ACTS Program Formulation

Background Information

NASA had a very significant role in the establishment of satellite communications, first with the Syncom program to prove the feasibility of the geo-synchronous orbit and later with the ATS and CTS programs, which developed the C and Ku bands and led to the establishment of the commercial satellite communications industry. At this point, NASA directed its efforts to other space endeavors, expecting that the industry would continue the needed technology development to keep the industry viable and competitive.

NASA's Re-entry into Communication R&D

In 1974, several organizations began to assess the consequences of NASA's decision to essentially eliminate satellite communication activities that focused on commercial applications [11]. The Electronic Industries Association (EIA) issued a position paper in January 1974, which urged NASA to reconsider its decision. In January 1975, the American Institute of Aeronautics and Astronautics (AIAA) issued a similar report. It urged NASA to re-enter the communication satellite field by sponsoring new families of application technology satellites. The report argued that from 1960 to 1973, "the federal government took the dominant role in communication satellite research and development, thereby providing the basis for low-risk operational system development by private enterprise in the 1960s and 1970s."

In the fall of 1975, NASA asked the National Research Council (NRC) to consider and report on the question: "Should federal research and development on satellite communication be resumed and, if so, what is the proper federal role in this field?" To undertake the study, the NRC formed a Committee on Satellite Communications, under the auspices of the Space Application Board. After studying this question, the consensus of the committee was that major advances in communication satellite technology *required* government investment, particularly in the areas where high technical risks were involved. This committee concluded that satellite communication R&D was an appropriate federal responsibility, and that NASA should resume the research and development activities needed to provide the new technology for future commercial communication needs. The NRC committee recommended, in a 1977 report [12], that NASA implement an experimental satellite communication technology flight program based on an assessment of need, technology projections, and service concept development. It recommended that the technical design of any NASA experimental communication satellite should support several end user service concepts, and that appropriate user groups should assist in the conceptual definition of both the needed technology and the experiments themselves. Based on the results of the NRC report, the increasing demand for domestic voice, video, and data traffic, and the foreign competition and prospects of trade disparity, President Jimmy Carter saw fit to reinstate federal sponsorship of communication satellite technology. Official sanction for NASA to resume its responsibility was contained in the October 1978 Presidential Directive (PD-42). This directive stated, "NASA will undertake carefully selected communication technology R&D. The emphasis will be to provide better frequency and orbit utilization approaches."

The NASA Satellite Communication Program for the 1980s

In 1978, as a result of the Presidential Directive, NASA began the process of rebuilding its R&D activities in the communication satellite arena [13,14,15]. The future technology program was planned in cooperation with the National Research Council's Space Applications Board Subcommittee on Satellite Communications, whose membership consisted of leading common carriers, spacecraft manufacturers, and representatives of communication users.

Market & System Studies

In this first phase of the NASA program, market and system studies were conducted to determine future service demand and whether or not C- and Ku-band satellites could satisfy it. Two contracts were awarded to common carriers: Western Union Telegraph Company, and U.S. Telephone and Telegraph Company, which was a subsidiary of International Telephone and Telegraph (ITT) [16,17]. The emphasis of these studies was to forecast the telecommunications traffic that could be carried by satellite competitively. During this same time frame, two other system studies were conducted—one each by Hughes Aircraft and Ford Aerospace, with supporting studies by TRW, GE, and the Mitre Corporation [18,19]. Their purpose was to identify the technology needed to implement cost-effective and spectrum-conservative communication systems. The results were combined to define potential commercial system configurations that could address the market for trunking and customer premises services that was expected in the early 1990s. System requirements derived from these postulated commercial configurations formed the basis for the technology development program that followed.

The market studies predicted that rapid growth in domestic voice, data, and video traffic would lead to a five-fold increase in U.S. communication demands by the early 1990s. A combination of these market projections and communication satellite license filings with the FCC portended a saturation of North American orbital arc capacity using the C- and Ku-band frequencies. To relieve the pressure of this expanding market, the 30/20 GHz frequency band was needed. As a result, the new NASA communication program for commercial application was named the 30/20 GHz Program and was structured to:

- Develop selective high-risk, 30/20 GHz technologies that focused on relief of orbit and frequency congestion and developing new and affordable services
- Promote effective utilization of the spectrum and growth in communications capacity

- Ensure continued U.S. preeminence in satellite communications

The technologies required to meet these objectives were judged to be of such high technical risk that they were beyond the capability of any one company to finance.

