3.4 - Satellites and the Internet as a "Passport To Knowledge"
A New Model of Teaching and Learning

By Geoffrey Haines-Stiles
Project Director
Passport To Knowledge
27 Washington Valley Road
Morristown, New Jersey 07960
Phone: 973-656-9403; Fax: 973-656-9813
E-mail: ghs@passporttoknowledge.com
Website: http://passporttoknowledge.com

Abstract

While business and government research agencies have begun to take full advantage of the Information Age, many secondary schools (at least in the United States) continue to operate on a "19th century model" of teaching and learning. Science education often relies on textbooks and "lab." (hands-on) projects that are implemented without real world context. From 1995-1998 PASSPORT TO KNOWLEDGE (P2K) worked with NASA's ACTS satellite project on 3 interactive learning adventures and effectively demonstrated that a new model of science education is practical and effective. Project evaluation by a nationally-recognized education research group provided convincing evidence of increased mastery by students of factual content, improved attitudes towards science and high technology, and useful practice in the research skills needed in the world of 21st century work beyond school.

Examples of video and other content, together with a review of statistically-meaningful results, are provided from all 3 P2K Modules that used ACTS: LIVE FROM THE STRATOSPHERE (1995), LIVE FROM ANTARCTICA 2 (1997) and LIVE FROM THE RAINFOREST (1998.) Each project relied on a technical "first" only possible at that time through the use of ACTS. These included the first live video from a plane in flight at 41,000 feet (NASA's Kuiper Airborne Observatory carrying an infrared telescope); the first-ever video interaction from America's Palmer Station off the Antarctic Peninsula; and the first interactive video broadcast from the heart of the Amazon rainforest. The results, however, were much more than purely technical achievements: P2K, utilizing the full duplex communications possibilities enabled by ACTS, was able to structure educationally meaningful interactions and experiences involving not just satellite television, but also Internet based opportunities. ACTS also provided invaluable project coordination between home base and the remote sites. P2K has continued with LIVE FROM THE SUN and LIVE FROM THE STORM, incorporating the lessons of the earlier projects, while utilizing new technologies such as streaming video as they emerge.

1. Introduction And Overview

In 19th century Europe, the so-called "Grand Tour" was considered an essential component of an education appropriate for the aristocrats who would soon lead their nations. Sons (and it was then, of course, mainly males) of rich families would travel the Continent accompanied by knowledgeable tutors to sample the culture and life style of the Renaissance and the Enlightenment at the actual locations in Italy and Germany where the artistic or scientific breakthroughs of Raphael and Michelangelo, Leonardo and Galileo, had occurred.

In the late 20th century satellite communications and the Internet have been able to provide hundreds of thousands of students across America and around the world with access to sites and sights formerly the preserve of the privileged few, taking them—virtually—to scientific frontiers such as the Antarctic or the Amazon. Accompanying the students as guides and virtual "tutors" were some of the world's leading researchers who served as online and on-camera mentors. Instead of paintings and fine arts, students could explore penguin habitats, encounter the birds and insects of the rainforest, or see and hear what astronomers actually do during flights aboard an airborne observatory.

This profoundly democratic revolution in educational opportunities is likely to expand still more in the early decades of the new Millennium and to appeal to "lifelong learners" in homes and libraries, and not just to students in school. From 1995-1998, in 3 separate pilot projects, NASA's ACTS satellite program was instrumental in proving the feasibility of these revolutionary opportunities and in making the possibilities clear to policy-makers as well as students, teachers and parents. The audio and video opportunities afforded by ACTS

prefigure the future of broadband multimedia using the next generation Internet and new software. ACTS helped make the future of educational telecommunications come to life today. This paper details the technical infrastructures employed, the unique interactive opportunities enabled, and the real learning that resulted.

