



Extending ACTS Operations Through a University-Based Consortium

Robert Bauer and Richard Krawczyk
Glenn Research Center, Cleveland, Ohio

Dennis Irwin and Hans Kruse
Ohio University, Athens, Ohio

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized data bases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at <http://www.sti.nasa.gov>
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at 301-621-0134
- Telephone the NASA Access Help Desk at 301-621-0390
- Write to:
NASA Access Help Desk
NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076



Extending ACTS Operations Through a University-Based Consortium

Robert Bauer and Richard Krawczyk
Glenn Research Center, Cleveland, Ohio

Dennis Irwin and Hans Kruse
Ohio University, Athens, Ohio

Prepared for the
Seventh Ka-Band Utilization Conference
sponsored by the Istituto Internazionale delle Comunicazioni
Santa Margherita Ligure, Genoa, Italy, September 26–28, 2001

National Aeronautics and
Space Administration

Glenn Research Center

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100

Available electronically at <http://gltrs.grc.nasa.gov/GLTRS>

EXTENDING ACTS OPERATIONS THROUGH A UNIVERSITY-BASED CONSORTIUM

Robert Bauer and Richard Krawczyk
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Dennis Irwin and Hans Kruse
Ohio University
Athens, Ohio 45701-2979

1.0 ABSTRACT

The Advanced Communications Technology Satellite (ACTS) program was slated for decommissioning in October 2000 as was announced at the 6th Ka-band Utilization Conference in May 2000. Quite a celebration was had at that event too centering on the decommissioning of this very successful technology program [1]. With plans in place to move the spacecraft to an orbital graveyard and then shut the system down, NASA was challenged to consider the feasibility of extending operations for education and research purposes provided that an academic organization would be willing to cover operations costs. Continuing operations of the system was determined viable and in the fall of 2000, an announcement was made by NASA to consider extending operations. Plans are now in place to continue the operations of ACTS through a university-based consortium led by Ohio University, Athens, Ohio. Initial plans are for two more years of operations, with options to extend up to a total of four years.

This paper will present the change in plans to continue operations of ACTS. A description of the multi-month transition of the spacecraft to its new and final orbital location is provided. With the spacecraft at this new location, an update on its performance is presented as well as estimates of long-term performance. The consortium development will be presented along with its organization, membership and operations plans for using ACTS.

2.0 INTRODUCTION

During the ACTS Conference 2000 which was held in May 2000 in conjunction with the 6th Ka-band Utilization Conference, the keynote speaker, Mr. Joseph Rothenberg, NASA's Associate Administrator for Space Flight suggested to the ACTS team to investigate the possibility of further utilization of any available capability of the ACTS system by transferring its operations to universities as an educational resource. This was undertaken by the team and determined, in general, to be technically feasible. To find an interested party willing to take over operations, an announcement was made by NASA in the fall of 2000. Only one university, Ohio University, expressed interest in pursuing this opportunity. This paper describes the transition of ACTS from the end of the NASA Experiments Program last May to its current status of having its operations supported by an education-based consortium with a potential for up to four more years of operations.

3.0 ON-STATION STATUS

Since launch in 1993 the ACTS spacecraft was actively maintained at its assigned orbital station of 100° West longitude. When spacecraft retirement planning began in early 1999, updated fuel estimates indicated a very low amount of remaining hydrazine. The safest option to minimize orbital debris issues was to move the satellite to the orbital gravity well at 105.2° West longitude on the geostationary arc (Figure 1). In April 2000 as ACTS neared its planned end of mission in June 2000, the routine East/West station keeping maneuvers that maintained this 100° W. position were discontinued. ACTS began a slow natural drift

