U.S. Development and Commercialization of a North American Mobile Satellite Service

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ABSTRACT

U.S. policies promoting applications and commercialization of space technology for the "benefit of mankind," and emphasis on international competitiveness, formed the basis of NASA's Mobile Satellite (MSAT) R&D and user experiments program to develop a commercial U.S. Mobile Satellite Service. Exemplifying this philosophy, the MSAT program targets the reduction of technical, regulatory, market, and financial risks that inhibit commercialization. The program strategy includes industry and user involvement in developing and demonstrating advanced technologies, regulatory advocacy, and financial incentives to industry. Approximately 2 decades of NASA's satellite communications development and demonstrations have contributed to the emergence of a new multi-billion dollar industry for land, aeronautical, and maritime mobile communications via satellite. NASA's R&D efforts are now evolving from the development of "enabling" ground technologies for VHF, UHF, and L-Band mobile terminals, to Ka-Band terminals offering additional mobility and user convenience. Many aspects of NASA's MSAT Program are described in detail.

INTRODUCTION

U.S. Commercial MSS Context

The remarkable growth in recent years of a diverse mobile communications market clearly demonstrates the concept of people emancipating themselves from wall plugs for a variety of communications applications. Mobile satellite communications systems will comprise an important segment of this market, staking out, and likely increasing, their market share for specific applications such as remote/"thin-route" communications in which the Mobile Satellite Service (MSS) is considered the optimum choice.[1] User needs such as interoperability, wide-area coverage, and reliability combine to boost the mobile satellite's utility for public safety and disaster communications as well as numerous other applications.

NASA's commercial space policy encourages private sector involvement in commercial space endeavors. Commercially provided mobile satellite communications are considered a viable alternative to direct public expenditures for acquiring and maintaining Government communications platforms to meet Government research and communications needs. In addition, U.S. technology policies in the 1980s emphasized and encouraged programs that would enhance U.S. competitiveness in international markets. Finally, the 1958 National Aeronautics and Space Act and other U.S. technology policies mandated "socially beneficial" as well as commercial applications of space technology. The combination of all of these factors formed the backdrop for NASA's highly cooperative Government/industry MSAT Program.[2]

During almost 2 decades of leadership in developing communications satellites, NASA and Goddard Space Flight Center conducted over 100 land, aeronautical, and maritime mobile satellite experiments and studies, using

NASA experimental satellites. Among these were the ATS Series satellites (1, 3, 6) launched in the 1960s and 1970s, and the Communications Technology Satellite (CTS), launched in 1976. The CTS was a cooperative Department of Communications/Canada (DOC)/NASA direct broadcast satellite technology development program begun in the late 1960s. The ATS and CTS series were precursors to today's Mobile and Broadcast Satellite Services, paving the way for the current small ground terminal market, and opening up many new frequency bands for satellite services, including L-Band.

Through this experience, NASA determined by the late 1970s that the necessary technology development and regulatory actions appeared feasible for the commercialization of MSS. Through extensive market studies conducted in the early 1980s, NASA concluded that a vast rural communications market existed that was, as yet, untapped. Also, international interest in mobile communications markets was growing, prompting NASA to develop a strategy for the U.S. commercialization of MSS.

NASA's approach to accelerating MSS commercialization in the United States revolved around a basic requirement: the need to reduce the financial and market risks to commercializing the MSS industry.[3] These risks were associated in part with the technology, namely market aggregation for this specific service and the viability and cost of the technology. A significant risk was also presented by the regulatory process. Both of these problems gave rise to a NASA R&D risk-reduction strategy that incorporated technical, regulatory, financial, and institutional elements. All of these elements are critical aspects of the equation needed to commercialize the MSS in the U.S. context, in essence helping to make private commercial space ventures competitive to alternative investments.[4] Inherent limitations of spectrum and orbital slots and other key challenges associated with financial and market risks to the MSS formed the cornerstones of the NASA Mobile Program. These were: (1) development of efficient ground technologies and techniques to conserve power, spectrum, and orbit at the lowest possible cost to users; (2) development of a user base for the technology; (3) allocation of frequencies for a viable MSS; and (4) development of financial incentives to attract industry involvement.

