INTRODUCTION BY EDITOR

The article following is perhaps unique among the many papers published thus far in this column. It covers not only the development of some of the technology required to turn the dream of commercial satellite communications into reality, but describes the policy decisions and politics involved in making this happen in the United States and elsewhere in the world as well. Policy questions raised and discussed include, first, the question of whether satellite communications in the United States should be government-run or a commercial enterprise; followed by the issue of how control should be manifested in international communication satellites. These policy questions in modern times are probably unique to satellite communication systems.

Joe Pelton, the author, is well positioned to write an account of the early days of satellite communications in all of its ramifications, in both the policy and technical areas, having been present and working at Comsat Corporation, as well as later at Intelsat, during much of the period under discussion. We plan to follow this article with one focusing more on the communication technologies developed at Comsat during the early days of satellite communications. That article will be written by one of the engineers working at Comsat at the time. In the meantime, I am sure all readers will enjoy this article. Note that a number of readers of previous articles in this column have responded with letters to the editor commenting on, or expanding on, those articles. We urge you to send in your comments and or/questions about this article or any of the earlier articles as well.

—Mischa Schwartz

THE START OF COMMERCIAL SATELLITE COMMUNICATIONS

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INTRODUCTION

John Logsdon, the long time director of the Space Policy Institute at George Washington University, when he talks about the history of space, often starts by saying: "The policy people and not the engineers always win." The meaning of his statement is that the engineers can design wonderful technology, but it is the politicians and the governmental officials who ultimately decide how, when, where, and why it is actually used. This, in many ways, is certainly the case with regard to the early development and use of satellite communications technology for global communications. The evolution of satellite communications technology came rather quickly in the late 1950s and early 1960s, but international politics related to the Cold War shaped how this technology was deployed and how quickly it was used. U.S. efforts to recover from the global impact of the Sputnik launch by the Soviet Union placed great emphasis on developing all forms of space technologies. Thus, the U.S. government placed great political importance on the creation of a global satellite system with a U.S. launch vehicle and spacecraft technology leading this new venture.

This is the early story of how satellite communications began, and how these amazing devices revolutionized global communications and helped to realize the electronic global village we live in today. The first applications of communications satellite began with the relay of international telecommunications services (i.e., telephone, telex, and television) — essentially as an extension of terrestrial national networks. Over time the technology and the applications matured. This led ultimately to the creation of national satellite systems for domestic television, radio, and telecommunications, the creation of maritime satellite systems to provide services to ships at sea, the offering of aeronautical mobile satellite services to aircraft, land mobile satellite services to supplement cell phones, and direct broadcast satellite systems to beam television and radio to individual subscribers. In some ways evolving satellite technology competed with terrestrial submarine cable, and in some ways these systems worked in tandem. In later decades, other commercial satellite applications also emerged. These now include remote sensing, Earth observation, space navigation, and meteorological services. The complete story is too complex to relate in a single article. The focus here, therefore, is on the early years and the creation of the Communications Satellite Corporation in the United States and the creation of the International Satellite Communications Consortium (Intelsat) from which other commercial satellite systems have evolved. To complete the story, however, some of the more important evolutionary steps that have now occurred within the satellite industry to develop maritime and mobile satellites and broadcast satellites, and to use satellite for domestic as well as international purposes are noted.

THE HISTORY

Ever since Sir Isaac Newton discovered gravitation and wrote down the Law of Gravity, it has also been scientifically known that the launch of artificial satellites in Earth orbit would be technically possible. How do we know this? Isaac Newton's own publications showed illustrations of how an object fired with enough velocity could be launched into Earth orbit. The idea that an artificial satellite might be put to practical use is also centuries old. Everett Edward Hale, as early as 1867 when he wrote *The Brick Moon*, speculated on the use of artificial satellites for communications, navigation, and remote sensing. Indeed, he envisioned that such satellites would go into a medium Earth orbit. He specified an orbit that would cross over the North and South Poles orbit with a period of about 90 minutes and that after a number of revolutions these satellites would "see" the entire world below. Today's commercial remote sensing satellites are deployed in much the same manner. Lest we give him too much credit for technical sophistication, he also thought that a crew (for some reason consisting of 17 men and two women) could live in outer space and could communicate by jumping up and down to create messages in Morse code. It was not until 1945, however, that a detailed and specific technical concept emerged about how to deploy an artificial satellite for telecommunications purposes in geosynchronous orbit.