In 1979, NASA designated the Lewis Research Center (LeRC) in Cleveland, Ohio, to be its lead center in planning and executing the commercial communication satellite technology R&D Program. In 1999, the Lewis Research Center's name was changed to the Glenn Research Center (GRC), in honor of John Glenn, astronaut and U.S. Senator from Ohio.

Early communication satellite systems employed simple, bent-pipe transponders with a single antenna beam to cover a large region (such as the continental United States). The new NASA program needed to develop technology that would allow the frequency spectrum to be used more efficiently. One technique to accomplish this was to cover the region with many small spot beams so that the same frequency could be reused simultaneously in non-adjacent beams. Such frequency reuse increased the capacity of satellites by a factor of five to ten times that of a single beam satellite, with only a modest increase in spacecraft size, power, and weight. The technology to accomplish this high degree of frequency reuse employed antennas with high-gain spot beams and electronic systems with onboard switching and processing to inter-connect the spot beams. In addition, the high-gain antenna allowed for smaller aperture user terminals at higher data rates. This was the technology developed by NASA.

<u>Technology Feasibility & Flight System Definition</u>

In 1980, the program moved forward in two phases. The first phase was to 1) continue the market studies to increase confidence in the forecast for orbit saturation and 2) to do proof-of-concept development of the identified technologies. The proof-of-concept program was a laboratory (breadboard) type of development to prove that the technologies were feasible. Approximately $50 million was expended on the first phase. If the first phase proved successful, the second phase would consist of developing an experimental flight system to demonstrate that the technologies could provide reliable communications services.

The first phase was fully supported by the entire service provider and satellite manufacturing community. The second phase of the program was the one that became controversial. The service providers had great concern about how reliably the technology would work in space, and therefore, argued for a flight program. Some satellite manufacturers, however, had reservations about proceeding with a flight program because they felt it would give the winning contractors of the NASA procurement an unfair competitive advantage. This controversy continued throughout most of the life of the ACTS program.

Program Coordination with Industry

Two industry committees were formed to guide the program. The NASA Ad Hoc Advisory Committee was created to provide general policy direction. The committee included notable representatives of both the system supplier and service supplier industry. Their contribution provided timely and sage review of the program, as well as providing NASA with insight into the industry philosophy relative to the roles and responsibilities of both government and the private sector.

The second industry committee was a Carrier Working Group (CWG), consisting of representatives from all the major satellite service providers. The CWG was charged with helping NASA formulate the technology and flight system requirements, develop experiments, and provide overall guidance. These requirements and experiments were deemed necessary by the CWG to demonstrate the readiness of not only the technology, but of its service applications as well. Coordination was also established between the Department of Defense and NASA, especially in the development of various critical advanced technology components.

Proof-of-Concept Development

The purpose of the proof-of-concept (POC) technology development was to demonstrate the technical feasibility of the key component building blocks [20,21]. The approach NASA used was to issue multiple contracts to various aerospace and related companies for the development of each high risk technology: *multiple spot beam antenna, base band processor, TWTA, wide-band switch matrices, low-noise receiver, GaAs FET transmitter, GaAs IMPATT transmitter,* and *ground antenna*. Duplicate awards for most of the critical technology components were employed to increase the probability of successful development, and to produce multiple sources for communication hardware. In addition, multiple awards helped to ensure that a variety of perspectives and technical approaches were brought into each development. These contracts called for the development of the technology, the construction of POC versions of the components, and their testing in the laboratory to verify performance.

The POC hardware substantially reduced the risk associated with the planned development of the flight system. Another product of these technology contracts was the prediction of feasible component, subsystem, and system performance levels. NASA used these performance predictions to provide guidance for follow on technology development. Service providers and manufacturers could also use these predictions in planning activities for the commercial system designs of the early 1990s.

The Department of Defense (DOD) participated in the NASA POC pro-gram. Several of the critical technology POC elements that were of interest to the DOD were co-funded by DOD and NASA. To enable the effective transfer of information that was generated in the program, all contractors were required to prepare task completion reports. These reports were presented at periodic industry briefings (only for interested U.S. parties) hosted by NASA.

Flight System Definition Studies

The need for a flight test program reflected the fact that much of the required technology had never been demonstrated in space. The flight test was to ensure that the technology base was mature and validated, providing the level of confidence recommended by industry as being necessary for commercial exploitation. The initial planning called for two experimental satellites to be built and flown; one to demonstrate telephone trunking for high volume users in metropolitan areas, the second to demonstrate customer premises services using small and inexpensive earth terminals located at customer locations.