Scope of the Paper

This paper describes the evolution of NASA's MSAT Program and how it is structured to address technical, institutional, financial, and regulatory risks involved in MSS development. Discussion includes historical and current MSAT-X portions of the program, as well as the evolving Personal Access Satellite System (PASS) and Advanced Communications Technology Satellite (ACTS) Mobile Terminal (AMT) Experiment program thrusts (Figure 1).

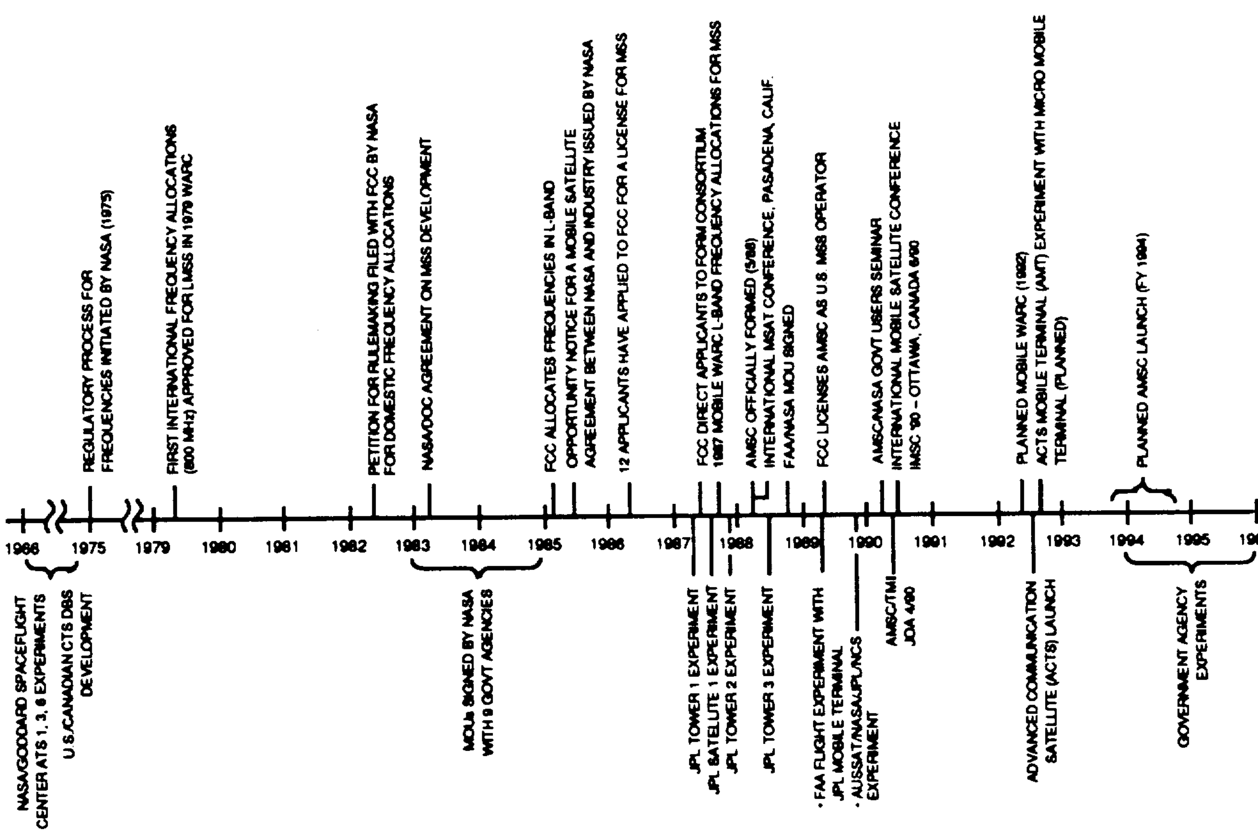

Fig. 1. Key dates in NASA MSAT development

MSAT PROGRAM UPDATE

Program Objectives

The primary objectives of the MSAT Program are to: (1) accelerate the introduction of the first U.S. commercial MSS and (2) enable and enhance future generations of mobile satellite systems.[5] The program was designed to be a highly cooperative Government/industry effort, focused on industry and user needs, and in particular on reducing the risks to industry of commercial MSS development.

MSAT and MSAT-X

NASA's MSAT Program (including the MSAT-X Task) consists of the following elements: (1) high-risk enabling technology R&D, (2) regulatory aspects of MSS, (3) a NASA launch offer to industry, (4) Government agency user experiments, and (5) institutional relationships to support MSS commercialization. In 1982, the Jet Propulsion Laboratory (JPL) was designated the NASA MSAT Program lead center for MSS studies and critical technology identification and development. JPL's MSAT-X Task is focused on mobile satellite communications ground segment development and satellite experimentation; however, MSAT-X also includes the Program's Government/industry interface subtask.

Technology Development. The MSS is a satellite-based communication system, providing voice and data communications to mobile users. Satellites, in geosynchronous orbit, relay two-way digital transmissions over a wide geographical coverage area, making this type of mobile communications ideal for rural (thin route) areas, or as an augmentation of terrestrial systems.

There are three constituent portions of the system. The first is the land-based portion of the network, including the Network Management Center which oversees the operations of the network; gateways, which provide interfaces to other networks such as the Public Switched Telephone Network (PSTN); and base stations, which are normally centers for dispatch operations, not necessarily connected to other networks. The second is the satellite (space segment). The third is the mobile terminal, which is located within the mobile vehicle and comprises the radio, antenna, and user interface. A principal challenge is to have the mobile terminal be low-cost and small in size to ensure a wide customer base and economic viability.[6]

By the early 1980s, the technology critically needed for a first-generation system was considered feasible. A large (10-meter) spacecraft antenna and other vital technologies had already been developed and demonstrated by NASA and Goddard Space Flight Center. Because of the limited bandwidth expected to be available and geostationary orbit placement considerations, the emphasis was on developing or improving the spot beam technology; spectrum-efficient modulation and coding techniques; small, low-cost, low-powered mobile ground terminal hardware; high- and medium-gain directional antennas; and frequency-sharing techniques.

The JPL MSAT-X Task consists of five aspects of ground segment/mobile terminal technology development: (1) steerable, medium-gain vehicle antennas supporting orbit reuse and power conservation; (2) near-toll-quality digital speech at 4800 bps; (3) efficient modems (4800-9600 bps) for 5-kHz channel transmission; (4) network architecture and multiple access techniques for optimal system throughput; and (5) propagation studies to reduce design uncertainties.[7]

First- and second-generation designs are complete, and a prototype terminal has been developed and demonstrated by JPL, with substantial industry involvement and user experimentation. A pre-prototype, mechanically steered, tilted array antenna and an 8 DPSK-TCM modem were developed in-house by JPL. However, in support of the program's technology transfer goals, industry and universities were significantly involved in system development through R&D contracts. Two contractors were involved in the development of antennas: Teledyne-Ryan Electronics and Ball Aerospace developed and delivered breadboards of the phased-array antennas. Speech coders were developed through R&D contracts, one with the University of California at Santa Barbara and another with the Georgia Institute of Technology.

Numerous MSAT-X experiments have been conducted using tower-mounted and satellite transponders. A series of pilot field experiments (PiFEX) was planned and implemented to demonstrate the ability of the moving vehicle to acquire and track the signal and to test the end-to-end link of all subsystem technologies. Three of the PiFEX tests were conducted with a transponder atop a 1000-ft tower to emulate the satellite (Towers 1, 2, and 3). Other tests were conducted using actual satellites in 1987 and 1989. Satellite testing with the mobile terminal was conducted in a flight environment aboard a Boeing 727 in 1989, in cooperation with the Federal Aviation Administration's (FAA's) Technical Center, using INMARSAT's MARECS-B2 Satellite. An L-Band satellite experiment, with JPL- and industry-developed mobile terminal hardware, was also conducted by NASA/JPL in cooperation with AUSSAT, using the Japanese ETS V Satellite's southern beam. Conducted in Australia in 1989, this experiment was made possible through an agreement between AUSSAT and Japan's Communications Research Laboratory (CRL). The National Communications System (NCS), one of the Federal Government agencies having a Memorandum of Understanding (MOU) with NASA, participated in this experiment to validate some of its requirements for a mobile terminal.

Many systems and market studies have been conducted by JPL, including some newly developed network ing techniques and protocols that are being evaluated in JPL's research test bed. Propagation effects studies conducted in JPL's mobile terminal laboratory housed in the propagation measurement van continue to be invaluable in validating MSS technology. A recently completed cost study of the mobile terminal equipment, conceptually upgraded to incorporate state-of-the-art technologies, indicates that manufacturer's costs are within a reasonable range of estimates.[8] The overall result of these efforts has been the development of a significant body of knowledge in L-Band communications. This information has been documented and disseminated through technical publications, conferences, and workshops designed to promote technology transfer, and facilitate increased user/industry involvement.

Regulatory Aspects. Spectrum allocations and licensing are crucial to being able to obtain investment capital. NASA's effort in the area of regulatory risk reduction was focused on obtaining primary frequency allocations and adequate bandwidth in the 800-MHz band or L-Band or both. This was initiated by NASA in 1975, as part of the U.S. preparations for the 1979 Space World Administrative Radio Conference (WARC). After more than 4 years of domestic proceedings, the United States included in its international positions recommendations for frequency allocations in the 800-MHz band. However, during subsequent Federal Communications Commission (FCC) domestic proceedings on terrestrial mobile allocations in the early 1980s, opposition to an MSS allocation became evident, especially in the 800-MHz band. To preserve the commercial viability of the MSS, and to facilitate the commercialization of its technology, NASA filed a Petition for Rulemaking in 1982 for frequency allocations for the MSS.[9] The Petition argued for an 800-MHz allocation and received formal support from more than 80% of the 92 filings on the Petition.

The number and substance of the filings were clear evidence of the broad user constituency formed as a result of more than 20 years of public and private sector user experiments. This same user community serves, in effect, as a partially aggregated market for QUALCOMM, GEOSTAR, and INMARSAT. The American Mobile Satellite Consortium (AMSC) should also benefit from this process, which has served to reduce the market risk to all.

The FCC Rulemaking Proceeding, initiated by NASA, resulted in frequency allocations in 1985 for the service in L-Band rather than the 800-MHz band, due to economic, political, and regulatory considerations.[10] L-Band allocations were then extended worldwide as an outcome of the 1987 Mobile WARC, culminating 12 years of domestic and international regulatory efforts to achieve this goal.

Unresolved issues remain concerning licensing, transborder operations, interoperability, standards, inter-system interference, coordination, service areas, and additional spectrum provisions for growth of domestic and international MSS.[11] These are serious problems since the numbers of planned systems are increasing substantially. International and national working groups and regulatory bodies are working to resolve most of these issues so that many, if not most, can be resolved before or during the planned 1992 WARC.

Industry/Launch Offer. Reducing financial risk was the objective of NASA issuing an Opportunity Notice for a Mobile Satellite Agreement to industry in 1985 to provide standard launch services for the first U.S. licensed MSS provider, in exchange for satellite capacity for Government experimentation.[12] It was anticipated that combining experimental and operational modes on the same satellite in a Government/industry joint venture or partnership would reduce costs to both parties and significantly expedite the commercialization process.[13] Twelve companies had filed applications for licenses with the FCC by 1986; however, they were later directed by the FCC in 1987 to form a consortium. Eight of these companies eventually formed the AMSC by May 1988, and the AMSC finally received its license in May 1989.[14] The AMSC (now "Corporation") and Telesat Mobile Inc. (TMI) Canada signed a Memorandum of Understanding in the summer of 1989, and, pursuant to this MOU, have recently signed a Joint Operating Agreement (JOA) for providing roaming capability and mutual satellite capacity backup (April 25, 1990). AMSC and TMI are each currently involved in procuring their satellites. AMSC and NASA negotiations are under way for the exchange of a launch and satellite capacity, based upon the 1985 Opportunity Notice. The launch is currently carried on NASA's mixed fleet manifest, with a planned launch date in Fiscal Year 1994. AMSC plans to initiate early service (data only) prior to this launch date via leased space segment capacity.

Further indication of the market viability of this service is the expressed interest that other companies have in marketing related services. On an international basis, competing MSS providers are considering the use of portions of the same spectrum allocated in the 1987 Mobile WARC. Annual projections for the MSS business in the 1990s are placed in the multi-billion dollar range.[1]

Government Agency/User Development Experiments. A key component of the approach to address market risk relates to fostering market aggregation. Between 1983 and 1988, NASA signed MOUs with 10 Government agencies to be experimenters on the satellite for a 2-year period or more, using bartered capacity. These agencies include eight federal and two state agencies. Additional agencies have recently expressed interest in participating in the experiments, prompting the development of a plan for soliciting experiment proposals to allocate experimental capacity, based upon proposal merit and experiment value. Implementing these experiments will be linked to the outcome of AMSC/NASA negotiations for the launch; however, the substantial interest of Government agencies in experimentation, indicated in a recent Government users' seminar, clearly illustrates the potential Government demand for the service.

Throughout the development of the MSAT mobile terminals, the MOU agencies were encouraged to interact with the NASA/JPL research staff. Two agencies, the FAA and the NCS, also participated in satellite experiments with the system, relevant to their agencies' operational concerns. These experiments were successful, and served to validate the usefulness of the system in meeting the operational requirements important to the users. They also afforded the users an opportunity to become familiar with the system in a "hands on" setting.

Institutional Relationships. Both international and domestic institutional relationships are included in NASA's program structure (Figure 2). In 1983, NASA and Canada's DOC extended their earlier cooperation from the 1970s CTS Program, through signing an agreement to foster development of a North American MSS. Domestically, the institutional strategy has been aimed at developing a strong Government user base for the technology as well as disseminating relevant technical information to industry (the intermediate user) in a timely fashion. NASA's formalized relationships with 10 Government agencies that have signed MOUs to be experimenters with the satellite capacity, like Canada's Government trials program, support the objective of user base development. JPL's use of industry and university R&D contracts for developing the mobile terminals was designed to promote closer Government/industry ties and cooperation. A Government/industry interface subtask at JPL supports the integration of NASA's launch offer activities with Government experiment planning and oversees the dissemination of MSAT-X technical information to industry and user groups.

A whole family of institutional relationship issues pertinent to a viable domestic and international MSS is evolving to include: ownership, tariff arrangements, service backup agreements, interoperability, service area overlaps, priority of traffic, network control, and conflicts with international carriers. The recent establishment of a JOA by AMSC and TMI, described previously, should address one or more of these issues.

Advanced MSAT Research in Ka-Band

NASA's MSAT Program is now evolving to research and development in Ka-Band technologies, based upon projected use of, and constraints upon the L-, C-, and