This was in an article that appeared

in October 1945 in *Wireless World*, a U.K. publication. Here Arthur C. Clarke explained for the first time how three space stations in geosynchronous orbit could provide virtually total worldwide communications coverage. He explained the physics of this "magic orbit" whereby a satellite can seem to hover exactly above the Earth's equator all the time. With detailed calculations, he showed why there was only one unique circular orbit some 22,230 miles (or 35,870 km) above the Earth's surface where this was true. The required orbital speed needed at this altitude, based on the Earth's gravitational mass, plus the need to match the world's sidereal rotation of 23 hours and 56 minutes (i.e., the Earth rotates on its axis every 24 hours, but it also advances around the sun four minutes every day), produces a single solution.

This article was published after Clarke had circulated the essential concepts and technical calculations in June 1945 in a detailed letter to colleagues. At the time most considered the idea to be science fiction. Indeed, the Clarke article on global communications space stations in *Wireless World* was not even the cover article for the October 1945 edition [1]. Arthur Clarke's daily calendar for the year reveals that this article — which in some ways gave birth to an industry that represents over $100 billion in revenues today — produced a paltry royalty payment of only 15 pounds sterling [2].

When I talked to Arthur Clarke in the mid-1980s at Barnes Place, his home in Sri Lanka, about his seminal article, he explained that in 1945 he did not consider the idea practical any time soon — and certainly not worth patenting. Indeed, he conceded that publishing the article in *Wireless World* alone actually served to eliminate the possibility of a patent. At the time he published the article in 1945, Clarke envisioned that the space stations would need a full-time crew whose round-the-clock function would be to replace burned out radio tubes and perform other maintenance functions. Of course in 1945 the transistor, which made possible the electronic computers necessary to compute orbits and provide reliable solid state electronics to replace radio tubes, had not yet been invented. In short, Clarke did not seek to patent the concept of communications satellites in geosynchronous orbit because he envisioned that such a system would be many years in the future.

The breakthrough invention of the transistor actually came in the late 1940s through the creative work of William Bradford Shockley, John Bardeen, and Walter Houser Brattain at Bell Labs [3]. This fundamental breakthrough led to many innovations from the transistor radio to the modern computer; indeed, it spawned the entire "Silicon Valley" culture that has served to transform the world in almost every conceivable way over the past half century. Certainly the transistor transformed the concept of a communications satellite and the practical utilization of outer space from a far-off dream to a practical reality — and it did so in less than a decade.

The launch of Sputnik by the Soviet Union in October 1957 in a single stroke convinced the world that the launch of artificial satellites was now a practical engineering feat. It also stirred global Cold War politics into a new state of frenzy. President John F. Kennedy's election in November 1960 can, in part, be attributed to the "missile gap" that the United States public viewed with some concern as the U.S.S.R. deployed ever more sophisticated and larger capacity rockets, including launchers with cosmonauts aboard. This concern over the U.S. missile gap was a subject of concern to the American public in the late 1950s and early 1960s as the embryonic U.S. rocket program seemed to be having great difficulty getting off the ground in every sense of these words.

At the very end of the Eisenhower administration, in December 1960, a very "lame duck" President Eisenhower delivered a speech that addressed the future prospects of communications satellite systems and how they might be deployed on a commercial and private-enterprise-led basis, presumably with American technology leading the way. Eisenhower, on December 30, 1960, well after the election of John F. Kennedy over Richard M. Nixon had been decided, set forth his views as follows:

"The commercial application of communications satellites, hopefully within the next few years, will bring all the nations of the world closer together in peaceful relationships as a product of this nation's program of space applications… This nation has traditionally followed a policy of conducting international telephone, telegraph, and other communications services through private enterprise, subject to Government licensing and regulation… I have directed the National Aeronautical and Space Administration (NASA) to take the lead within the Executive Branch both to advance the needed research and development and to encourage private industry to apply its resources toward the earliest practical application of space technology for commercial civil communications requirements…" [4].