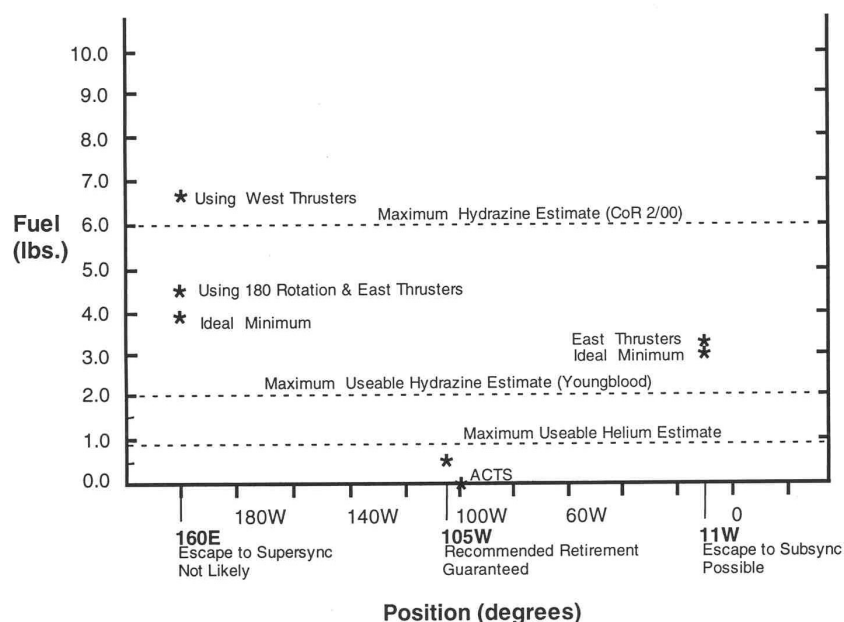


Figure 1: ACTS retirement options

towards the gravity well at 105.2°. On June 18, 2000, a 5-minute burn of the West facing hydrazine thrusters on the spacecraft accelerated the drift rate to 0.075 degrees per day. To move a spacecraft in orbit, the orbit height is either raised (moves West), or lowered (moves East) from the geostationary altitude.

The activity of moving ACTS past the several active commercial satellites between 100° and 105° was an involved process since ACTS is very low on fuel. It could not be maneuvered far above its neighbors for the relocation. As a result, a daily conjunction analysis was done by NORAD/Cheyenne Mountain Operations Center (CMOC) in Colorado to predict the minimum spacing between ACTS and the satellites it was about to pass. The commercial satellite operators were kept informed of ACTS current orbital elements and the ACTS Project was advised of planned station keeping maneuvers by the satellites it was approaching.

The westward drift of ACTS was stopped by a 4-minute burn on August 11, 2000 followed by a 30 second trim burn on August 16, 2000. After monitoring the satellite orbital stability for nearly two months a final 3-second trim burn was done on October 12, 2000. Long term predictions for the natural gravitational effects on this parking orbit indicate approximately 0.2° variation from 105.2° (Figure 2). This will assure that the retired ACTS satellite does not impinge on nearby active geostationary satellites.

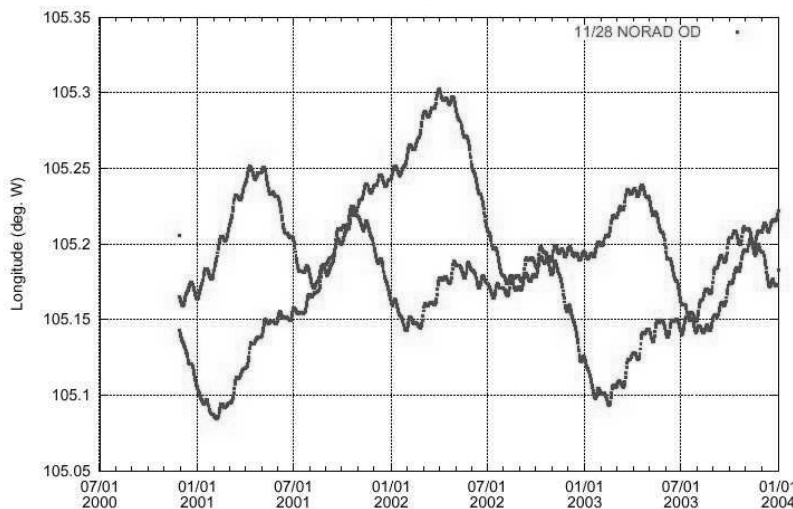


Figure 2: Long term prediction of nodal crossings

4.0 OPERATIONS EXTENSION

In October 2000, NASA announced its willingness to extend operations of ACTS for education and research purposes to an education-based consortium. The terms that NASA offered included that the consortium was expected to fully fund the operations since there was very limited program funding for ACTS operations in 2001 and none beyond. A workshop was held by NASA in October 2000 to present this opportunity. The Ohio Board of Regents which is the state's overseeing body of all its universities, expressed interest in pursuing this and identified Ohio University as the lead organization in forming the consortium.