Multiple partners were involved in all three "Modules" described here, principally NASA and NSF and the research centers and individuals supported by the two agencies. Lead in organizing each project was PASSPORT TO KNOWLEDGE (P2K), headed by Geoff Haines-Stiles and Erna Akuginow. Haines-Stiles was Senior Producer and Series Director on Carl Sagan's Emmy-winning COSMOS series, which has now been seen by some 600 million people around the world. Akuginow was formerly a producer/director for CBS Television in news and documentaries. Together they developed and coordinated far-flung teams of producers, cinematographers, online content experts, educational researchers and many more skilled artists and craftspeople to develop, produce and distribute interactive learning experiences known as "electronic field trips." P2K's mission was, and remains, to excite students (primarily middle schoolers, ages 11-14, but also with many upper elementary [ages 8-10] and high schoolers [ages 15-16] participating) about science and the research process. P2K also connects students with researchers who serve both as sources of up-to-date information, and role models for careers in science and high technology.

P2K prototyped and continues to use a unique combination of video, online and hands-on media to bring the remote locations to life, as summarized in the slogan "100% video… 100% hands-on… 100% online" meaning that P2K regards each medium as equally important but that each is used for what it can best contribute to the overall learning experience. Each project includes:

1) live satellite television broadcasts, distributed via non-commercial, educational public television and direct to schools and networks equipped with the appropriate downlink equipment. Videotapes are also distributed via multiple channels.
2) hands-on activities appearing in printed Teacher's Guides and online, accompanied by worksheets and posters to provide educators with a "turnkey" package to support them in implementing topics on which they may not have received formal or current training. The Guides correlate all activities to key science content suggested in the National Science Education Standards developed by the National Academy of Sciences and the AAAS/Project 2061 "Benchmarks."
3) online resources, including both e-mail and WWW, which provide extensive background information, the opportunity for interaction with the researchers, and also support distributed communities of both teachers and students.

Each of the three "Modules" (the name P2K gives to the package of integrated media) discussed in this paper differs in detail, but all relied critically on ACTS, which was itself operated in several different configurations. The dedicated and skilled researchers and engineers from the ACTS project teams at NASA Lewis (now the Glenn Research Center) and the NASA/Caltech Jet Propulsion Laboratory pushed the communications envelope, taking the ACTS satellite and its ground stations literally to "extremes."

In LIVE FROM THE STRATOSPHERE JPL's mobile antenna facilitated the first-ever 2-way video interactions to and from a jet airplane in flight high in the stratosphere during actual scientific observations. During LIVE FROM ANTARCTICA 2 the ACTS uplink dish was situated as far south as it could possibly be and still successfully transmit to the satellite. In LIVE FROM THE RAINFOREST temperatures and humidity were both higher than in any other deployment or test. Through all 3 projects the ACTS teams and P2K worked closely and collegially with each other to identify and resolve complex technical and logistical issues. (Individual acknowledgements for exceptional cooperation appear at the end of this paper.)

2. Live From The Stratosphere

During the initial pilot P2K project known as LIVE FROM OTHER WORLDS (LFOW), which used a dedicated NASA-NSF satellite link from Antarctica to NASA Ames, P2K was approached by the Airborne Astronomy group and networking engineers at Ames about the possibility of incorporating an educational activity within an ACTS project that was to use JPL's mobile terminal aboard the Kuiper Airborne Observatory (KAO), a converted C-141A jet with an infrared telescope pointing through a port on its side. The steerable antenna—the Broadband Aeronautical Terminal custom-built by JPL—automatically tracks ACTS, making it possible to transmit full duplex video, audio, and data between the ground and an aircraft flying anywhere in the Western hemisphere.

The ACTS activity had originally been designed to support in-flight diagnostics of the telescope and other instrument problems, as well as to allow "remote" observers to control the telescope and downlink data. Building on the positive response of teachers and students, and NASA management to LFOW and LIVE FROM ANTARCTICA, LIVE FROM THE STRATOSPHERE was born. (The communications network developed to support LFS appears in figure 1.)

