Online Journal of Space Communication

Volume 1
Issue 2 *NASA's Advanced Communications Technology Satellite [ACTS] (Fall 2002)*

Article 17

September 2002

Survey of Advanced Applications Over ACTS

Robert Bauer

Paul McMasters

3.1 - -Survey of Advanced Applications Over ACTS

By Robert Bauer
NASA Glenn Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
E-mail: robert.bauer@grc.nasa.gov

Paul McMasters
Analex Corporation
3001 Aerospace Parkway
Cleveland, Ohio 44142
E-mail: paul.mcmasters@grc.nasa.gov

1.0 Abstract

The Advanced Communications Technology Satellite (ACTS) system provided a national testbed that enabled advanced applications to be tested and demonstrated over a live satellite link. Of the applications that used ACTS, some offered unique advantages over current methods, while others simply could not be accommodated by conventional systems. The initial technical and experiments results of the program were reported at the 1995 ACTS Results Conference, in Cleveland, Ohio. Since then, the Experiments Program has involved 45 new experiments comprising 30 application experiments and 15 technology related experiments that took advantage of the advanced technologies and unique capabilities offered by ACTS. The experiments are categorized and quantified to show the organizational mix of the experiments program and relative usage of the satellite. Since paper length guidelines preclude each experiment from being individually reported, the application experiments and significant demonstrations are surveyed to show the breadth of the activities that have been supported. Experiments in a similar application category are collectively discussed, such as, telemedicine, or networking and protocol evaluation. Where available, experiment conclusions and impact are presented and references of results and experiment information are provided. The quantity and diversity of the experiments program demonstrated a variety of service areas for the next generation of commercially available, advanced satellite communications.

2.0 Overview of the Experiments Program

Communications satellites have made tremendous technological strides since the early 1960's first passive reflector of the orbiting balloon ECHO, the first real-time transponder of TELSTAR I, and the first geosynchronous SYNCOM series. To encourage new business development and economic growth as well as ensure national security, the US Government has historically supported programs to make the long-term, high risk research, development and applications investment needed to achieve revolutionary technology advances for communications satellites.

NASA's ACTS program was the most recent example of this. It developed high-risk, advanced communications technologies usable in multiple frequency bands and applicable to a wide range of future communications systems for industry, NASA and other government agencies. The approach was to flight test the high-risk technologies that fell outside the sponsorship of the private sector and then validate them through an Experiments program. The flight validation of the technology allowed industry to adapt the technology to its individual commercial requirements at minimal risk. The Experiments program provided an opportunity to demonstrate user applications over satellite that showed improved services, and verified new services and opportunities made possible from the higher frequency system's smaller earth stations and broadband data rates.

After the satellite's launch in September 1993 and two-and-a-half month on-orbit system checkout, the Experiments program began on December 1, 1993. The program had an initial duration of two years. The results from these two years of operations were thoroughly presented and documented at the ACTS Results Conference held in Cleveland, Ohio in 1995 [1]. With a highly successful experiments program underway and fully functional payload, the program was extended two more years. At the end of the four years, experimenter interest and unresolved issues involving broadband satellite/terrestrial network protocol interoperability warranted further extension of the program.

In August 1998, the spacecraft's operations were altered to allow the system to drift on-orbit in the North/South attitude so that extended operations could be carried out with the little remaining on-board fuel. New goals were also defined for the Experiments program that provided a more focused program with an emphasis on supporting the goals of NASA's four Enterprises [2]. These latest goals were to use ACTS as a testbed to: 1) demonstrate NASA's and other government agencies' transition to commercial systems; 2) test, and evaluate communications protocols for their interoperability with terrestrial systems; 3) evaluate narrow spot beam, Ka-band satellite operations in an inclined orbit; and 4) use ACTS in verifying Ka-band satellite technologies. After 81 months of operations with the close of the Experiments Program on May 31, 2000, the satellite will have supported 104 experiments and over 80 demonstrations.

3.0 Experiments Operations Summary

In reviewing the Experiments Program from 1993 through March 2000, the organizational mix of experiments and experimenters offers top level insight into the usage of the satellite. Organizationally, three categories are considered: industry, university, and government. Generally, two periods are considered. The first covers the initial two years of operations whose results were reported on in great length at the 1995 ACTS Results Conference [1]. The second covers the remaining four years of operations from 1996-2000. Quality and impact of the experiments are difficult to quantify; however, presenting statistics about the experiment operations reveals the composition of the experiments program and relative usage of the system. Overall, 104 experiments were initiated over ACTS, with 59 during the years '94-'95, and 45 during the years '96-'00. Experiment hours on the spacecraft totaled over 74,000 throughout the whole program.

3.1 Unique Participating Organizations

The 104 experiments were proposed by fewer than 104 organizations. Several organizations were involved in more than one experiment. Of all the selected experiments, how many unique organizations were represented? The 104 experiments were proposed by 61 unique principal investigator (PI) organizations coming from government, industry, or academia. Repeating organizations performed 43 of the experiments. Another 68 unique organizations participated as co-investigators.