A Space Act agreement was signed by NASA, the Ohio Board of Regents, and Ohio University as a three party agreement on March 19, 2001. The agreement is structured so that Ohio University would take over payload operations on the spacecraft by May 01, 2001. Ohio University has since formed a consortium, the Ohio Consortium for Advanced Communications Technology (OCACT), and acts as the managing member [2]. NASA retains the operating license of the spacecraft. It has two contractors, Lockheed Martin, and Lockheed Martin Global Telecommunications (formerly Comsat Laboratories) as its spacecraft and master control station operators respectively. Ohio University is responsible for the full reimbursement of NASA's operations costs, and does this through the consortium membership. NASA provides 4 earth stations and their initial installation, and up to a total of 12 earth stations to Ohio University. The arrangement allows the education community access to a large communications satellite for learning about spacecraft operations, as well as using the system's transponders for communications applications. It also is flexible to allow other organizations, such as commercial companies, to become consortium members and use the ACTS wideband Ka-band payload for Ka-band component and subsystem verification, wideband applications, and new services demonstrations.

5.0 SYSTEM PERFORMANCE

ACTS has now taken up permanent residence at its new geostationary slot at 105.2° W while retaining its capabilities as a Ka band test bed. This includes the four wide-band transponders, the high gain, multiple spot beam antenna and two modes of on-board

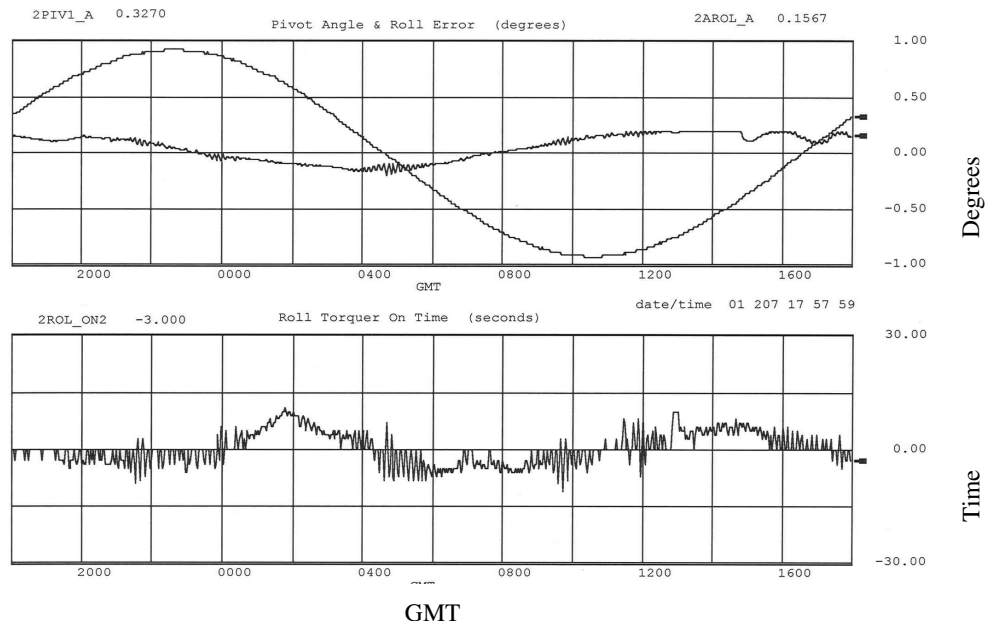
switching. Both Baseband Processor (BBP) and Microwave Switch Matrix (MSM) modes have been exercised recently and are considered healthy and available for consortium use.

The traveling wave tube amplifiers (TWTA) still provide stable performance with 46 watts of RF power in the commercial downlink band of 19.2 to 20.1 GHz. Their operational life should be equivalent to the best space TWTA's so many more years are expected. Although the pre-launch thermal modeling and previous years of experiment operation were based on three active TWTA's it is considered feasible to run all four TWTA's if needed for MSM mode bent-pipe operations while still maintaining a tolerable thermal environment. The solar array still has 25 percent power margin and data from the last semi-annual eclipse season indicated well-matched battery cells.

Given that telemetry data for the communication payload and satellite bus components indicate they are healthy and still have redundancy available, the issue of satellite pointing is now being addressed. The remaining hydrazine fuel, estimated at only a few pounds, was insufficient for reliable super-synchronous disposal of ACTS, but will be more than adequate for at least four more years of pitch axis momentum control.