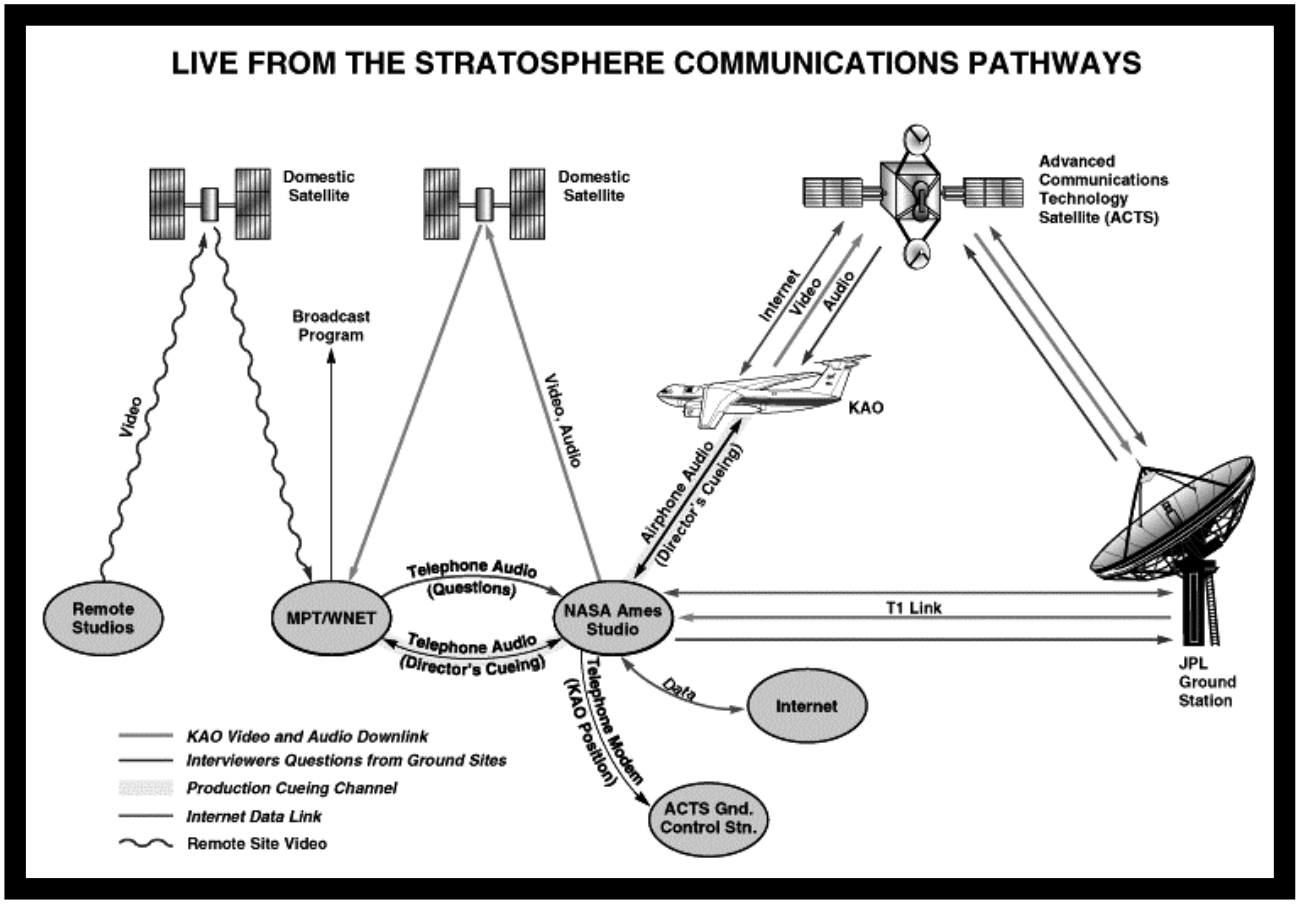

Figure 1. VIDEO AND AUDIO CONNECTIONS SUPPORTING LIVE FROM THE STRATOSPHERE (COURTESY NASA QUEST)

As plans matured it was realized that this was to be the KAO's last research season, after a career which included breakthrough observations of the heart of the Milky Way, close-up views of Supernova 1987a, the measurement of water on Mars, studies of the heat emitted by Jupiter, Saturn and Neptune, and water vapor in Comet Halley. The 4th video in the series, the live, five hour "Night Flight to the Stars", was in fact the last operational flight of the KAO, and was fittingly shared with thousands of students across America using ACTS. Altogether more than 10 hours of TV were produced, 8.5 of which were live and interactive, and 7.5 of which came directly from the KAO in flight. Hundreds of sites were able to downlink video, and about a dozen sites (at museums, science centers, and planetariums in Texas, New Jersey, Washington, DC, Colorado, North Dakota, Hawaii and across the United States) were able to interact via live two-way video and audio.

High points of the programs included students in Chicago at the Adler Planetarium controlling the KAO's telescope; young patients in an Atlanta Hospital interacting directly with the astronomers, showing how satellite communications could liberate those otherwise confined and shut off from the world; an overnight camp-in at the Liberty Science Center, NJ, with nearly 500 students, teachers and parent-chaperones gathering for an evening dedicated to science, and astronomical questions originating form the site of a high school football game in Booneville, MS, and being relayed directly via ACTS to the KAO.

Reactions from teachers and students showed the impact of being able to travel virtually on board the KAO, a capability only made possible through ACTS. As Marilyn Wall, from the John Wayland School, Bridgewater, VA, wrote:

> *Videos are so important. They give the students a chance to see what people look like and to feel more a part of the program. It helped to generate a feeling of being there and knowing the individuals to whom the students were directing questions …The most significant motivational factor for the involvement of my students was the "live broadcast." Watching the live broadcasts my students felt as if they were part of the crew, that they were "virtually" aboard the KAO. It made the "Live From..." series truly interactive …The live broadcasts made my students felt they were a part of this "live" mission, that they were part of the KAO crew …This was indeed an electronic fieldtrip, taking my students beyond their everyday realm of experience and knowledge. Through the broadcasts the students became active learners, and they had the opportunity to work with scientists, students, and field experts …It helped them to understand the astronomers aren't all starry eyed and staring off into space …They were placed in a position to share and exchange information with their peers and experts in other geographic and culturally diverse locations. The live broadcasts enabled my students to work cooperatively with the KAO crew.*
>
> *I was very excited to find out about LFS and NASA's attempt to involve the public with its work and NASA's efforts to let kids participate in some of their programs of discovery. Keep it up, NASA!*

Teacher Jake Chaput from Arlington Elementary in New York state wrote:

> *My class viewed the Oct. 5 LFS program …We were able to get one of our question relayed during the program. My class went wild with enthusiasm when they heard "A question from Arlington Elementary School in Poughkeepsie, NY". Questions poured out from the class after the initial success.*

Middle school science teacher, Tim McCollum, reported in an e-mail on "Midnight Science Gala in the Land of Lincoln":

> *On the evening of Friday, Oct 13, 1995, Charleston Jr. High School in Charleston, IL had its first ever midnight science gala. We were fortunate enough to be able to have crystal clear viewing of the LFS transmission on both NASA Select and our local PBS affiliate WEIU-TV at Eastern Illinois University. Over 100 students attended the event which ran from 8:30 pm CDT to midnight. We had 20 parent volunteers and 20 middle school majors from EIU serve as supervisors and helpers (although on computers, the kids were the real teachers!) While the kids loved the activity, the parents and college folks were the ones most impressed with the application of technology—needless to say, a GREAT P.R. booster for the school.*
>
> *As a 23 year teacher, my greatest pleasure was seeing the kids so excited, having so much fun, and keeping such late hours actively involved in a SCIENCE activity. I doubt if they'll always remember the wavelengths of IR, but I know they'll forever look back to junior high as the time they once met at midnight for a* scien-terrific *evening of food, fun and discovery.*

3. Live From Antarctica 2

The first LIVE FROM ANTARCTICA series had utilized pre-existing NASA and NSF communications assets at McMurdo Station and Amundsen-Scott South Pole station, although P2K had to "borrow" one of NOAA's GOES satellites to create the world's first-ever live video telecast originating directly from the South Pole. However, on the other side of the Continent, across the Drake Passage from South America, no broadband communications whatsoever existed at Palmer Station, America's 40-person research base devoted to marine biology and the study of sea-birds and penguins. Once more, ACTS facilitated the previously impossible.

P2K approached the ACTS team at JPL and found them receptive to what would be a test of the most difficult and remote ACTS uplink ever attempted. NSF communications engineers provided data indicating that while ACTS was visible from Palmer, the angle was extremely low over the horizon. That added to the extreme cold and the fact that re-supply was only by ship and only once or twice during the research season meant that

extremely careful pre-planning was required. Ann Devereaux and Daniel Gutrich of the Satellite Communications Group in the Communications Systems and Research Section 331 at JPL volunteered for the assignment, ably supported by Tom Jedrey and Brian Abbe who coordinated efforts at home base at JPL. At Palmer, Devereaux and Gutrich set up a satellite terminal that linked the video signals through ACTS to JPL. From JPL the signals were sent via a T1 circuit to the Television Center at Mississippi State University (MSU), Starkville, MS, where the final television production was completed and uplinked to satellites accessible by PBS stations across America. JPL engineer Tom Rebold, from the Radio Science Systems Group in Section 331, also assisted in the effort, working at MSU to ensure that the signals were received at their intended targets.

As Devereaux reported in an interview published in JPL's UNIVERSE magazine:

> *"Dan and I took about 12 crates of material to help us set up the satellite terminal," Devereaux said. "We brought a 1.2- meter antenna dish, which we set up on a patio outside one of the buildings there, and also had a couple of racks of satellite gear—which included electronics used to talk to the satellite—and tons of spares. We brought as much stuff as we could conceivably need," she added. "Obviously, you couldn't go to an electronics store down there."*

In order to give the flavor of true field research, LFA2 also connected via a terrestrial microwave relay to several nearby islands on which penguin, petrel and plant research was ongoing. The ACTS team worked closely with NSF communications engineers to ensure end-to-end integration of local phone lines, RF radios and the satellite signals. In the first program, which focused on a marine Long Term Ecological Research project, one live signal originated on board the Research Vessel "Polar Duke," with an additional live link from the on-shore communications facility where the ACTS equipment was situated. Ann Devereaux reported live on how the communications links were organized, and teachers reported that their students were fascinated by how the signals were routed as well as with the natural history and earth science content of the broadcasts.

Despite all the technical and logistical challenges the duplex ACTS satellite link operated nominally throughout the entire 2 month plus period during which the production team was on site, enabling pre-recorded segments to be transmitted from Palmer to MSU to be integrated with the live programming. Audio from the United States, including student questions from Maine, Hawaii, Mississippi and several other states were successfully relayed to the researchers appearing live on camera in the Antarctic.

Once more teachers reported that students were fascinated by the programs and the project. (Each comment originates from a different teacher and school.)

> *Kids get very excited when they realize this is real science in real places...*
>
> *I only wish there could be more of these programs. My kids got so excited about learning (during) the weeks we do these kinds of activities. Keep up the good work.*
>
> *I did this project with a pupil adjustment class (students with severe behavior problems) that range from grade 2-5. The students in this group LOVED the project. We constructed a life size model of Antarctica in a corner of (the gym)*
>
> *I teach computers and use the program as an example to students as to how Internet communications can enhance learning and scientific understanding of the world...*
>
> *In comparison with other online programs, this is by far the most superior I have found...*
>
> *My students were absolutely delighted to have each of their questions answered in a way that they could understand. They were thrilled to have one of their questions answered "live from Antarctica" during broadcast 2...*
>
> *They found the information very interesting and I don't think fully comprehended the scope of what was happening in terms of the technology involved, but they began to be awed by it. My students are special education L(earning) D(isabled) and EMI...*

The kids and I loved it and hated to see it end. Isn't there any way to extend the study and cover other aspects of life and study down there? The fact that it is coming "live" is really a super plus with the kids. It made it so very real…

As part of the 3-year NSF grant awarded to P2K, an extensive evaluation by the Center for Children and Technology of the Education Development Corporation (Newton, MA and NYC) provided qualitative and quantitative feedback on the impact of the project on student learning outcomes and attitudes. Results clearly showed that the project was far more than a mere "pilot" or "demonstration" and resulted in significant learning. These concrete statistical results are more substantial than those reported for other electronic field trips and distance learning projects. (The full report is accessible online via http://passporttoknowledge.com/storm under EDUCATORS/EVALUATION.)

Specifically referring to the interactive opportunities enabled by ACTS, the survey found that:

97% of *teachers* thought experts' answers "useful and understandable"
95% of *students* thought experts' answers "useful and understandable"
94% responded that the Q&A format was "an effective way to share information with students about Antarctica"

In terms of student interest in the videos, results showed that:

0% were "bored", and
93% said that the "programs interested students in Antarctica and science"

4. Live From The Rainforest (Lfrf)

The third and final P2K project utilizing ACTS featured the first-ever live educational broadcasts from the heart of the Amazon rainforest, a location that exposed ACTS uplink equipment to the hottest and most humid conditions every experienced.

According to Bauer, et al:

> Interestingly, while not as remote (as that experienced during LFA2), it was said that the infrastructure at the rain forest site was poorer than in Antarctica. On-site diesel generators that powered the remote hotel (at the Ariau Jungle Tower) intermittently failed. The reflector and outdoor unit were established on a helipad, while the indoor equipment was in one of the few air-conditioned rooms in the facility. The hotel site is built on stilts and the location was accessible only by boat as it was the end of the rainy season and the river was still high. The daily downpours, nearly continuous 100% relative humidity, and daily temperatures of about 90 degrees F made for perhaps the harshest environment in which ACTS equipment has operated.

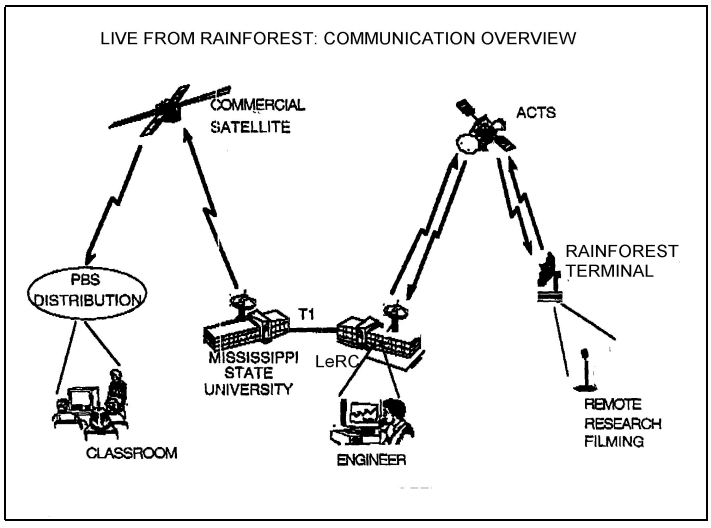

Figure 2. ACTS CONFIGURATION IN SUPPORT OF LFRF (COURTESY SINGHAL)

As reported in an unpublished MSS by LeRC ACTS LFRF project manager Adesh Singhal, this was the first time that NASA LeRC (now Glenn Research Center) took the lead role in providing the communication link. LeRC led the effort to provide the live video link from the field research site in the Amazon over ACTS and terrestrially linking it to Mississippi State University where the interactive segments were formatted into final programs broadcast on April 7, 14 and 21, 1998. These programs were also simultaneously transmitted live across Brazil through collaboration with co-producer NEON RIO, and TV Cultura, Sao Paulo.

Singhal writes:

> LeRC's involvement to support this activity also supported NASA's mission to provide and enhance scientific and educational programs for school children across America. This also provided the Public Broadcasting Service's viewing public with an opportunity to learn about NASA's Advanced Communications Technology Satellite and its communications technology using the Ka band, and how it can be used for long distance learning …In completing the objectives of this experiment., the LFRF activity exercised several of the ACTS communications technologies, including the use of Ka band, the use of steerable and fixed spot beams from single transmit and receive antennas.
>
> Live video and audio of the Rainforest researchers at work was channeled to the on-site T1VSAT terminal, which utilized a 1.2 m dish for transmit and receive out of and into the rainforest site. The T1VSAT took composite video from the rainforest and relayed it through ACTS to the LeRC ACTS fixed station. From LeRC, the video was sent over commercial telephone lines via a T1 circuit (1.8Mbps) to the main production hub at Mississippi State University. After formatting and editing, personnel at the television center then uplinked the signal to a commercial Ku-band television satellite, which made the signal accessible to public television stations and any school or other educational institution with the appropriate downlink dish. The operational mode used for the LFRF operations was the baseband processor bandwidth on demand configuration. The satellite's capability for producing uplink and downlink beams through the steerable antenna was used to allow communications to the remote site in the rainforest. At the same time the spacecraft's Ka band antennas were able to maintain a fixed coverage on the Cleveland, OH, area, where LeRC is located. By using the on-board processing, the ACTS satellite served as a "Switchboard in the Sky", allowing a continuous data flow of up to 1.8 Mbps from the rainforest site (in the steerable beam) to LeRC (in the Cleveland fixed beam) , and vice versa. The T1VSAT terminal operates with the fully digital TDMA baseband processor mode of the satellite and was the original workhorse terminal of the ACTS ground segment. It can support a full T1 circuit plus four 64 kbps channels for a total throughput of 1.8 Mbps while bursting to the satellite at 27.5 Mbps. (Terminal and other parameters are appended.)

As the ACTS system provided full two way communications, live feedback video and audio was also sent back to the rainforest via the LeRC ACTS fixed station. LFRF classroom participants were able to send e-mail questions in real time and have their inquiries routed directly to the researchers in the Amazon. Logistical discussions of production details were also supported between with P2K and LeRC personnel located on-site before, during and after the live television broadcasts. Such logistical discussions were crucial in planning and debugging production logistics and should not be ignored in any future such projects. The ACTS link also allowed e-mail exchanges between the rainforest site and elsewhere. FIELD JOURNALS and BIOGRAPHIES, provided online at the LFRF website provided a behind-the-scenes view of life in the rainforest.

Bauer, et al, reported on technical results as follows:

> All three live shows were supported with the ACTS link. The video quality was claimed to be the best ever of these "Live from..." series largely because a full T1 link was never feasible before. The 1.2-m dish was shown to be adequate for maintaining an uplink clear-sky margin of 13 dB (with continuous coding used) and a downlink clear-sky margin of 9 dB (with continuous coding used) and using the spacecraft's steerable beam antenna (55 dBW EIRP, 13 dBi/K G/T). The estimated predicted availability at these margins was about 99% at both 30 GHz and 20 GHz during the rainiest season (Feb.-Apr.). Before anything was shipped a 2.4-m dish was considered to obtain 6 dB more margin. But calculations indicated that for the type of rain predicted for the area and the extra hardship in transporting the larger dish to such an inaccessible site, there was little to gain in link availability (about 0.4% at 20 GHz)

considering the relatively short duration of the activity. Experience showed that the terminal remained operational during light rains. Link margins greater than 50 dB are needed to maintain 99.9% availability at 30 GHz and this, in general, is considered impractical to support for ACTS or any operational commercial Ka-band system in this region (ITU-R rain zone P).