This view of how to develop, deploy, and operate global satellite communications did not exactly fit the vision of the newly elected Kennedy administration. Kennedy wanted "space" to be a part of his "New Frontier." He and his advisors wrestled with how to make this so amid the rigors of a Cold War conflict with the Soviet Union and specific concerns about the much discussed "missile gap." At the same time, Kennedy also had a fervent desire to galvanize the nation to a new sense of initiative and American accomplishment in many areas — particularly in space. He also wanted this American space initiative to be consistent with his other global initiatives such as the Peace Corps.

He thus began his administration with a number of pronouncements about new American initiatives in outer space. He, his staff, and the National Space Council sent a flurry of messages to the Federal Communications Commission (FCC) and NASA, which had been hastily formed by an Act of Congress in 1958 in response to the Sputnik and other early Soviet launches. Kennedy also communicated with industry about what urgent research goals were to be pursued and about what role industry might play [5].

What most people remember of this time was the President's speech to a Joint Session of Congress on May 25, 1961. This speech, known formally as the "Special Message to Congress on Urgent National Needs," was the one in which he issued the special challenge of sending astronauts to the moon and returning them within the decade. This speech and what became the challenge to go to the Mmoon is one of the best-known elements of the Kennedy legacy. However, in that speech Kennedy also called for other space achievements that included the Rover nuclear launch system and the rapid development of satellite communications technology and systems. He explicitly called for $50 million dollars (which in those days was still real money) for "accelerating the use of space satellites for worldwide communications." He ended his speech by emphasizing the need: "…to move forward, with the full speed of freedom, in the exciting adventure of space" [6]. Clearly the stupendous goal of sending people to the Moon and returning them safely was the headline, but the

Kennedy administration in this speech and in the United Nations speech that followed saw the potential of satellite communications as an instrument of peace, a Cold War symbol of American leadership, and an opportunity for one-upmanship on the Soviet Union.

It was in September 1961 that President Kennedy went to the General Assembly of the United Nations and called for the establishment of a single global satellite system that would: "…benefit all countries, promote world peace, and allow non-discriminating access for countries of the world" [7]. This speech set the stage for the United Nations to adopt resolution 1721 Section P, formally establishing that "communications by means of satellite should be available to the millions of the world as soon as possible on a global and nondiscriminatory basis" [8].

Thus, the creation of global satellite communications became at once part of the United States' initiative to show its expertise and competence in space technology. It also became a part of the U.S. effort to demonstrate leadership toward world peace and assistance in many areas from the establishment of the Peace Corps to the championing of a global satellite system that would be available to all nations on a non-discriminatory basis. These dual objectives later complicated Kennedy's effort to get the Communications Satellite Act of 1962 through the U.S. Congress. Communication satellites were on one hand an attempt to fight a Cold War with the Soviet Union and to champion "free enterprise" and world class American technology over communism; but on the other hand it was to promote the cause of a peaceful world and global intergovernmental cooperation.

THE DEVELOPMENT OF SATELLITE TECHNOLOGY

As all of this political activity was transpiring, a lot had been happening in terms of developing new launch systems and satellite communications technology-and in a remarkably short period of time. After several failures, the first successful U.S. launch was led by Werner Von Braun who oversaw the launcher development. But it was American scientist James Van Allen who took the lead in designing the Explorer 1 experimental satellite that rode on the Von Braun vehicle. Van Allen installed a Geiger counter within the Explorer satellite along with a radio relay. The Explorer 1 was able to detect extremely high-energy radiation surrounding the Earth in concentrated belts. These quickly became known, of course, as the "Van Allen Belts." The existence of these belts proved quite important to the deployment of future communications satellites since the radiation from these belts could knock out satellite communications electronics. Thus satellites were deployed to avoid these belts and also shielding was added to protect the satellite electronics.

With the creation of the National Aeronautics and Space Administration (NASA) in 1958, a new civil American space capability was built within the U.S. government. In parallel, capability was developed within the U.S. military and within industry. American telecommunications companies such as ATT, ITT, RCA, Western Union, and Western Union International as well as aerospace companies such as Hughes Aircraft, TRW, Ball Aerospace, General Dynamics, McDonnell-Douglas, Lockheed Martin, General Electric, and North American Aviation also began to expand their capabilities.

Within the telecommunications industry, a good deal of attention was quickly focused on the practical commercial uses of space — particularly in the context of communications satellites. From 1958 through 1965 there were in quick succession a number of experimental launches that advanced knowledge and engineering capabilities in space.