In 1980, the two-flight concept was reduced to a single experimental spacecraft, primarily emphasizing customer premises services. This proved to be a wise decision since the introduction of fiber optics a few years later significantly reduced the cost for terrestrial trunking services, making satellites non-competitive.

In February 1982, Dr. Burt Edelson became NASA's associate administrator of the Office of Space Science and Application, and played a very important role in keeping the program alive. When the program was seriously threatened in 1982, Dr. Edelson restructured the 30/20 GHz program by broadening its applicability to the entire frequency spectrum for satellite communications. As a result, the experimental satellite system was renamed the Advanced Communications Technology Satellite (ACTS), and it focused primarily on the technology of multi-beam antennas and associated onboard switching and processing. Spacecraft capacity was reduced to a minimum for technical verification and experimentation only.

Dr. Edelson provided key leadership for the ACTS program during his tenure at NASA, and has been a vocal proponent of the program and its benefits ever since. Two other NASA managers who provided important leadership to the NASA Communications Program were Joe Sivo and Bob Lovell. Joe Sivo was the chief of the Communications and Applications division at NASA's Lewis Research Center in Cleveland, Ohio. Joe was the "Father of ACTS" and led the LeRC team in the late 1970s and the early 1980s as NASA restructured its communication program. Bob Lovell became chief of the Communications division at NASA Headquarters and worked with both Dr. Edelson and Joe Sivo to structure the ACTS program and guide it through technical and political hurdles in the early 1980s. Without Sivo, Lovell, and Edelson, the ACTS flight program would have never gotten off the ground.

Concurrent with the POC technology development, NASA was working with industry to define flight system concepts that would demonstrate ACTS technology readiness and its service capabilities. During the period of 1981-1983, the major spacecraft manufacturers—Ford Aerospace (now Space Systems Loral), Hughes Aircraft, TRW, GE, and RCA (both now part of

Lockheed Martin) were funded by NASA to conduct system studies for defining a R&D spacecraft (ACTS) that could be flown by NASA. NASA then used the results from these system studies to develop the Request for Proposal (RFP) for the ACTS spacecraft and ground system. This RFP was issued by NASA in early 1983, with a proposal due date of June 1, 1983. Since the RFP required the development of very high-risk technology that had never been flown before, a cost-plus-fixed-fee type of contract was specified.

The five separate flight system studies were conducted to get a wide range of views on what the ACTS spacecraft configuration should be and to promote competition for the procurement of the spacecraft. As it turns out, this process did not accomplish the latter objective and was complicated by the fact that there was not a clear consensus for the need for a flight program to prove the feasibility of the new technology.

The Reagan administration espoused a minimal government involvement ideology. At the time, the Republican administration took the position that it was not the proper role of government to conduct a flight program for the purpose of proving technology for commercial purposes, especially for a profitable industry. There were many arguments presented by the Republican administration as to why the government should not sponsor the flight verification. These included arguments that the government was not capable of predicting technology for commercial application, and that the spot beam, frequency-reuse technology was not necessary because there was plenty of C-and Ku-band spectrum for future use. However, as we know today, the use of spotbeams allows a great increase in the amount of frequency reuse so that a single satellite can have a very large capacity. Without this spot beam increase in capacity, many of the mobile and broadband satellite systems under development in the late 1990s, such as Iridium, Globalstar, Spaceway, Astrolink, and iSKY (formerly called KaStar), would not have been economical. All the developers of these systems make a strong case that their spot beam systems meet the current FCC requirement to more efficiently use the spectrum. The FCC has added this requirement since they realized that the frequency spectrum is a scarce resource.

Congress in the 1980s was increasingly concerned about U.S. economic competitiveness in high technology industries. They were sensitive to areas such as satellite communication being challenged by foreign entities, where the federal government could improve U.S. competitiveness. The Democratic Congress listened to the arguments of the U.S. commercial satellite industry in support of a flight verification program and decided it should be conducted. This debate between the Republican administration and the Democratic Congress (including each side's constituencies) over the need for the ACTS flight test continued through launch of the ACTS in September of 1993. Later chapters in this book cover this debate in much more detail. It is sufficient here to say that the difference in philosophy between the White House and Congress was great enough that Reagan's budget left the program without funds for five years in a row, and that Congress restored the funds in each budget during those five years. If nothing else, the ACTS program may have set a record in this regard.