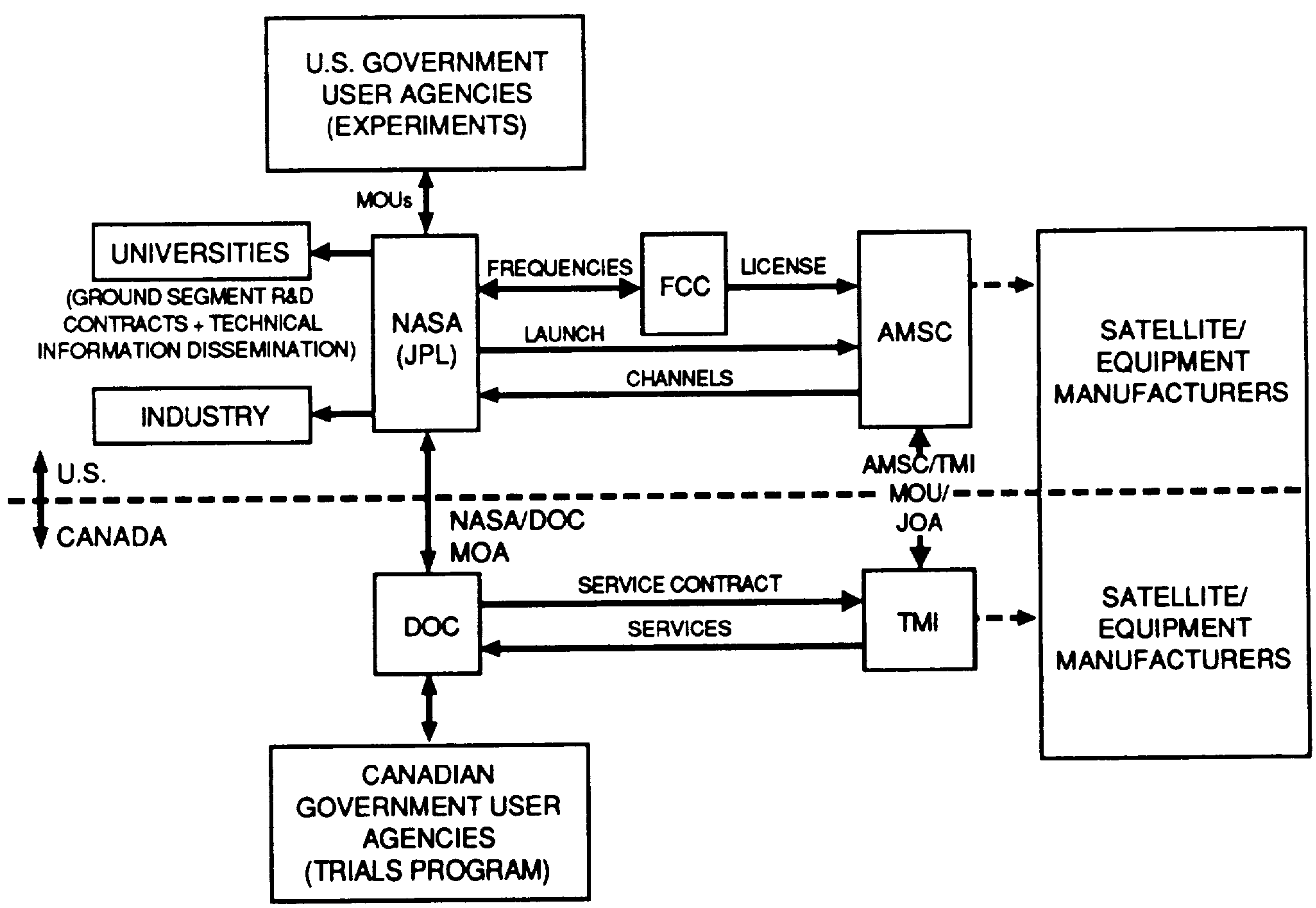

Fig. 2. Mobile Satellite Communications Program: Institutional Arrangements (NASA/DOC/Industry)

Ku-Bands. Although technical and economic challenges exist, the tradeoff is the availability of spectrum and orbital parking slots, making Ka-Band an important follow-on of L-Band research for mobile satellite applications.[1] Two research thrusts are under way at JPL: (1) PASS technology development and studies to evaluate a number of terminal options for personal communications, including stationary, transportable and ambulatory (personal) options; and (2) the development of a terminal for an ACTS satellite experiment planned for 1992. The Acts Mobile Terminal experiment is linked to the PASS task by providing an early demonstration of a mobile micro terminal application of the ACTS satellite as well as a "satellite of opportunity" for validating other PASS technologies.

LESSONS LEARNED

Value of User Experiments

Emphasis on user involvement in mobile satellite applications helps to validate system usefulness and refine its design. It also provides users and industry with an early awareness of and exposure to evolving technology, thus addressing the "push" and the "pull" of technology transfer. In addition to supporting market aggregation, this also serves to help support regulatory positions, when needed. An excellent example of user involvement was the AUSSAT experiment, which gave the NCS an opportunity to conduct an early experiment over an L-Band satellite. This experiment served as an excellent opportunity to give visibility to U.S. technology developments in a highly cooperative international setting.

Value of Information Dissemination

Because technology transfer is dependent in part upon technical know-how, good quality information and effective information dissemination methods are essential. Technical publications, conferences, workshops, and technical interchanges are all useful mechanisms that support technology transfer.

Importance of Addressing Technical, Regulatory, Institutional, and Financial Aspects of the MSS

Accelerating commercialization requires that the complex interactions of technology readiness, institutional, market, and policy factors impacting a technology's commercialization pathway be molded into an integrated program strategy. Integrating program elements associated with a variety of potential barriers has helped to keep this pathway open.

The Case for Lowering Risk

Reducing the risk to industry is only partly addressed through Government R&D and demonstrations of long-term, high-risk advanced technologies. To attract private investment, it is essential that industry be assured of direct benefits (i.e., profits of sufficient magnitude) that a specific investment (e.g., MSS) is attractive compared to other alternatives.[2] Expectations of profits are associated with risk, especially in areas such as defined markets, regulatory delays, and system costs. This constitutes a strong case for a multi-faceted, risk-reduction strategy.

Viability of MSS

Market viability can be seen in cost studies, market projections, and increasing public and private sector applications and demand for this service. Viability and growth of the system should continue when mobile satellite is viewed as a complementary as well as a competing system.[1] Its ultimate viability, however, is likely to depend upon the allocation of sufficient spectrum to assure its financial viability in a commercial world.

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