When ACTS initiated inclined orbit operations to conserve fuel in 1998 a new attitude control scheme had to be devised. The on-board attitude processor was programmed to pivot the momentum wheel through a daily sinusoidal profile that keeps the momentum vector perpendicular to the equatorial plane to avoid roll and yaw perturbations as orbital inclination increases. Although tracking ground terminals were needed as ACTS moved over a greater north-south range the satellite's new mode of control maintained spot beam footprints very close to original specifications for two more years of experimentation. After ACTS was moved to its new geostationary location at 105.2 W, a 0.8° eastward pitch bias was added to restore much of the original beam pointing geometry. As orbital inclination neared 2° in late 2000, the expected hardware limitations were causing abrupt periods of degraded beam pointing as the momentum wheel pivot hit its limits and the magnetic torquer saturated in an attempt to restore roll control. The ACTS operations contractor, Lockheed Martin, is developing a modified inclined orbit control scheme that uses the roll and yaw magnetic torquers more actively while keeping the pivot from exceeding its control range. Figure 3 illustrates the pros and cons of this method over a 24-hour period. Although inclination is currently 2.4° the pivot angle is kept within 1° and the roll torquer on time is still well within its 30-second saturation level. This margin should help control roll during magnetic storm events.

The roll pointing error in the upper chart is a fraction of the inclination, but yaw effects may prove to be more significant for users farther away from the sub-satellite point. Maintaining an effective schedule for users of the spot beams may be one of the challenges ahead. The broader beam of the one-meter steerable antenna can also be used for any location in the western hemisphere if the link budget is sufficient.



**Figure 3: TOP - Pivot Angle (taller curve), and Roll Error (flatter curve)
BOTTOM- Roll Torquer On Time**

6.0 CONSORTIUM DEVELOPMENT AND PLANS

The core goal of extending ACTS operations is to provide educational opportunities to engineering and communications students interested in satellite operations. However, it was clear from the start that the consortium needed a broad base of support to be financially viable. Indeed, the attendees at the ACTS Extension Workshop held in Cleveland, in October of 2000, represented a full range of public and private entities, as shown in Figure 4.

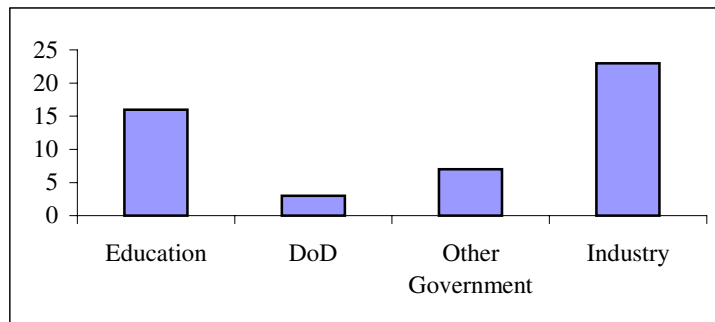


Figure 4: Distribution of individual attendees at the ACTS Extension Workshop

In subsequent discussions, six areas of interest were identified. The consortium is likely to be involved in the following activities:

- A. Space Education: Ohio University and other educational institutions will use ACTS as a “laboratory” to educate students in subjects such as orbital mechanics, spacecraft control systems, spacecraft operations, RF engineering, ground station deployment and operations, and network management.

- B. Educational Content: ACTS will be used by OCACT members to deliver educational content (e.g., from remote locations), to students in K-12 institutions, in collaboration with established educational content providers and foundations.
- C. Engineering verifications: Several members are developing Ka-band hardware and will use ACTS to characterize the performance of these components and verify their designs.
- D. Final ground-station testing: Several members are designing and building commercial-grade Ka band ground-stations. ACTS will be used for final testing of these stations prior to production use on future Ka-band satellites.
- E. “Proof of Concept” demonstrations: OCACT members will conduct demonstrations of telemedicine, satellite telephony, satellite-based Internet access, and other, similar applications to promote the use of Ka-band services in the future.
- F. Extended field and marketing trials: Once commercial-grade ground-stations become available, one or more OCACT members plan to offer pre-commercial service in the form of extended field trials.