Bidding on the ACTS Contract

The response to the ACTS RFP was disappointing because only one proposal was received. The team submitting the proposal consisted of RCA as prime integrating contractor and supplier of the spacecraft bus, with first-tier subcontractors TRW (for the communication payload) and COMSAT (for the Master Control Station). Second-tier subcontractors included Motorola for the base band processor and Electromagnetic Sciences (now called EMS Technologies) for the spacecraft's antenna beam-forming network. Since TRW, Motorola, and Electromagnetic Sciences had developed major pieces of the ACTS technology in the proof-of-concept development program, this team was very competent. Because the team represented a large cross-section of the U.S. industry involved in satellite communications, NASA believed that objectives of the program could still be achieved by the single bid.

ACTS was to be placed into a low earth orbit by NASA's space shuttle, and the RFP required that the payload be constrained to as small a space in the shuttle's cargo bay as possible. One option was to use a Payload Assist Module PAM-D perigee stage to place ACTS into a geostationary transfer orbit (GTO) after deployment from the shuttle. Some pre-proposal studies showed that this approach would result in the ACTS only using one quarter of the shuttle's cargo bay volume. The next alternative was to use a larger capacity perigee stage—a PAM-A—which would take up more volume in the cargo bay. NASA wanted to restrict the payload's volume in the cargo bay to limit the total cost of the mission, including launch. At this time, shuttle launch costs were based on the volume occupied in the cargo bay. This logic was somewhat questionable since the shuttle was not always flown with a full load. In fact, the NASA cost model used a shuttle load factor of 3/4 capacity to determine the pricing for payloads. Potential bidders questioned this requirement and sought a change. Prior to the receipt of proposals on June 1, 1983, Robert Berry, director of Space System Operations at Ford Aerospace, wrote to NASA on May 3, 1983, [22] and stated the following:

> "We believe that the technical approach which would create the least risk to NASA would be a PAM-A configuration satellite, unconstrained by the volume limitations of the PAM-D family of perigee stages. We have made the case that it is in NASA's best interest not to discourage the offer of a PAM-A configuration. It seems obvious to us that NASA's objectives in achieving an ACTS program offering innovative and unique associations with other government or commercial users can only be satisfied with a PAM-A equivalent spacecraft. We further believe that as the definition of NASA's high technology payload evolves, weight, power, footprint area, thermal considerations, and performance margins will move toward the limitation of the PAM-D configuration. On the other hand, ample margin would still exist with a PAM-A configuration."

Ford Aerospace had planned to offer a PAM-A class spacecraft for the ACTS mission. We also had received notification from another payload user of their firm commitment for another payload, which would have been incorporated, on our satellite configuration along with the ACTS payload. In addition, we had been informed by a satellite operating company of its interest in leasing the ACTS payload, thus providing potential cost reimbursement to NASA. However, RFP 3-511907 quantitatively defines the assignment of launch costs to overall program costs, but offers no quantitative offset for the substantially greater capability of a PAM-A configuration. This quantitative imbalance confers an apparent competitive cost advantage to a PAM-D class satellite configuration even though that configuration will not support the full achievement of NASA's overall program objectives. Should NASA subsequently decide that a PAM-A equivalent configuration is desirable for ACTS, Ford Aerospace would be pleased to offer a competitive solution.

In a December 1983 *Aviation Week & Space Technology* article [23], Berry went further and said, "There is no way the ACTS payload is compatible with the McDonnell Douglas Delta (PAM-D) class upper stage." It was expected that the ACTS contractor would use a standard commercial bus to limit the non-recurring costs for the spacecraft. Ford Aerospace wanted to bid its standard PAM-A bus, which evidently would have taken up considerable volume in the shuttle. They must have perceived that this would have made them non-competitive, so therefore did not bid. As it turned out, Berry's statement that the ACTS weight requirement was beyond the PAM-D capability was true. When RCA bid the ACTS job, they proposed a PAM-A con-figuration with the antenna reflectors folded across the top of the spacecraft to minimize the volume taken up in the shuttle. Not long after the contract was awarded, the folded reflector design was replaced with a truss structure arrangement that significantly increased the needed volume in the cargo bay.

When ACTS was launched, it took up approximately one half of the cargo bay's volume. NASA's concern with limiting shuttle costs and its procurement regulations forbidding informal discussions with potential bidders after release of the RFP, resulted in improper treatment of a contractor's input. In hindsight, it is obvious that it would have been better for the program had the shuttle launch costs not been included in the proposal evaluation. The result would have been the receipt of two proposals instead of one. The other major potential bidder for ACTS was Hughes Aircraft Company. Although the reasons were not publicly stated, Hughes chose not to submit a bid for ACTS.

