Perspectives on the Historical Significance of the Research and Development in Satellite Telecommunications Undertaken at COMSAT Laboratories

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Executive Summary

COMSAT Laboratories is where the foundation of modern satellite technology was invented and developed. Virtually all the communications satellites we rely on today can trace their technology back to COMSAT Laboratories. The idea behind the creation of COMSAT Laboratories can trace its roots to the speech given in 1961 by President Kennedy committing the United States, among other things, to put a man on the moon by the end of this decade, and represents the embodiment of President Kennedy's commitment to bring the benefits of satellite telecommunications technology to all countries of the world, and thereby promote greater world peace and understanding. Over the years, hundreds of engineers from around the world learned about satellite technology at COMSAT Laboratories, which they were then able to share this knowledge with their home countries. In recognition of the groundbreaking work done there, COMSAT Laboratories received several awards, including two Emmys and the NASA/US Space Foundation Space Technology Hall of Fame Award. As of 1999, COMSAT Laboratories had a patent portfolio covering numerous aspects of satellite communications technology, including approximately100 active patents, with another 70 in the filing process.

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To fully appreciate the historical significance of COMSAT Laboratories, it is first necessary to step back in time to the early 1960s and the global geopolitical/ideological battle being waged between the United States and the Soviet Union, each attempting to win over the hearts and minds of the rest of the world, albeit accompanied by radically different visions of the desired world order that would come from those efforts. One of the most consequential battlegrounds involved outer space, including both the race to the moon and the development of space-based technologies intended to significantly improve the ability of the world to communicate and interact with one another.

On May 25, 1961, President Kennedy, in his historic speech on "Urgent National Needs," shared his vision on the United States' future in space with the U.S. Congress. That speech was most famous for his oft-quoted declaration expressing his belief "that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth." This commitment was critical to winning "the battle that is now going on around the world between freedom and tyranny . . . [and] the impact of this adventure on the minds of men everywhere, who are attempting to make a determination of which road they should take." Less well remembered, but equally important, President Kennedy in the same speech also called for the creation of an international communications satellite system, committing "an additional 50 million dollars [to] make the most of our present leadership, by accelerating the use of space satellites for world-wide communications." These commitments in the space race were crucial components of the ongoing competition between the United States and the Soviet Union as to which would prevail in their global geopolitical/ideological struggle, undertaken at a time when it appeared that the Soviet Union was clearly well ahead in space technology.

To spearhead this effort, the U.S. Congress boldly enacted the Communications Satellite Act of 1962, which represented an audacious but ultimately exceptionally forward looking approach for bringing the benefits of satellite technology to the world. Through this legislation, the foundation was laid for the creation of a private company, the Communications Satellite Corporation (COMSAT), to serve as the United States' "chosen instrument" for sharing the benefits of satellite technology with the rest of the world. This ultimately involved two distinct prongs. The first prong involved the creation of the political and commercial apparatus needed to operate a global satellite network, which led to the creation of an international organization that later became INTELSAT (International Telecommunications Satellite Organization), with the mission of bringing affordable satellite telecommunications service to all countries of the world. The second prong addressed the means required to develop the necessary technologies that made satellite services possible and then to share them with the rest of the world. It was that prong that led to the creation of COMSAT Laboratories, as the chosen instrument to serve as the primary research engine for development of satellite technology throughout the formative days of the satellite industry. Needing a permanent location from which COMSAT Laboratories would operate, COMSAT announced on November 1, 1966, that it had purchased 210 acres of land outside of Clarksburg, Maryland. Less than three years later, its doors opened for business on September 8, 1969.

While the original idea for utilizing the geosynchronous orbit for communications purposes was put forward by the renowned scientist and science-fiction writer Arthur C. Clarke in an article he authored appearing in the October 1945 issue of *Wireless World*, the reality of the potential of this technology to revolutionize the way in which the world communicated did not come to fruition until nearly two decades later.