Once again, teacher and student responses were extremely positive: verbatim comments may be found in the DISCUSS section of the LIVE FROM THE RAINFOREST website.

5. "Passport To Knowledge" Plans For The Future

P2K has deeply appreciated the opportunity to work with the ACTS program on 3 such ambitious but ultimately successful projects. We are convinced that connecting students and teachers directly with researchers and real-world locations can have a profoundly beneficial impact on science education in the United States and around the world. While ACTS may no longer be operational, the lessons of these 3 Modules will continue to inform and inspire our efforts. In 1999, P2K created and distributed LIVE FROM THE SUN, focusing on the NASA-ESA SOHO mission and behavior of the Sun during Solar Maximum. In 2000 came LIVE FROM THE STORM, part of an ongoing PASSPORT TO WEATHER AND CLIMATE Module in which both NOAA and NASA are supporters. Future plans call for projects looking at the oceans, volcanoes and earthquakes, black holes and the new view of the Universe provided by recent NASA and other missions, and LIVE FROM THE HEART OF THE CELL. Based on results of the past projects involving ACTS, P2K will continue to emphasize real-time interaction and virtual exploration of remote sites. Thanks to the trailblazing work of ACTS, the new "Grand Tour" can include sites all around our world and even across the Universe, and be accessible to anyone, anytime, anywhere. Satellite TV and the Internet can truly serve as a "passport to knowledge" for everyone.

6. Acknowledgements To Acts/NASA Staff Contributing To The P2k/Live From Projects

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Tom Rebold, NASA/Caltech JPL
Greg Kubat and John J. Diamond, NASA Glenn Research Center (LERC)
Robert Bauer and Adesh Singhal, NASA GRC
Brian Abbe and Tom Jedrey, NASA/Caltech JPL
Ramon de Paula, NASA HQ
and all the other NASA, NSF and NOAA staff involved in the projects discussed above.

7. References And Further Information

Passport To Knowledge main site: http://passporttoknowledge.com
Live From The Stratosphere http://passporttoknowledge.com/lfs
Live From Antarctica 2 http://passporttoknowledge.com/antarctica2
Live From The Rainforest http://passporttoknowledge.com/rainforest
Additional Technical Details
Rainforest http://www.grc.nasa.gov/WWW/PAO/pressrel/98_17.htm
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Stratosphere http://www-sisn.jpl.nasa.gov/ISSUE38/stratosphere.html

Appendix

Live From The Rainforest / ACTS Terminal Parameters

ACTS Remote Terminal:	Steerable Beam
ACTS Connection:	Clev. Spot Beam
Service Dates:	4 d/wk,4hr/day,Mar.20-Apr 21
Frequency:	Ka band(30ghz uplink,20ghz downlink)
Data Rates:	Continuously selectable to 1.8Mbps
Communications Mode:	Full Duplex

Channel capacity:	28(64Kbps) channels (One T1 with 24 channels for video/voice plus 4 extra channels for voice/phone/data)
Terminal Specifications:	
Location	Ariau Tower Lodge (60 kms from Manaus)
Satellite Elevation	43.586Deg
Satellite Azimuth	-85.89Deg
Antenna	1.2 Parabolic dish:Gain 89.8 dBm Tx, 85.9 dBm Rx
Transmit Power	41dBm
Bit Coding	QPSK
Data Coding	Reed Solomon encoder