The first U.S. artificial satellite that might be characterized as a "communications satellite" was really almost a publicity stunt to capture world press attention and to indicate that American technology in this area was starting to move forward. This was the U.S. Signal Corps' SCORE satellite that was launched on an Atlas rocket on December 18, 1958. It was a low-power "broadcasting satellite" that continuously sent out a recorded message from President Eisenhower, simply proclaiming: "Peace on Earth, Goodwill to Men." This small satellite had only enough battery power to last 12 days to the end of the year [9].

On August 12, 1960 a meteorological satellite called Echo-1 was launched to conduct some ionospheric experiments. Dr. John Pierce, an engineer at Bell Labs who later designed the Telstar communications satellite, had the inspiration to suggest that the Echo-1 100-ft inflated metallic balloon could also be used to test the idea of a passive reflector for communications signals. This idea had been tested by bouncing signals off the moon in the 1940s, but here was a much more viable experiment. The result of the Echo-1 and Echo-2 experiments was to conclude that a passive reflector would not produce sufficient throughput capacity to support a commercially viable telecommunications service. The lesser-known U.S. military experiment known as "West Ford" similarly concluded that bouncing signals off of a passive space-based reflector without active amplification was essentially a non-starter — again because the achievable throughput was too low [10].

The first two-way interactive communications satellite was the Courier 1 B launched in October 1960. This satellite's capacity was limited to only 16 teletype channels. Although this was a miniscule capability, it led the way to more sophisticated communications with the ability to receive, translate to other frequencies, and retransmit amplified signals back to Earth [11]. By 1962, the experimental satellites had become increasingly sophisticated. John Pierce and his team at Bell Labs had designed the Telstar satellite, while RCA had designed the Relay satellite. Both of these satellites were launched by NASA into low Earth orbit. These were active repeater satellites capable of supporting multiple voice channels and even low-quality television transmissions. There were even experimental television broadcasts to Tokyo. Although the Soviet Union was launching quite large satellites into orbit by this time, the United States was showing significant technical advances in building increasingly complicated and functional satellites with micro-electronics.

The Relay and Telstar satellites demonstrated the feasibility of solar cell and battery powered systems, tracking and command, active space antennas for reception and transmission, radio system filters, and amplifiers. The ability to launch such satellites — at least into low Earth orbit — was clearly established as well (Fig. 1).

The only major open question was whether artificial communications satellites could be successfully deployed into the more difficult geosynchronous orbit, almost a tenth of the way to the moon. There were also questions about the huge path loss that would occur when a satellite transmitted from such a high orbit so far above the Earth. It was the opinion of many that only high gain antennas with accurately pointed beams could successfully operate from so far out in space.

There was also the open political question as to what entity would pro-

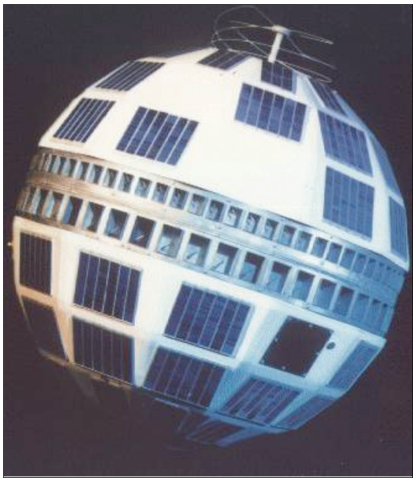

Figure 1. *The Telstar Satellite prior to launch in 1962. (photo xourtesy of NASA).*

vide communications satellite services on behalf of the United States and how these services would be provided internationally in terms of institutional arrangements. The telecommunications industry had organized, and, with the particular support of the powerful Senator from Oklahoma, Robert S. Kerr, they introduced a bill that would make the U.S. space telecommunications services a strictly private and commercial venture, under governmental licensing and regulations. On the other side of the issue, Senator Estes Kefauver, who had run for Vice President with Adlai Stevenson on the Democratic Presidential ticket, had a much different take on how the future should unfold. He introduced a bill that would make satellite communications a governmentally operated service. His logic was that the U.S. government had developed much of the space technology at public expense and that the public should benefit from this new development as owners and operators.