Ensuring the ability to provide reliable and cost-efficient telecommunications services utilizing satellites operating 22,300 miles above the earth's surface presented COMSAT Laboratories with a myriad of technical and engineering challenges that were not present in the case of other modes of communications and thus unlike any that had been undertaken before. The hurdles began with addressing the unique characteristics of radio signal transmission and propagation overly extremely long distances (in this case 22,300 miles up to the satellite and then back to earth), including minimizing the effects of interference, echo, and transmission delay. Then there was the need to design a device (satellite) that could operate 22,300 miles in space with no credible way to effectuate in-orbit repairs in the event of any system failure or in-orbit mishap, so measures to ensure the long-term sustainability of a satellite containing sophisticated electronics in orbit were essential, including state of the art electronic systems and sufficient built in redundancy to address potential system failures in orbit. There was also the matter of assuring the availability of on-board power to maintain the functioning of the satellite and to maintain its proper location in orbit over a multi-year time period, which among other things required the development of extended lifetime batteries and the ability to effectively harness solar power through sophisticated solar cell technology. There were concerns as to durability, both for the sensitive electronic components to survive the pressures of launch and then to operate in an environment completely different than being on earth – that of outer space. Each satellite in orbit had to be capable of surviving passage through two harsh environments: the tremendous mechanical stresses of launch and the vacuum of space with its accompanying radiation. An equally daunting separate set of issues then arose in connection with the ground infrastructure needed to communicate with satellites in space, as well as the ground control facilities to maintain the satellite's healthy operation. Finally, to allow this revolutionary technical advance to be shared with the entire world, the economics had to be such, both in space and on the ground, that the services provided were as economical and low cost as possible.

To meet these challenges, so as to meet the commitments embodied both in President Kennedy's May 1961 address, and the subsequent resolution adopted by the United Nations General Assembly on December 21, 1961 (Resolution 1721 (XVI)), calling for the availability of "communication by means of satellites . . . to the nations of the world as soon as practicable on a global and non-discriminatory basis," it was necessary to bring together the leading experts in a variety of fields necessary to fully develop the potential for satellite technology, and to provide them with state-of-the art laboratory facilities to allow them to conduct their research. By the early 1970s, COMSAT Laboratories had assembled in Clarksburg a professional staff of over 400 individuals committed to tackling the challenges posed by space based telecommunications.

To successfully discharge its multi-faceted mission, COMSAT Laboratories was equipped with a number of large chambers to test whole satellites, as well as smaller chambers to test systems and specific components, such as antennas and attitude control systems. The internal organizational structure (subject to some refinement over time) was built upon the expertise and work of six distinct divisions or programs: Communications Techniques Division; Network Technology Division; Microwave Technology Division; Microelectronics Division; Spacecraft Technology Division; and System Development Division. Additionally, a separate unit was formed in the 1980s to spearhead COMSAT's participation in NASA's Advanced Communications Satellite Technology (ACTS) Program, for which COMSAT designed and implemented the ground segment and control station for the ACTS Satellite. Not only was significant research conducted at COMSAT Laboratories throughout its operational existence, but through a very generous and creative internship program, engineers and scientists from around the world were able to come to COMSAT Laboratories and to learn firsthand the basic technologies involved, which they were then able to share back in their home countries. This internship program was part of the larger effort to share the benefits of satellite technology with the entire world.

Since its creation, COMSAT Laboratories engineers and scientists tirelessly worked to improve the efficiency and quality of satellite communications in numerous ways, including the following key developments:

- To address the distortive impacts on voice communications transmitted via satellite, COMSAT Laboratories, through the application of adaptive digital techniques, developed an echo canceller that virtually eliminated echo.

- To improve the efficiency and reduce the cost of satellite transmission without impairing transmission quality, COMSAT Laboratories developed specialized filters that enabled transmit of multiple separate signals (carriers) with well-defined bandwidths through a transponder, achieving significant reductions in size and mass without sacrificing quality.

- COMSAT Laboratories developed SPADE (short for "Single channel-per-carrier Pulse Code modulation multiple Access Demand Assignment Equipment"), the world's first international digital voice communications service specifically addressed to facilitating efficient transmission of smaller bit streams, thereby allowing for more economical use by developing countries.

- COMSAT Laboratories spearheaded development of the world's first commercially viable flat plate antenna for direct broadcast satellite TV reception.

- To significantly improve the throughput of communications links via satellite, COMSAT Laboratories helped develop an entirely new transmission technique, focusing on the allocation of satellite capacity as a function of time rather than by frequency. This technique, which came to be known as TDMA (Time Division Multiple Access) revolutionized the efficient operation of satellite transmissions and is a hallmark of the satellite industry today.

- To significantly improve battery performance, COMSAT Laboratories led the way in the development of the nickel hydrogen oxide battery.

- COMSAT Laboratories conducted extensive research on the transmission and reception of communications signals over satellites using very small antennas, different frequencies and mobile earth stations. These experiments led to field trials that paved the way for providing mobile maritime communications services via satellite, which today serves as the foundation for mobility services provided over air, ground and sea, including satellite news gathering activities.

- More recently, in the 1990s, COMSAT Laboratories was recognized for its role in the development of monolithic microwave integrated circuits (MMICs), which are important for their ability to integrate multiple essential functions in a single chip. These efforts, providing for enhanced reliability, miniaturization, weight reduction and cost efficiency in circuit design, resulted in significant cost saving for large scale MMIC production.

- Through much of the 1980s and 1990s, COMSAT Laboratories was a key participant in the Advanced Communications Technology Satellite (ACTS) Program, a program spearheaded by NASA to develop an experimental satellite that played a central role in the development and flight-testing of technologies today being used on the latest generation of commercial communications satellites. The ACTS Satellite, as the first all-digital communications satellite, supported standard fiber-optic data rates, operated in both the Ku- and Ka-frequency bands, and pioneered dynamic hopping spot beams and advanced onboard traffic switching and processing.

Given that a critical aspect of COMSAT Laboratories mission was to share the technical knowledge and the understanding of communications satellites developed with the rest of the world, in addition to the internship program previously mentioned, COMSAT Laboratories originated the first journal devoted exclusively to satellite communications technology and systems. Since the first issue appeared, the COMSAT Technical Review (CTR) published over 400 papers and notes initiated by members of COMSAT's professional staff and collaborators, confirming COMSAT's reputation for R&D excellence. By the early 1990s, the CTR was a key resource for scientists and engineers in mores that 70 countries, presenting state-of-the art advances, trends, and applications of communications technology in support of an expanding market for communications services in the global community.

COMSAT Laboratories also prioritized good citizenship in support of its home state of Maryland. COMSAT Laboratories hosted the 4-H Adventures in Science Program, which matches volunteer scientists and professionals with children ages 8 to 15 and their parents for extracurricular, hands-on participation in science and technology projects. And through the Maryland Industrialist Partnerships (MIPS) program, COMSAT Laboratories carried out joint research programs with University of Maryland researchers, fostering the commercialization of technology and economic progress in the state of Maryland.

In recognition of its efforts in support of satellite news gathering, COMSAT received an Emmy issued by the National Academy of Arts & Sciences in 1993 for its outstanding achievement in the sciences of television technology for miniature, lightweight, rapid deployment earth terminals for satellite newsgathering. Newsgathering via satellite had become an indispensable element in the virtually instantaneous reporting then and now demanded by the global community. This technology played a crucial role in bringing the people of the world face to face with the human side of major events and rapidly unfolding political crises worldwide. COMSAT had previously (1974) been the recipient of the International Directorate Emmy Award, issued by the International Academy of Arts & Sciences, honoring individuals or organizations for their outstanding contributions to international television.

In 1997, COMSAT Laboratories was one of the recipients of the 1997 NASA/US Space Foundation Space Technology Hall of Fame Award, in recognition of CCOMSAT Laboratories significant contributions to the success of the Advanced Communications Technology Satellite (ACTS) Program.

As of 1999, COMSAT Laboratories had a patent portfolio covering numerous aspects of satellite communications technology. The portfolio includes approximately100 active patents, with another 70 in the filing process.

The research and developmental work that was performed at COMSAT Laboratories served as the backbone for all aspects of satellite technology as it has evolved. Moreover, that work led to developments in related fields that today are utilized in a multitude of important ways, including the development of the solar power industry and advancements in extended battery lifetimes, which can sustain a broad range of commercial activities, such as the cost-effective development of electronic vehicles. Nor is it a stretch to say that the seminal research conducted at COMSAT Laboratories regarding the transition from analogue to digital transmission of radio signals lies at the foundational core of today's internet. All told, the many contributions made by COMSAT Laboratories represented an essential element of the United States' ability to honor its commitment to share with the rest of world the benefits of satellite telecommunications, thereby promoting greater world peace and understanding.