Hughes Ka-band Filing

Hughes questioned the ACTS program in principle as unnecessary subsidization of commercial operations and duplication of military technology development. To emphasize their point, they filed an application with the FCC in early December of 1983 for the development, launch, and operation of a two-satellite Ka-band domestic system. Their satellites were to be equipped with high-power spot beams focused on 16 major U.S. metropolitan areas. As such, it would allow the use of two meter customer-premises earth stations for business data services such as teleconferencing, high-speed document distribution, and remote printing. The first of their two proposed satellites was to be launched in December of 1988.

Hughes noted in this filing that they expected the orbital allocations at the C- and Ku-bands to be exhausted following the next round of FCC assignments. In essence, Hughes agreed with NASA's C- and Ku-band saturation projections, which had been derived by Western Union. In fact, Hughes quoted the Western Union market study in their filing. This filing, however, was contrary to other statements made by Hughes during the same time period that warned of a coming glut in transponder capacity. This contradiction and other factors led to speculation by observers [5] that Hughes opposed the ACTS flight program on purely competitive grounds. Nothing ever came of the Hughes filing, but it did set the stage for consistent Reagan administration opposition to ACTS. The administration turned against continuing ACTS as a flight program after Hughes filed with the FCC. Since ACTS and Hughes' system used the same 30/20 GHz frequencies, senior Hughes executives argued against continuing the program before the Office of Management and Budget (OMB) and NASA, claiming that a government-funded program would be redundant. When the Reagan administration sent its budget proposal for NASA to Congress at the end of January 1984, it reduced the funding to so small a level that a flight program could not proceed.

<u>ACTS Contract Signed</u>

In the ensuing months, a battle over the ACTS flight program was waged in the U.S. Congress. Congress became convinced that the ACTS program objectives were valid and important to carry out. In the latter part of May 1984, despite administration opposition, they approved a $40 M increase for the ACTS program to reinstate the flight verification phase. After President Reagan signed the FY 1985 authorization and appropriation bills, it cleared the way for a contract signing with RCA on August 10, 1984, for the development of the ACTS flight system. This funding battle over ACTS between the administration and Congress continued for the next four years, with the administration trying to terminate ACTS each year.

As initially proposed by RCA, ACTS system development was to take place over a five-year period with an engineering model development being completed in three years. Because of the complex coordination between the user terminals, the master control station, and the onboard switch system in setting up on-demand circuits, the development included a comprehensive, three-month test of the ACTS ground system with the spacecraft. The proposed five-year development time contrasts with the normal commercial satellite development of three years, and reflects the fact that the ACTS technology was well beyond the current state-of-the-art. With the ACTS contract awarded in August of 1984, the scheduled launch date was September of 1989. As described in a later chapter, funding cutbacks, development problems, and other difficulties caused the launch to be delayed until September of 1993.

Changing Times

What is the proper role of government in technology development? The NASA ACTS program served a very important role in advancing satellite communication because the commercial satellite communication industry in the 1980s could not afford to take on the risk associated with the necessary technology. The business climate in the 1980s was entirely different than in the late 90s. Today, non-traditional satellite companies such as Motorola, iSKY, and Pasifik Satelit Nusantara (PSN)—to name just three—have found investor partners to put up billions of dollars for implementation of revolutionary satellite communication systems employing advanced technologies. Iridium is a 66 25 LEO satellite system that provides mobile communication anywhere in the world. iSKY is a GEO satellite system that provides broadband communications for the consumer Internet in the United States. In the case of PSN, the system is a GEO, handheld mobile communications system called ACeS. All three systems use multiple spot beam antennas, and both Iridium and AceS have on-board digital processing. Iridium also has inter-satellite links to provide global connectivity. Because of the success of many new satellite systems—such as NASA's ACTS, DOD's MilStar, and Hughes' DirecTV—many satellite service providers now view new technology not as a major risk factor but as a means to introduce new services. Another major difference today is that the perceived market potential is *much* greater than it was in the 1980s.

In the 1980s, communications satellites were still in their infancy and large sums of capital were not available for risky ventures. The ACTS flight program was a proper role for the government in the 1980s. Due to differences in the business climate and the maturity of many technologies, a similar flight program is not considered necessary today. This is discussed in more detail in Chapter 9, "The Role of Government in Technology Development."