Of the 61 unique PI organizations over the course of the whole program, 43% came from industry (26) while those from government and academic sectors were fairly balanced with 26% (16) and 31% (19), respectively (see Table 1, first line of the three sub-tables). In comparing the unique organization mix between the first and second periods of the experiments program, the most noticeable change is a 14% increase in industry participation during the second period (from 38% to 52%). For universities, the participation remained about the same from the first period to the second. The number of government organizations decreased from 30% to 19% during that same time.

3.2 Selected Experiments

Of the 104 experiments, if just the type of organization (industry, government or academia) that proposed each is categorized without concern of multiple experiments coming from the same organization, another mix can be developed. This mix indicates that overall, the most number of selected proposals came from government organizations. The PI mix of selected experiments over the whole program is composed of 50% (52) from government organizations, 34% (35) from industry, and 16% (17) from academia (Table 1, second line of the three sub-tables). The strong government involvement can be attributed largely to NASA being identified as the PI in 14 experiments that involved industry and academia partners. The second period of the experiments program saw a 21% increase in government organization experiments (from 41% to 62%) from the first period. The contribution from universities dropped 13% (from 22% to 9%), while the involvement from industry PI's slipped 8% (from 37% to 29%) during the second period.

3.3 Experiment Usage

A third look at usage of ACTS is made by experiment hours used. Here there is also a predominance of government usage at 84% over the whole program and 91% over the second period (see Table 1, third line of the sub-tables). Industry usage represented 21% during the first period and only 4% during the second, while academia used 19% during the first period and 5% in the second. This heavy government usage can be ascribed to the shift in the Experiments Program goals that emphasized NASA/government benefit, and to several NASA-led, statistically oriented, technology verification experiments requiring long-term data collection. Weekends

and off-hours during the weekday evenings were often assigned to these experiments when autonomous data collection occurred. Other experimenters seldom used these hours preferring to utilize the highly contentious daytime weekday hours. Especially true of the industry experimenters, non-government experiments were usually very focused on testing something specific, or demonstrating an application that resulted in completion within a short duration. Another factor that influenced spacecraft usage was the introduction of the ACTS Usage Policy in April 1997. Users were often charged for their satellite time during most of the second period depending on several factors. This resulted in very intense experiments that, for the most part, lasted hours or days instead of weeks and months when charges were involved.

Table 1: ACTS USAGE AND PARTICIPATION

	FY94-95							
	G		I		A		Totals	
Unique PI Organizations	12	30%	15	38%	13	33%	40	100%
Selected Experiments	24	41%	22	37%	13	22%	59	100%
Experiment Hours Used	11409	60%	3979	21%	3549	19%	18937	100%

	FY96-00							
	G		I		A		Totals	
Unique PI Orgranizations	4	19%	11	52%	6	29%	21	100%
Selected Experiments	28	62%	13	29%	4	9%	45	100%
Experiment Hours Used	50671	91%	2035	4%	2605	5%	55311	100%

	Entire Program							
	G		I		A		Totals	
Unique PI Orgranizations	16	26%	26	43%	19	31%	61	100%
Selected Experiments	52	50%	35	34%	17	16%	104	100%
Experiment Hours Used	62080	84%	6014	8%	6154	8%	74248	100%

G = Government, I = Industry, A = Academia

4.0 Experiment Types

Within the ACTS Experiments Program, experiments are grouped into three general areas identified as Technology Verification, Propagation, and Applications. A listing of all the approved ACTS Experiments can be found at http://acts.grc.nasa.gov/about/experiments as a table with experiment number, Principal Investigator (PI) organization, experiment title, organization category, earth station category, experiment focus, and experiment period.

4.1 Technology Verification and Characterization

Experiments that verify and characterize the specific technologies on ACTS are classified as technology verification experiments. For the purposes of this paper, this category is expanded to also include technology characterization experiments, that is, experiments that primarily needed to utilize a Ka-band satellite link to characterize new Ka-band hardware. Since the 1995 Conference, nine technology verification experiments were initiated by NASA Glenn Research Center (GRC) that verified and characterized the basic ACTS technologies, such as, multibeam antenna (MBA) performance, Ka-band communications, on-board baseband processing operations, wideband channel operations, and rain fade compensation in the TDMA mode. Five of these completed in 1998.

Since the beginning of inclined orbit (I/O) operations in 1998, four new technology verification experiments were implemented by NASA GRC to investigate the effect of inclined orbit operations on system performance. "T1VSAT Statistical Performance in Inclined Orbit" reports Ka-band propagation and systems effects on the ground segment during baseband processor mode operations [3]. "ACTS Fade Compensation Algorithm Characterization in Inclined Orbit" investigated Ka-band propagation and systems effects on the performance of the baseband processor's fade compensation technique using a time domain analysis. Similar measurements were made in "Ka-band Propagation Effects on Communications Link Performance" which involved a time domain analysis of Ka-band propagation effects on the USAT performance in a tropical or sub-tropical rain zone

especially antenna wetting. "Multibeam Antenna Performance in Inclined Orbit" examined the overall pointing stability of the MBA on a regular basis throughout inclined orbit operations to record how well the pointing of the narrow spot beams was maintained while the spacecraft drifted. The results of these last two are reported in [4].

Two other experiments utilized ACTS Ka-band transponders to verify and characterize new commercial Ka-band ground segment hardware. The first is Lockheed Martin Western Development Laboratory which used ACTS to characterize the performance of a large (~8-m) reflector for a Ka-band ground station for an undisclosed customer. The other was by Bellcore working with the Glenn Research Center in verifying high speed data traffic measurement using the wideband channel of ACTS and a new piece of test equipment being developed by Bellcore.

4.2 Propagation

The introduction of Ka-band for satellite communications to the US brought with it the need to characterize the increased impairment effects of the atmosphere on this frequency band. The propagation experiments were a very important part of the Experiments Program, and perhaps may have been the most enduring contribution ACTS made to the communications satellite community. The majority of the effort focused on an extensive 5-year data collection program that finished in March 1999. The spacecraft's beacons in the uplink frequency band (27.5 GHz) and downlink band (20.2 GHz) were monitored using identical receive-only stations located in seven sites across North America. The data has been processed and analyzed and used to verify and improve propagation fade models. The results of this campaign were well documented and reported through the ACTS Propagation Studies Workshops organized by the Jet Propulsion Laboratory [5], and various journals and technical papers [a good sample is cited in 6]. Since the 1995 Results Conference, two other experiments were added. One by NASA GRC looked at atmospheric depolarization effects. Another experiment by NASA GRC and Florida Atlantic University made use of two propagation terminals after the 5-year data set was collected to investigate short distance site diversity gain at Ka-band using different diversity separations. The results of these activities are being reported at this conference [7]. Another propagation-related experiment involved NASA GRC and ITT which, in the spring of 2000, investigated wideband dispersion effects by making amplitude and group delay measurements over a 300 MHz bandwidth with special interest in data collected during convective rain events.

4.3 Applications and Networking

The majority of ACTS experiments used the system to test, evaluate, and demonstrate activities. Many of the activities included showing the improved capabilities that wider bandwidth communications using relatively small Ka-band terminals can provide; demonstrating new services to customers and business strategists; and networking, protocol evaluation and interoperability between terrestrially and space-routed networks. These experiments are discussed further in section 5.0.

5.0 Application Experiments

Since the 1995 ACTS Results Conference, 45 new experiments were approved for using ACTS. Of these, 30 were applications oriented. The applications experiments were sub-categorized into 4 areas: business development and service improvement; health, education and public wellness; telescience; and broadband network interoperability and protocol verification. All of these experiments utilized some aspect of ACTS technologies that precluded them from achieving their results with current commercial satellites. There are many papers and reports of these activities available in the literature; key papers are referenced. Some activities were brief or proprietary, and therefore, very little documentation can be found. Others were ongoing at the time of this writing and results were not yet available.

5.1 Business Development and Service Improvement

This type of experiment included activities where the major intent was to develop, in a broad sense, some business line or product of the organization, or improving the service it provides to its customers using ACTS-like technology. Government or academia could also be included here when the focus was improving their operations.

• Lockheed Martin hosted a very successful experiment in late 1996 through the spring of 1997 that was done in cooperation with a team of nearly twenty organizations from Japan and the US. Key organizers included the Jet Propulsion Laboratory (JPL), the Communications Research Laboratory, and Sony Studios. It involved a duplex double satellite hop using ACTS from JPL to Hawaii and Intelsat 701 at 180° E from Hawaii to Japan for the purpose of demonstrating high definition television near real time editing between two very distant studios. Further description of this can be found at [8], [9].

• American Telephone and Telegraph (AT&T) was involved in a short week-long experiment in April 1997 that involved characterizing a CDMA transmission technique that was being considered for its proposed Ka-band satellite venture, *Voicespan*. Coincidentally, this system was withdrawn about two weeks after the ACTS experiment.

• The Naval Research and Development Center (NRaD) worked with JPL in 1997 to install the JPL ACTS Broadband Aeronautical Terminal on the Navy vessel, USS Princeton. This link provided unprecedented data rates of 1.5 Mbps to the ship at sea that demonstrated how a very small Ka-band terminal with two-axis tracking can operate in the heavy EMI environment of a Navy ship while providing wideband duplex communications. The communications link provided other non-operations related benefits, such as a near real time email link for the crew. It was also cited as perhaps the key to saving the life of an ill Greek freighter's master that was diagnosed over the satellite link while at sea [10].