Figure 5 shows an estimate of the distribution of expected usage over these project types. The figure is based on the intentions of the consortium member that have been made public at this time; some members are involved in several projects. These data show a fairly even distribution of activity. Figure 6 breaks down the funding contributed by the members into the same categories. The comparison between figures 5 and 6 points out that extended ACTS operations are currently supported almost entirely by commercialization projects, a result that may well be explained by the absence of a commercial Ka-band satellite over the North American continent. This situation also represents a challenge facing the consortium; that is, the long-term funding distribution will need to shift to the educational institutions and organizations (most likely in the form of grants) and become more aligned with the distribution of projects.

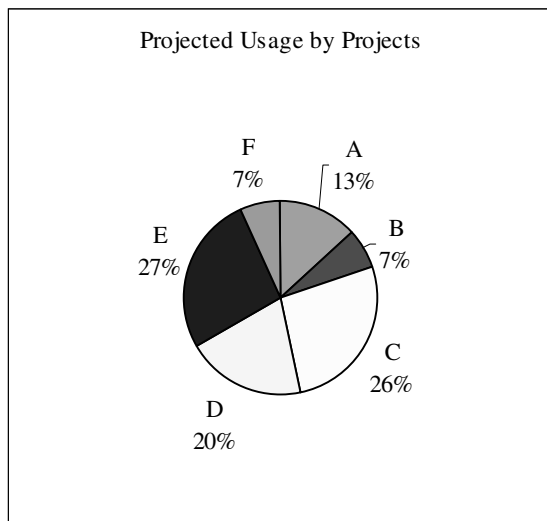


Figure 5

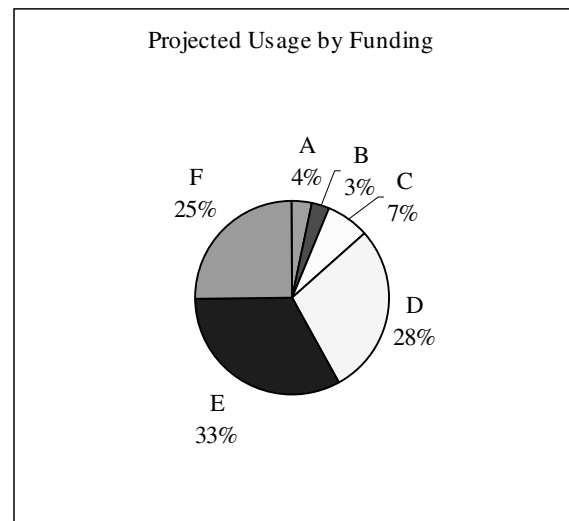


Figure 6

Projected ACTS usage broken down by the number of projects (figure 5) and the funding allocated to these projects by the consortium members (figure 6).

6.1 INSTITUTIONAL SUPPORT AND THE FORMATION OF THE ACTS CONSORTIUM

There are a number of “corporate” forms that a consortium can take. A consortium can be a stand-alone not-for-profit or non-profit entity formed under the laws of one of the states, or a consortium can be an outgrowth of an existing entity. In the case of ACTS, it was clear that the time and expertise required to form a separate entity were not available. In addition, it was clear that significant seed funding would be required to convince NASA management to continue operations. This set of circumstances necessitated the formation of the consortium as part of the Ohio Board of Regents of Higher Education as the signatory of a reimbursable Space Act agreement detailing the use and operations of ACTS and because of the limited management resources of the Regents’ staff, delegation of the formation and daily operations of the consortium to Ohio University or another institution under the authority of the Regents. The institution, in turn, must have significant financial, legal, and management resources and a high level of commitment to operate an asset as valuable and complex as ACTS.

In the case of Ohio University, a number of personnel at the faculty, staff, and student levels were experienced as users of ACTS or other spacecraft, the elements of an operations center (office space, laboratory space, ACTS-specific hardware, and infrastructure for ground station installation) were available, the College of Engineering and Technology and the College of Communication were willing to risk significant financial resources and commit faculty and management to the consortium, and the Office of Legal Affairs was willing to participate materially in the inevitable negotiations necessary to develop consortial agreements with the disparate organizations interested in joining the consortium. Most importantly, the entire management structure of the university, including two department chairs, two Deans, the Provost, the Vice President for Finance, the Vice President for Research, and ultimately the President of the university supported the development of a financial and management loan package worth almost US\$600,000.