The Kennedy Administration, which was eager to launch the technology and show a clear space success, found itself on the horns of a dilemma. Kerr and Kefauver were both Democrats, and this was threatening to blow up into a full-scale political wrangle with threats of a prolonged filibuster. John A. Johnson, then NASA General Counsel (and my boss for the five years I spent at the Communications Satellite Corporation) was called to the White House. He was asked to help rescue the situation. Johnson had been detailed to Senator Kerr's staff by NASA to draft the "private only" version of the Comsat Act of 1962. Kennedy's team assigned him the task of drafting a "compromise" version of the Comsat Act of 1962 that bridged the gap between a "private approach" and a "public approach." The Kennedy White House version that emerged was essentially to mandate the creation of a "Communications Satellite Corporation" to be capitalized at $200,000,000 as a public corporation. Half of the stock would be sold to the public at $20 per share, and half of the stock would be apportioned (at the same price) to the telecommunications companies AT&T, RCA, ITT, Western Union, and Western Union International. In a nod to Senator Kefauver, the President would appoint three directors to the COMSAT board in addition to the six who would come from the telecommunications companies and six from the publicly held stockholders. Furthermore, the FCC, the State Department, and the then existing Office of Telecommunications Policy in the White House would give guidance to that corporation with regard to matters of national interest and national policy. In addition, NASA was designated under the bill to provide technical advice and input. This compromise (closer to the Sen. Kerr and industry approach than the Kefauver public approach) was able to win enough votes for passage.

One of the "assumptions" inherent in the bill was that the communications satellite system to be deployed would be a low Earth constellation with several dozen satellites deployed in this manner in order to provide global coverage. The physics of satellite orbits are such that the closer a satellite is to the Earth's surface, the less total coverage of the globe is possible. (One can take a basketball and shine a flashlight on it from several feet away and illuminate it all. As one moves the flashlight closer to the basketball, the area illuminated gets stronger in intensity, but the beam also shrinks to a smaller and smaller area. The same physics applies to a satellite beaming signals to Earth.) Thus, a low Earth orbit constellation requires many dozens of satellites to provide complete and continuous global coverage. About a dozen satellites can cover the Earth from medium Earth orbit, and only three satellites in geosynchronous (or geostationary) orbit can cover virtually the entire inhabited world with only the polar regions not having complete coverage. Also, the Earth station antennas on the ground can be continuously pointed in the same direction to a geosynchronous satellite. A ground antenna tracking a medium orbit satellite must move and follow an orbiting satellite, while a ground antenna operating to a low Earth orbiting satellite must track very fast or have a low-gain "omni-antenna" that can receive at all angles above the ground.

When the Comsat Bill was passed in 1962, the projected cost of a communications satellite plus its launch was assumed to be between $5 and $10 million; thus, a capitalization of $200 million seemed reasonable at the time. In this case, however, technology intervened to provide a more efficient result [12].

The passage and signing into law of the Comsat Act of 1962 spurred both technical and political action. On the technical front, Dr. Harold Rosen and his team at Hughes Aircraft embarked on the design and launch of a series of three experimental satellites. This satellite series was known as Syncom — or, if you will, a type of satellite that could operate from geoSYNchronous orbit.

Rosen and his team thus conceived of a type of satellite that could achieve Arthur C. Clarke's vision by being successfully launched into geosynchronous orbit. The first in this series, Syncom 1, ended up as a NASA launch failure, but Syncom 2 was successfully launched in 1963, and demonstrated that this type of launch and deployment into an equatorial circular orbit 22,230 miles (35,870 km) above planet Earth was possible. Then Syncom 3 launched in 1965. The success of Syncom 2 very significantly caught the attention of the officials of the newly formed Comsat Corporation. They quickly contracted with the Hughes Aircraft company (Contract HS 303) to build an upgraded version of the Syncom satellite. This new satellite would have the effective capacity of 240 two-way voice circuits or one low-quality black and white monochrome television channel. Since the transatlantic submarine voice cables, such as the TAT-1 cable first laid in 1956, had a capacity of 36 voice circuits and no live television capability, a satellite with this type of capability seemed to represent a major breakthrough indeed. (Note the TAT-1, TAT-2 and TAT-3 submarine cables were later upgraded with time assignment speech interpolation [TASI] and other technologies to achieve higher capacity, but they were still far less capable than the Intelsat satellites, especially Intelsat III satellites with 1200 voice circuits plus two television channels launched in 1968 and 1969. Today, however, things have switched

Figure 2. *The Intelsat I (F-1), known in the world's press as "Early Bird." (Photo courtesy of the Comsat Legacy Project).*

again with very-high-capacity fiber optic submarine cables being deployed across the oceans [13].)