• Globalstar did a brief few-day experiment in the fall of 1997 with the JPL and a New Zealand firm, CES, Ltd. that looked at a time-smearing coding technique to be applied to mobile and personal satellite communications.

• Caterpillar implemented a month long experiment in the summer of 1997 primarily through Carnegie Mellon University that looked at the feasibility of using very small terminals and satellite communications to support advanced embedded control and information systems to improve the quality, performance and serviceability of its products (large earth-moving and construction vehicles).

• NASA's Advanced Air Transportation Technology (AATT) project is developing new technologies and tools to enable free-flight – an operating system in which pilots will have the freedom to select their path and speed in real time. This activity was supported by NASA GRC's Space Communications Office using T1VSATs in a link between GRC and the Lockheed Martin facility in Atlanta, Georgia for several months in early 1998. The tests utilized TCP/IP with the free-flight software to demonstrate and evaluate its performance under actual satellite link conditions. The use of high-bandwidth small size terminals and demand assigned multiple access which allowed varying data rates to be routed to multiple locations were identified as important in showing that satellite communications could provide a feasible solution to supporting the project's distributed communications architecture.

• Lockheed Martin Systems, Inc. utilized ACTS in the spring of 1998 in a very important demonstration to a potential customer that demonstrated the use of TCP/IP and satellite communications to reduce the cost space network operations. The live demonstration was part of the proposal by the contractor team led by LMSI. The demonstration, no doubt, helped the team to win the business from NASA for the Phase 2 Consolidated Space Operations Contract worth about US $3.4 B [11].

• A demonstration experiment was performed for INTELSAT at its headquarters in Washington, DC in February 1999. The goal was to compare side-by-side various Ku- and Ka-band services to the consortium's senior management, technical committee and planning committee. The results of the demo were expected to give the attendees realistic expectations on the capabilities of both current (Ku-band) and future (Ka-band) satellite technologies. Because of the corporate sensitive nature of the results, no reference on this activity is available.

• The lack of electrical energy in rural communities of developing countries is well known. The portability of a USAT and the versatility of ACTS as well as the advantages of Ka-band satellites provided an opportunity for Florida Solar Energy Center and NASA GRC to test Supervisory Control and Data Acquisition (SCADA) with a photovoltaic/diesel hybrid power generator designed for rural communities in developing countries. Initial tests in the late spring of 1999 showed that the satellite link supported 2-second data transfers with an error rate of less than 1%. Using SCADA to monitor these systems in remote areas allows technical assistance to be provided from remote experts [12]. Results from work being done in 2000 are forth coming.

• The promise of widely accessible wideband two-way communications via satellites operating at Ka-band frequencies will only be realized when low-cost ground terminals are readily available. These higher frequencies impact ground stations in overcoming the propagation impairments and the production of devices such as power amplifiers. The new systems are using switched-beam TDMA architectures, which demand the use of a burst modem. Raytheon Telecommunications Company saw an opportunity to be such a provider. Prototype earth stations were built and tested in the summer of 1999 over ACTS as being representative of future Ka-band satellite systems that incorporate a 1-m dish and 2.5 W SSPA with a receiver noise figure of about 4 dB. The performance was adequate to demonstrate many applications that will take advantage of broadband terminals soon to be operating at Ka-band [13].

5.2 Health, Education, and Public Wellness

Improving health care service especially to the rural populations is a very specific type of application that can be greatly enhanced by satellite communications. In addition, as the costs of health care rise, it is hypothesized that costs may be reduced by pooling physician specialists in centers of excellence, which can be linked to small and medium sized medical practices. While the immediate use of telemedicine is often associated with remote interaction of a physician with a patient, it also includes bandwidth intensive applications involving large file transfers such as for radiology, post procedure and intra-procedure image analysis, as well as research and records keeping.

- A telemedicine demonstration was performed in July 1996 in the rural state of Montana that allowed physicians to get a taste of space-aged medicine. Using a portable diagnostic package developed for Space Station astronauts by Krug Life Sciences and USAT links provided by NASA GRC, examinations were performed between remote clinics at an Exxon refinery and the Indian Health Service Hospital at Crow Agency, and the local hospital, St.Vincent Hospital and Health Center. The participants thought the small size of the terminal was very impressive and easy to accommodate, and the voice and picture clarity was very good [14].
- The Mayo Clinic's use of High Data Rate (HDR) Earth Stations built on its earlier T1VSAT experience with ACTS. During a yearlong activity from the spring of 1996 through 1997 Mayo expanded to wideband applications. This second experiment included studies of remote digital echocardiography, store-and-forward telemedicine, cardiac catheterization, and tele-consultation for congenital heart disease where terrestrial data transmission were combined with satellite communications [15].
- The University of Hawaii worked with Georgetown University Medical Center and Tripler Army Medical Center using HDR terminals from February 1997 through January 1998 to improve radiological techniques in fighting prostate cancer. The technique combined distributed high speed computing to allow 3-D volume rendering of radiation therapy planning images for treatments. While the bandwidth needed for this is about 300 Mbps, OC-3 rates were determined adequate. Background on the application can be found at [16].
- NASA GRC in cooperation with the University of Virginia, the Cleveland Clinic, and the Ashtabula County Medical Center in northeast Ohio utilized T1VSATs beginning in the autumn of 1998 to demonstrate satellite transmission of mammography images. Using image compression, TCP/IP protocols, and multicasting transmission techniques, improved mammography imagery distribution between rural areas and major medical centers was achieved [17]. This activity is being reported at this conference [18].
- Expanding the classroom to areas around the globe can enhance a student's schooling experience as well as enlighten the student with experiences that would be difficult to obtain otherwise. Two primary activities utilized different aspects of ACTS technologies for bringing interactive sessions with scientists from remote locations to grade school classes. The first activity, called "Live from Antarctic-2" was a revisit to Palmer Station, Antarctica in early 1997 by the Passport to Knowledge group, but this time with an ACTS terminal. The station utilized the hardware from the Jet Propulsion Laboratory's ACTS Broadband Mobile Terminal but with a fixed 1.2-m reflector set-up as a fixed station. A half-rate T1 link (512 Mbps) provided live video and audio over the ACTS bent-pipe mode which was the highest speed link achieved by this group from such a remote location. The second activity was also coordinated by Passport to Knowledge about one year after the first in 1998 and was called "Live from the Rainforest." The experiment used a T1VSAT set-up in the jungle of Amazonia, Brazil. Using only a 1.2-m dish, a full T1 rate was achieved with the ACTS digital baseband processor that provided for high quality video during the live broadcasts, as well as a data link for internet access and large file transfers back to the US. This activity is being reported at this conference [19].
- The detection and rapid response to major accidents or other emergency incidents is a problem in most of the world and is compounded in rural areas where detection and response can be very slow. Southwest Research Institute's (SwRI, in San Antonio, Texas) SatLink project is helping to resolve these problems by investigating using advanced satellite communications to improve communications to emergency vehicles. The ultimate goal is to automatically obtain and maintain satellite connectivity in both a mobile and static environment for remote emergency management and control. A demonstration of this occurred in September 1999 in Scottsdale, Arizona; however, limited funding prevented a complete analysis [20].

5.3 Telescience

Science can benefit from satellite communications in ways such as where an observing station has limited accessibility (e.g., large telescopes and remote areas), or interconnectivity between dispersed data sets and

computing facilities is needed (e.g., global weather modeling). For example, with remote observing, all members of large consortiums can participate in obtaining the data. One part of the team can focus on obtaining the observations while another part can be analyzing the scientific results from the last observation. Two experiments were sponsored by NASA's High Performance Computing and Communications (HPCC) program that involved remote science applications with ACTS.

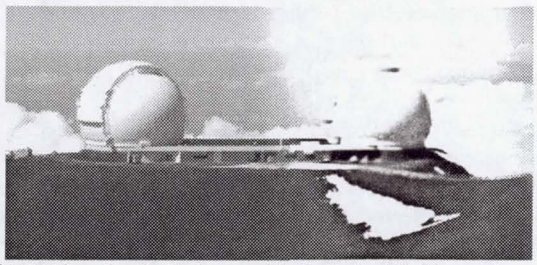
- The first activity supported tele-astronomy from from the 10-m Keck II Observatory on Mauna Kea in Hawaii. The observatory was linked by a fiber ATM network to the HDR terminal located at the Tripler Army Medical Center on Hawaii. The 155 Mbps link to another HDR terminal at JPL in Pasadena, CA provided bandwidth not terrestrially available to Hawaii, from May 1996 through September 1997. While being an ideal real-world application for experimenting with high-speed satellite networking, concerns were expressed with the adequacy of TCP/IP being used over the HDR wide bandwidth, long-delay networks [21].
- The second activity utilized HDR terminals to connect super computing sites at NASA Goddard Space Flight Center and JPL to develop global climate modeling techniques. The experiment took place from March 1996 through January 1997. An important part of this was to extend the network to other supercomputer centers that are on the National Research and Education Network (NREN) and the HPCC terrestrial networks. Background information can be found at [22].
- A demonstration also was done in June 1999 by the Canadian Research Centre using the US Air Force Research Laboratory's Ka-band suitcase terminal at a remote Arctic location called the Haughton Mars Project. The Ka-band link provided a half T1 rate link (512 kbps) which was about 10 times greater than the highest offering from commercial sources [23].

These experiments clearly suggest that future commercial wideband satellites may provide the reliability and affordability necessary for long distance science while enabling greater collaboration in the process.

5.4 Broadband Network Interoperability and Protocol Verification

While terrestrial networks will likely be adequate for major population centers, satellites will be a primary provider of access to anybody in rural areas and networks not yet interconnected. To ensure that total interoperability is preserved between terrestrial and space-based solutions, the protocols used must be verified and modified to ensure ubiquitous usage regardless of the transmission path.

- Ohio University led a series of experiments over ACTS using T1VSATs that investigated hypertext transmission protocol (HTTP) and web browsing performance over satellite links and ways to improve transmissions. A traffic generator was developed based on real firewall traffic. Technical objectives included web-based traffic generation and scaling; internet-like delay scenarios; modified error control; protocol performance and strategy evaluation; and station coding comparisons. This activity is being reported at this conference [24].
- The development of small terminals and using them for space protocol verification has been of prime interest to the Air Force Research Laboratory in Rome, NY. The early work in the summer of 1997 developing a suitcase terminal evolved into an even smaller 44-cm briefcase terminal capable of supporting 500 kbps links. Working with the Canadian Research Centre, the experiment conducted terminal characterization and a variety of demonstrations over ACTS including some during military exercises [25]. Activity is planned through the end of the ACTS Experiments Program.



- Protocol verification has been of great importance to the Naval Research Laboratory. An activity in the fall of 1998 involved a link to a ship in Lake Michigan. It demonstrated unparalleled data rate transmission at 45 megabits per second (Mbps) using TCP/IP between a moving vessel at sea and a fixed-earth station [26]. NRL also participated in the industry/government consortium experiment investigating high speed transfers and platform interoperability over ACTS, and then developed its own experiment plan utilizing USATs in the spring of 2000. The experiment is to investigate high speed transfer to/from remote network nodes and simultaneous applications using the internet and world wide web access, TCP/IP based file transfers, and interactive and variable TCP/IP based multi-media production video. Results of the work being completed in 2000 are forth coming.
- An experiment by an industry/government consortium evaluated the performance of TCP/IP, SONET, and ATM over satellites at high speed transfers and over various computer platforms (experiment #118x, [27]). Its success prompted a follow-on experiment (experiment #154) that involves many of the same participants in the team and is building on the results of 118x. This latest activity is investigating large windows, fast-retransmit, fast recovery, selective acknowledgement, congestion, and error detection/correction. The collective work from

both of these experiments is being reported at this conference [28]. Results of the work being completed in 2000 are forth coming.

- The available bandwidth and significantly smaller earth stations at Ka-band make it potentially viable for mobile communications. Carnegie Mellon University (CMU) investigated the interoperability of satellite communications with a wireless local area network and the modifications needed to Mobile IP for operation in a long delay path to transfer a message from one node to another. Asymmetric links of 6 Mbps Tx/45 Mbps Rx between a USAT at CMU and NASA GRC were used. It was shown that mobile IP could be improved to eliminate packet drops during handoffs thereby eliminating unnecessary transmissions [29].
- After an earlier experiment on ACTS centered about measurement standards over satellite links, the National Telecommunications and Information Agency's (NTIA) Institute for Telecommunications Science (ITS) performed a follow-on experiment using a T1VSAT in late 1995 to early 1996 that incorporated ISDN with national security and emergency preparedness communications [30].
- A brief experiment by NASA GRC investigated ATM/TCP capabilities over high-bandwidth satellites utilizing the Link Evaluation Terminal in Cleveland, OH. However, the PI changed jobs and the experiment did not reach conclusion.
- California State University - Hayward used a High Data Rate terminal in an experiment that began in late 1999 and is planned through the end of the Experiments Program in May 2000. The experiment will explore and prototype a unique integrated infrastructure using the Internet, optical, and multi-media satellite communications. Results of the work being completed in 2000 are forth coming.
- A small consulting firm in Cleveland, ACT Corporation, performed a Web browser test to evaluate the retrieval of Web pages over a geosynchronous satellite with and without satellite optimized protocols in April 2000. For the case of satellite optimized protocols, software (SatBooster) by Flash Networks was incorporated. Results of the work being completed in 2000 are forth coming.

6.0 Conclusion

The ACTS Experiments Program, while initially conceived as only a 2-year program, evolved into a nearly 7-year program that involved a broad variety of organizations from industry, academia and government. The mix of principal investigator organizations, selected experiments and satellite usage were presented with the change in the mix between the first period of experiments ('94-'95) and the second ('96-'00). Many of the experiments were applications-focused as opposed to being technology verification or propagation focused. For the application experiments, four areas were identified: 1) business development and service improvement; 2) health, education and public wellness; 3) telescience; and 4) broadband network interoperability and protocol verification. Their results impacted the specific fields and application areas, but also demonstrated the flexibility and advantages of Ka-band systems in smaller terminals with higher throughput rates that will become commercially available with the next generation of wideband communications satellite systems under development. The experiments provided the technical implementers with a real-world testbed to resolve the technical issues in networking high-speed Ka-band satellites with terrestrial networks. The experiments also demonstrated the effectiveness of resolving technology gaps through collaborative teams comprising organizations from government, industry and academia.