This commitment was instrumental in convincing NASA to continue ACTS operations and to enter into a Reimbursable Space Act agreement for future operations by the consortium (*The Ohio Consortium for Advanced Communications Technology*) under the supervision of a NASA Liaison. The operational details of this relationship are still evolving; however, it is clear that continued significant involvement by NASA personnel is necessary and that the existing contractor support personnel must be retained, at least for the foreseeable future. In short, the management, operations oversight, and authority for spacecraft operations can be transferred to the consortium, but the retention of the expertise of the experienced operators of ACTS is crucial.

The structure of the consortium, as an entity sponsored by Ohio University, retains the university as Managing Member, with certain rights such as shutdown authority, payload usage priorities, and operational control. The Managing Member is also responsible for financial management. Other members join in either voting or non-voting status, depending on the level of financial commitment and as educational, not-for-profit, government, or industrial members. The consortium is governed by a council, formed by and from the voting members, and is responsible for annual financial and payload usage plans. Daily operations such as payload scheduling and ground terminal installation are the responsibility of a Managing Executive. As of July 2001, the consortium membership is in flux, but includes 3 educational institutions, 1 not-for-profit alliance of educational content providers, 2 government entities, and 3 industrial members. Negotiations are underway with an additional 2 government organizations and at least one industrial entity.

7.0 CONCLUSION

The opportunity to extend ACTS operations by transitioning them to a university consortium provides an excellent closing chapter on ACTS. Even though NASA funds to support spacecraft operations have expired, the payload continues to operate on primary systems and can continue to be a learning tool to academia, while still providing the only operational Ka-band system in the Western hemisphere. As cited in Space News, “NASA made a great decision when it decided to turn the ACTS over to students at the Ohio University...”[3]

8.0 REFERENCES

- [1] Proceedings of the Advanced Communications Technology Satellite (ACTS) Conference 2000, NASA/CP—2000-210530, December 2000.
- [2] <http://www.csm.ohiou.edu/ocact/>
- [3] Hands on Exploration—Editorial, *Space News*, April 9, 2001.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 2001		3. REPORT TYPE AND DATES COVERED Technical Memorandum
4. TITLE AND SUBTITLE Extending ACTS Operations Through a University-Based Consortium			5. FUNDING NUMBERS WU-322-10-2A-00	
6. AUTHOR(S) Robert Bauer, Richard Krawczyk, Dennis Irwin, and Hans Kruse				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration John H. Glenn Research Center at Lewis Field Cleveland, Ohio 44135-3191			8. PERFORMING ORGANIZATION REPORT NUMBER E-13000	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001			10. SPONSORING/MONITORING AGENCY REPORT NUMBER NASA TM-2001-211148	
11. SUPPLEMENTARY NOTES Prepared for the Seventh Ka-Band Utilization Conference sponsored by the Istituto Internazionale delle Comunicazioni Santa Margherita Ligure, Genoa, Italy, September 26-28, 2001. Robert Bauer and Richard Krawczyk, NASA Glenn Research Center; and Dennis Irwin and Hans Kruse, Ohio University, Main Campus, Stocker Center 333, Athens, Ohio 45701-2979. Responsible person, Robert Bauer, organization code 6160, 216-433-3431.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Categories: 17, 18 and 32 Available electronically at http://gltrs.grc.nasa.gov/GLTRS This publication is available from the NASA Center for AeroSpace Information, 301-621-0390.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The Advanced Communications Technology Satellite (ACTS) program was slated for decommissioning in October 2000 as was announced at the 6th Ka-band Utilization Conference in May 2000. Quite a celebration was had at that event too centering on the decommissioning of this very successful technology program. With plans in place to move the spacecraft to an orbital graveyard and then shut the system down, NASA was challenged to consider the feasibility of extending operations for education and research purposes provided that an academic organization would be willing to cover operations costs. Continuing operations of the system was determined viable and in the fall of 2000, an announcement was made by NASA to consider extending operations. Plans are now in place to continue the operations of ACTS through a university-based consortium led by Ohio University, Athens, Ohio. Initial plans are for two more years of operations, with options to extend up to a total of four years. This paper will present the change in plans to continue operations of ACTS. A description of the multi-month transition of the spacecraft to its new and final orbital location is provided. With the spacecraft at this new location, an update on its performance is presented as well as estimates of long-term performance. The consortium development will be presented along with its organization, membership, and operations plans for using ACTS.				
14. SUBJECT TERMS ACTS; Ka-band; Satellite; Communications; Consortium			15. NUMBER OF PAGES 14	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT	