site.

SciLinks launched

Another exciting event was the press conference held to introducing a powerful new initiative to join science textbooks and the World Wide Web. Secretary Riley joined NASA's Alan Ladwig, Senior Advisor to the Administrator, Daniel Goldin; NSTA's Executive Director, Gerald Wheeler; and William Talkington from Holt, Rinehart and Winston publishing company to premier SciLinks, which links students' textbooks to the power of the Internet.

SciLinks is a joint effort with textbook publishers and NSTA, with seed money from NASA. NSTA has launched and will maintain a web site that identifies key education web sites, each of which correlate with science topics presented in textbooks. These sites will be constantly monitored and updated for accuracy and currency by NSTA "web watchers." The textbooks, underwritten by Holt, Rinehart and Winston (a subsidiary of Harcourt Brace and Company), identify the availability of up-to-the-minute science information on the web with the SciLinks logo, printed at targeted subject points.

Following the panel speakers, students demonstrated the textbook/Internet-based program. The first textbooks hot off the presses for classroom distribution are Chemistry - Visualizing Matter and Environmental Science.

Special presentations and events

In addition to the courses, presentations, demonstrations, and workshops offered daily, featured speakers presented a variety of topics.

- Robert Ballard, founder of the JASON Project, spoke on "Celebrating the Spirit of Scientific Research, Exploration, and the Middle School Student."
- "Visualizing Ocean Exploration" was presented by Robert Gagosian, director of Woods Hole Oceanographic Institution.
- Paula Apsell of Nova spoke on "Supporting Science Education through Television."
- Meteorologist, channel 7 of Boston, Mishelle Michaels, presented "Weather - an Atmosphere for Learning."
- At the welcoming general session, NSTA President Steven Rakow gave the opening remarks, then introduced Stephen J. Gould, professor of geology and curator in invertebrate paleontology at the Museum of Comparative Zoology, who expounded on "Why We Can't Predict the Future - a Millennial Perspective." The Boston Arts Academy Chorus provided musical entertainment, singing the NSTA's new anthem, "Capture the Vision."
- The legendary physicist, Nobel Laureate, and teacher, Richard Feynman, sometimes described as the "greatest mind since Einstein," was remembered in a talk given by Mitchell Batoff and Gordon Clark, both of New Jersey. Feynman became well known while at the California Institute of Technology, Caltech, not only for his science, but for his ability to communicate its meaning to audiences at all levels.
- Julie Scardina, animal ambassador of Sea World and Busch Gardens, presented a talk entitled "Wild About Conservation Education."
- "What Were the Giant Extinct Lemurs of Madagascar Up To?" was the subject of Laurie Godfrey from the Department of Anthropology at the University of Massachusetts.
- The CEO of Radio Shack/Tandy Corporation, Leonard Roberts, explored the connection between business and education in his talk, "Business and Education - Partners in Sharpening America's Competitive Edge."
- Robert Kirshner of Harvard-Smithsonian Center for Astrophysics discussed the evidence that the Universe is expanding in his talk, "Is the Universe Accelerating?"
- Jocelyn Elders, former US Surgeon General, was a special guest at the NSTA President's banquet. Elders presented "Education - the Key to a Healthy America."
- A six-hour special session was held on Saturday evening from 6PM to midnight, entitled "A Stimulating Evening with 18 Legends." Filmed performances of renowned teachers and scientists, including Carl Sagan, the television personality known as Mr. Wizard (Don Herbert), and many, many more were presented to entertain and inspire.
- The Nobel Laureate Featured Panel discussed "Science Education for the 21st Century." The panelists, each of whom are Nobel Laureates, presented their vision of science education as we move into the next decade and what each believed to be important issues for consideration as the US seeks to remain an international leader in science education. The panelists were Richard Roberts,

director of research at New England BioLabs, Inc., and Leon Lederman, Director Emeritus of the Fermi National Accelerator Laboratory.
- The Brandwein Lecture, a regular conference event, was hosted by Joseph Renzulli, director of the National Research Center in the Gifted and Talented. Paul F. Brandwein was a world-renowned author, researcher, teacher, and international educator. The focus of Renzulli's talk was on the important objectives of the School Wide Enrichment Model.

Other speakers presented talks on navigating the conference for first time attendees, challenging science educators for the future, using the electronic journal as a new tool for educators, using information technology to bring science lessons to life, and on constructing and maintaining national science curricula standards

Awards

Conference award ceremonies spotlight the special achievements of educators and students. On Friday, March 26, more than 25 teachers from around the country were recognized at the NSTA Awards Program for their contributions to science education and their innovative teaching practices.

Additional to the organizational awards, NSTA administers competitions funded by private industry: Toyota Motor Sales Tapestry Awards, Duracell Inventors Competition, and Toshiba Laptop Learning Challenge.

Tapestry

The Toyota Tapestry awards were devised in an effort to keep students interested in science and learning. This year nearly $500,000 in grants were distributed to teachers from Kindergarten through grade 12 in 27 states. The grants are designed to enhance the teaching of science. The Tapestry competition is in its ninth year. Here are just some of the programs awarded:

- Stars of the Future, conducted at University high school (Tuscon), is a project by physics students and area astronomers to produce the first scientifically reliable "light map" of the Tucson skies.
- Robotic Design and Programming allows teams of elementary students to collaborate with undergraduate engineering students to design, construct, and program robotic models.
- Minds on Physics Internet Modules utilizes high-end Internet technologies to challenge students physics concepts.
- Project Create allows a thousand students to work through the process of solving real world broad-based engineering problems.
- From 2-D Graphing to 3-D Graphing uses imaging techniques, weaving together imaging skills and the concepts of graphing and mappping to portray visual images.
- Where Fingers Meet the Stars & Beyond is a tactual planetarium that provides visually impaired and normal sighted students the opportunity to experience the celestial skies at their fingertips.
- Variable Star Research works with astronomy professors teaching the process of how science research is done using telescopes.

"The Toyota TAPESTRY program makes it possible for teachers to create and implement innovative science projects for their students," said Gerry Wheeler, executive director of NSTA. "The program provides the resources needed for students to participate in hands-on, community-based projects."

Duracell

For 17 years the Duracell/NSTA Scholarship Competition has challenged 6th-12th grade students to design and create battery-powered devices that are educational, useful, and entertaining. Bright ideas - from a teaching tool that moves continents to an electronic pop-top opener, from a laptop security gadget to a color reader for the blind, from a new fire fighting safety tool to an outdoor strobe thermometer - were rewarded with savings bonds ranging in value from $20,000 to $500; 100 bonds in all.

The first place award for the 10th-12th grade category was given for the CoJack Computer Anti-Theft System, a small device that could also be applied to golf clubs or portable stereos. The first place award for the 6th-9th grade category was given for a battery operated moving map and educational tool for children, called World in Motion. This map shows the changes of Earth's continents from 170 million years ago to current times.

Second place awards were given for Temperature at a Glance and Insight to Color in the 10th-12th grade category and for the Flashing Fireman's Satety Boot and the Electric Soda Can Opener in the 6th-9th grade category. Temperature at a Glance is an outdoor thermometer designed to be read from a distance. The device projects a "ghost" image that displays the exact temperature. Insight to Color, a tool for visually impaired persons, audibly communicates the primary colors of anything viewed by its sensor. The Flashing Fireman's Safety Boot has lights on the soles of fire fighter' boots, which, in darkened or smoke-filled rooms, illuminates a fireman's position and may save lives. The Electric Soda Can Opener aids people with dexterity disabilities, such as arthritis.

Laptop Learning Challenge

This first-ever Laptop Learning Challenge was initiated to strengthen the educational use of technology in the classroom. The competition involved the creation of lesson plans for student investigations and activities, with math and science components, that can take place in the classroom or in the field. Winning programs involved 1) students in the study of farm fields using laptop computers and global positioning system receivers to map locations and create 3-D images and 2) students in the study of the human body and its response to physical activity using laptops at the running track to test, record, and compare running speeds and pulse rates.

"Laptop computers are becoming increasingly popular, and it's imperative that we assemble the good work of teachers who are using them as tools to teach science and mathematics." said Steven Rakow, NSTA president.

The top 20 lesson plans of the competition will be published in a book and CD-ROM produced by NSTA. Summaries of the plans will be posted on the NSTA web site this fall.

Founded in 1944, the NSTA has grown to 53,000 plus members, including science teachers of all grade levels, science supervisors, administrators, scientists, business and industry representatives, and others involved in science education.

Learn more about NSTA <http://www.nsta.org/>, the annual national conference <http://www.nsta.org/conv/boston.htm>, and the Mars <http://www.mars2030.net/> Millennium Project. Listen to Richard Riley and John Glenn by accessing the NSTA conference web page and clicking on the photos of each. You may need an audio player, which can be downloaded from that site. ■

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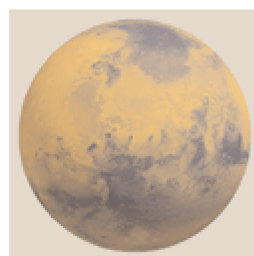
Introducing the Mars Virtual Exploration CD-ROM

Ames Research Center (ARC) recently licensed an interactive CD-ROM that allows students to virtually explore Mars. The CD-ROM also teaches the basic concepts of space exploration and explains the search for life in the universe. ARC developed the CD-ROM as a captivating way to educate students about Mars.

Designed for students in the fourth through eighth grade, the CD-ROM provides the equivalent of 40 hours of classroom instruction about the red planet. To use the CD-ROM, students divide into four teams and are assigned a research category in exopaleontology, meteorology, exobiology or volcanology, to conduct their search for life. For their mission objective, students virtually explore four landing sites on Mars and select the site best suited for their experiment.

Developed by the Educational Multimedia Research and Development Group of ARC Office of External Affairs, the CD-ROM also includes a teacher's guide and student logbook, which provide additional content and interdisciplinary classroom activities to complement the multi-media product. The CD-ROM has been licensed to Modern Supplies, Inc., for distribution.



Mars

Excerpted from NASA press release 99-22, written by John Bluck, Information Systems Liaison (Public Affairs), NASA Ames Office of External Affairs. Image courtesy of Jet Propulsion Laboratory's Planetary Photojournal.

Learn more about the Mars Virutal Exploration CD-ROM by emailing John Bluck <jbluck@mail.arc.nasa.gov>. ■

The goal of NASA's many outreach programs is to promote to the general public an understanding of how NASA makes significant contributions to American education systems and to institutions dedicated to improving science literacy. This newsletter provides one vehicle for reporting how applications and hardware used for space science and other NASA research and development can be adapted for use by teachers and their students and by non-NASA organizations.

Technology Facilitates Virtual Expeditions of Comets and Rainforests

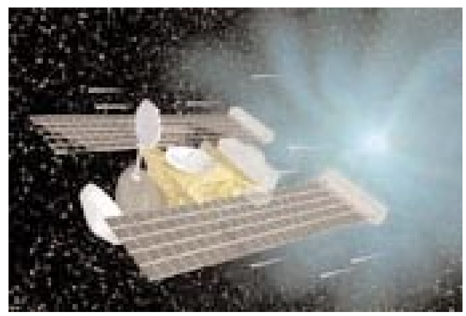
More than 14,000 Bay Area students, grades 3 to 10, were scheduled to attend the 1999 JASON Project X: "Rainforests - A Wet and Wild Adventure" at Ames Research Center (ARC) in California, March 1-12. Project X allowed students at ARC to talk via live satellite during 54 broadcasts to scientists and other students exploring the Peruvian jungle. Participating students learned about the impact of a giant comet or asteroid that struck Earth 65 million years ago. Some scientists think this impact caused a mass extinction that ended the reign of the dinosaurs, and also paved the way for modern rainforests, and mammals.

Founded by international explorer and RMS Titanic-discoverer Robert Ballard, the JASON Project is known for its ability to incorporate cutting-edge technologies, a multi-disciplinary curriculum, professional training for teachers and Internet communications into a comprehensive learning program. Not the traditional textbook style of learning, the JASON Projectuses advanced technologies to interest students in science and technology.

Robert Ballard

Through a satellite telepresence system, Project X brought the Peruvian Amazon live to students at 35 sites including ARC. About 3,000,000 students worldwide participated in the "virtual expedition," during which they climbed to a height of more than 100 feet to explore the layers of forest and to observe its inhabitants along a quarter-mile-long canopy walkway. On the ground, they peered inside an ant colony to see life under the forest floor.

Additionally, students were able to participate in a live chat with NASA's Stardust Comet Mission Director, Tom Duxbury. Stardust, launched in February of this year, is the first comet sample return mission, the first US mission dedicated solely to a comet, and the first robotic return of extra-terrestrial material from outside the orbit of the Moon. The primary goal is to collect comet dust and volatile sample during a close encounter with Comet Wild 2 in January of 2004. During the chat session Duxbury was asked aside from information on comets, what else will scientists learn from the Stardust mission.



"Analyzing the cometary particles on earth after the spacecraft returns in 2006 will tell us if comets contain material needed to support life on earth (water, hydrocarbons, etc.) and therefore we will know about the earth which has been impacted by comets for billions of years bringing these needed materials for life to earth," he replied.

JASON XI, entitled "Going to Extremes," will compare the National Oceanic and Atmospheric Administration's (NOAA) Aquarius Underwater Laboratory in the Florida Keys and NASA's International Space Station as research platforms that enable humans to go beyond their physical limitations to explore the unknown. Participants will be exploring these extremes through the thematic questions:

- What are the Earth's dynamic systems?
- How do these systems support life on Earth?
- What technologies do we use to study the Earth-Space system and why?

Through JASON XI,the path of ocean and space research and exploration will be traced. Ballard feels that in the past humans have been limited to very short visits to these extremes. The Aquarius Underwater Laboratory and the International Space Station will allow humans to study oceans and space for longer time periods, and in new and exciting ways.

Over the years, the JASON Project has been on quests to many remote places on the planet to discover where life exists and ask the question: "Is Earth the only planet in the solar system to support life?" JASON XI will focus on the interaction of basic physical and life science systems as a framework to understand what is essential for life to exist and propagate. The JASON XI research team will look at:

- The History and Spirit of Exploration
- The Extremes of Sea and Space
- Life Support Systems
- Human Physiology
- Exploration Technology
- Training to go to Extremes
- Research in the Extreme

The greatest discoveries all start with the question, 'Why?', says Ballard. "Why do we risk life and limb to explore the unknown, and how do we develop the techno- logies that allow us to overcome our physical limitations in these hostile environments? Human nature inspires us to explore."

Excerpted from a NASA press release written by John Bluck, Public Information-Office of External Affairs, Ames Research Center, and from the JASON web site. Images and Stardust Chat courtesy of the JASON web site.

Learn more about the JASON Project <http://www.jasonproject.org/> and the Stardust mission <http://stardust.jpl.nasa.gov/>. Read the transcript of the Stardust Chat. ■

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Celebrating Black History Month

The month of February is recognized nationally as Black History Month to celebrate the contributions of African-Americans to this country's cultural and political evolution. This observance commemorates the birthdays (in February) of such noted African-American pioneers as Frederick Douglass, W.E.B. DuBois, Langston Hughes, and Eubie Blake, and such institutions as the National Association for the Advancement of Colored People and the first Pan African Congress. Additionally, historians recall that the first African-American Senator, Hiram Revels, took the oath of office in February, 1870.

A predecessor to the current observance, "Negro History Week" was initiated in 1926 under the aegis of Carter Godwin Woodson, an African-American Harvard trained scholar. With the help of other scholars, both African-American and caucasion, Woodson organized lectures, exhibitions, and symposia to launch what he hoped would be a permanent observance of the African-American experience. Today, and for the past several years, this observance has expanded in length and is marked by government entities, schools and universities, and the general population with a variety of activities.

The first African American in space was Guion Bluford, Jr., a mission specialist aboard the STS-8 (Challenger) in 1983, STS 61-A (Challenger) in 1985, and STS-39 (Discovery) in 1991. The STS-8 Challenger mission, which was launched from Kennedy Space Center was the first shuttle to be launched and land during the night.

A graduate of Pennsylvania State University, Bluford earned an Masters of Science in aerospace engineering, followed by a Ph.D.in aerospace engineering with a minor in laser physics from the Air Force Institute of Technology. He later earned an MBA from the University of Houston-Clear Lake.

Bluford exercises on the middeck treadmill during his first shuttle flight, STS-8. Currently, Bluford is Vice President and General Manager of the Aerospace Sector of Federal Data Corporation, Brooks Park, Ohio.

The first African-American woman in space was Mae C. Jemison, who served as a mission specialist on STS-47 (Endeavour) in 1992. Astronauts on this cooperative mission between the United States and Japan conducted experiments in life sciences and materials processing.

Jemison earned a degree in chemical engineering from Stanford University in 1977 (she also fulfilled the requirements for a B.A. in African an Afro-American Studies), and earned an M.D. from Cornell University in 1981.

Astronaut Mae Jemison works in the Spacelab Japan (SLJ) module aboard Endeavour during the STS-47 mission. She is currently president of The Jemison Group, Inc., Houston, Texas. ■