Within the ACTS Project, continued interest has been expressed in using ACTS after the May 31, 2000 conclusion of the Experiments Program. This interest indicates that a commercial follow-on to ACTS as the next generation of Ka-band satellites should be well received. But for now, it is so long to this reliable partner! Those experimenters whose appetites for wideband satellite communications were whetted with ACTS are eagerly awaiting undoubtedly the initiation of a commercially available Ka-band wideband system.

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3.1 - Survey of Advanced Applications Over ACTS

Robert Bauer
NASA Glenn Research Center
Cleveland, Ohio

Paul McMasters
Analex Corporation
Cleveland, Ohio

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

Experiment Categories

- **Technology Verification & Characterization**
  - ACTS-specific technologies
  - Ka-band component/subsystem
- **Propagation**
  - Ka-band characterization - fixed and mobile
  - Other effects - de-pol, dispersion
  - Mitigation techniques - diversity, power control
- **Applications & Networking**
  - Business Development and Service Improvement
  - Health, Education, and Public Wellness
  - Telescience
  - Broadband Network Interoperability & Protocol Verification

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Experiment Program Goals

1. Demonstrate transitioning to future commercial satellite services in support of NASA & other government missions

2. Test, verify & resolve technical issues using Asynchronous Transfer Mode (ATM), Internet Protocol (IP), or other protocols over satellite, including interoperability issues with terrestrial networks

3. Characterization of the ACTS system and operations in inclined orbit

4. Verify new satellite Ka-band technology and hardware

* Defined for inclined orbit operations phase

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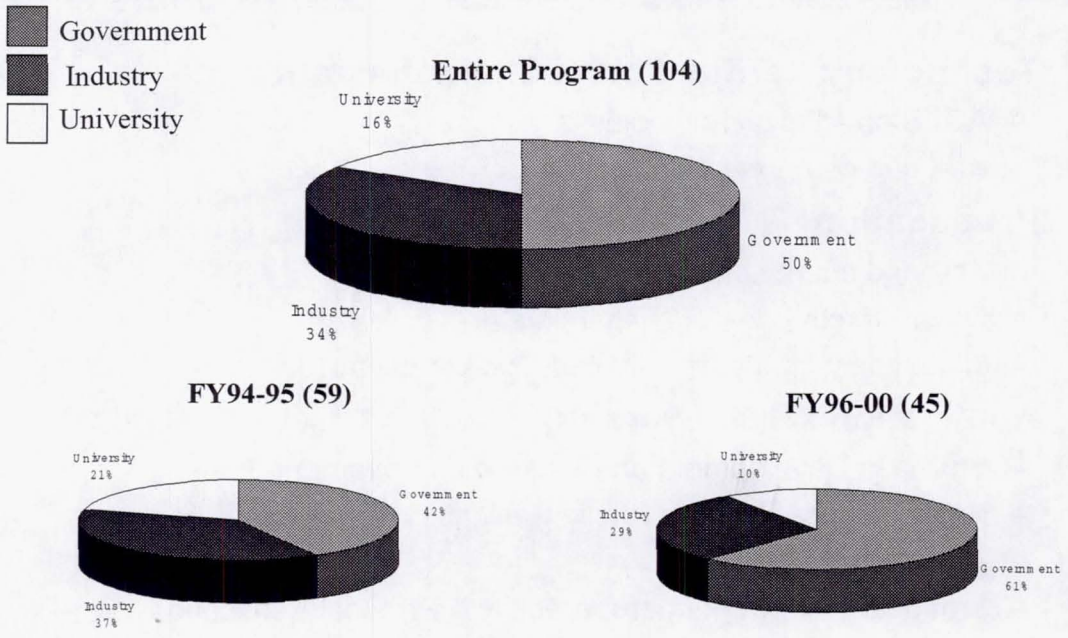
Selected Experiments



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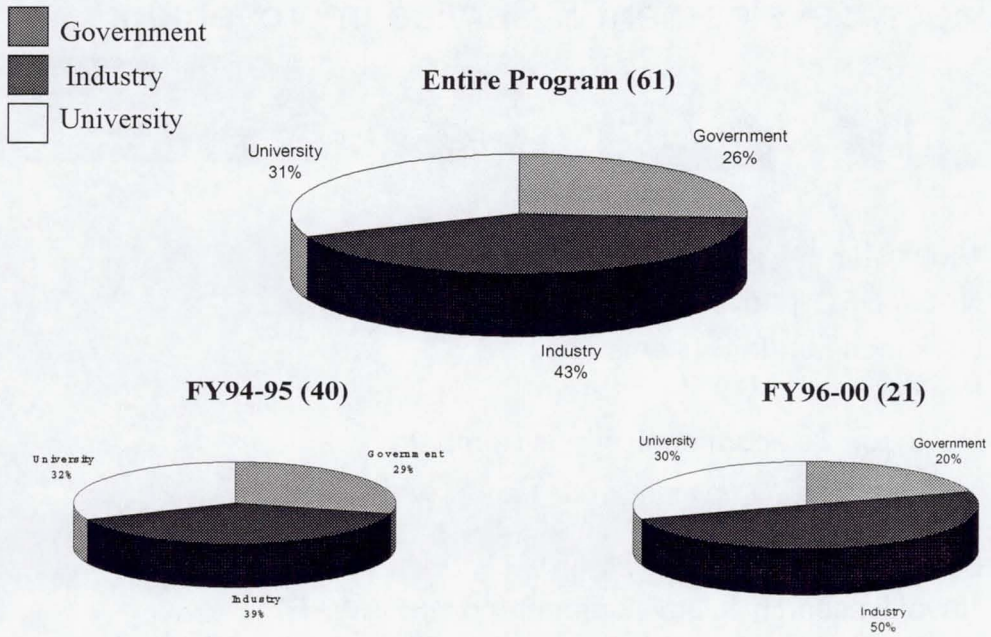
Unique PI Organizations



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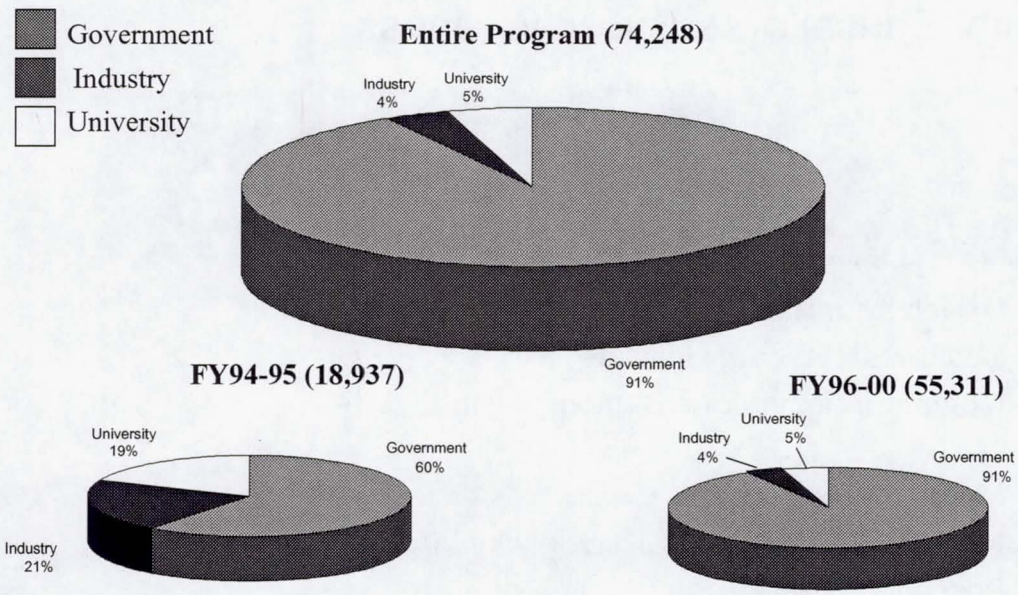
Experiment Hours Used



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Advanced Applications

Business Development & Service Improvement




- AT&T
- Globalstar
- NASA GRC - Advanced Air Trans. Tech'gy
- Lockheed Martin Systems, Inc.
- Intelsat
- Raytheon Telecommunications Company

- Caterpillar
- Lockheed Martin/JPL
- Naval Research & Development (now SPAWAR)
- Savannah State Univ/FL Solar Energy Ctr.

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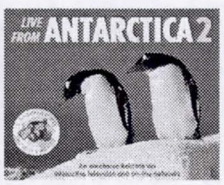
Advanced Applications

Health, Education & Public Wellness





- University of Hawaii
- Southwest Research Institute
- Montana Telemedicine Demonstration

- Mayo Clinic
- NASA GRC/Cleveland Clinic/Univ. of Virginia
- Passport to Knowledge

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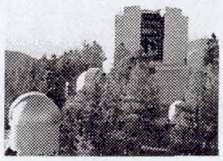
Advanced Applications

Telescience



- NASA HPCC - Keck Observatory
- NASA HPCC - Global Climate Modeling
- Haughton Mars Project

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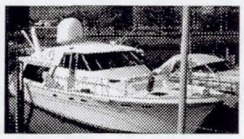
Advanced Applications

Broadband Network Interoperability & Protocol Verification

IETF


- NTIA/Institute for Telecommunications Science
- California State University - Hayward
- ACT Corporation
- NASA GRC

- Air Force Research Laboratory - Rome
- Ohio University
- Naval Research Laboratory
- 118x/154 Industry Consortium
- Carnegie Mellon University