On the political level, officials of the Comsat Corporation and the U.S. State Department began to visit other countries to discuss an arrangement for international institutional agreements about how satellite services would be provided. Early discussions with Japan and Australia went well, but in Europe a "game-changing" event occurred. The U.S. "model" for a series of bilateral agreements between the United States and other countries was firmly rejected by the European members of the European Council on Post and Telecommunications (CEPT). The Europeans insisted that there would need to be an international entity to oversee global satellite telecommunications. They also indicated that they felt the United States should not be in a position to exploit its technological advantage with regard to launch systems and satellite technology to dominate these service agreements [14].

Rancorous discussions followed, and these lasted for almost two years. European officials insisted that the Agreements signed in Washington, D.C. on August 20, 1964 be "interim arrangements" to be renegotiated after five years of experience had been gained. After a series of compromises, these international agreements indeed did lead to the creation of the International Telecommunications Satellite Consortium with the Comsat Corporation acting as manager for the system. (The name Intelsat was adopted sometime later, after the so-called Interim Communications Satellite Committee [ICSC] met to discuss a more succinct name.)

During the negotiations that lasted through the summer of 1964, France, in particular, argued for the possibility of regional systems and suggested that the United States should play a less dominant role in the ownership, and argued for international management of the system — particularly when final arrangements were negotiated between 1969 and 1973 [15].

Comsat, even before it had been formally designated the Intelsat system manager, had contracted with Hughes to design and launch the satellite that the world would come to know as Early Bird. In April 1965 this satellite was successfully launched — a low-power 85-pound cylinder surrounded by solar cells and with a squinted beam antenna that, instead of being completely omnibeam, was able to concentrate six times more power back toward Earth. This satellite, shown being assembled in Fig. 2, although modest in size and performance by today's standards, became the world's first commercial communications satellite.

The satellite had a very low-gain antenna and only 100 W of power. The result was a very power-limited satellite that needed to work to very high-gain ground antennas to close the link budget. As of spring 1965 there were less than a handful of the very-high-performance C-band radio frequency (RF) Earth station antennas available to receive the faint signal that this tiny and low-power Intelsat I (F-1) satellite was able to generate. These giant ground antennas with cryogenically cooled amplifiers were located in remote locations where there was a minimum of RF interference. After all, the "power" of the faint signal from Early Bird, by the time it reached Earth, was less than the power represented by a single snowflake falling to the ground.

The initial Intelsat locations were thus in places such as Goonhilly Downs, United Kingdom, Pleumeur Bodou, France, and Andover, Maine. Most of these early antennas were 30 m diameter parabolic antennas, but at Andover, AT&T Bell Labs engineers designed a rather exotic gigantic horn-shaped antenna (Fig. 3). System optimization studies clearly indicated that the next generation of Intelsat satellites should have greater power, higher-gain antennas, and a stabilized platform to allow accurate orientation and pointing of these improved antennas.

Despite the successful deployment of Syncom and Early Bird, the overall architecture of the Intelsat global satellite system was still a subject of some debate. The Initial Defense Satellite Communications System (IDSCS) that was also deployed by the United States military in 1965 was actually a low Earth orbit constellation of simpler satellites that were easier to launch and deploy. A study carried out by the ITT Corporation outlined how a low orbit constellation might be deployed to provide nearly continuous global coverage. However, the Japanese and Australian representatives to the Intelsat ICSC strongly argued against such a low orbit system because they both believed the geosynchronous technology had been well demonstrated. Furthermore, they stressed that their countries, in particular, would be subject to gaps in live and continuous coverage for minutes at a time.

After serious debate, the design specifications for the next generation of Intelsat satellites began. The result of this system optimization process was a new satellite design that would have a much larger solar cell array on the outside of the spacecraft, electronics that would support a throughput capacity of 1200 voice circuits plus two television channels, and a spinning body design that would allow a higher-gain antenna to be continuously oriented to Earth. This would be a "spinner" satellite with the outside drum with solar cells spinning at some 60 rpm, and the interior electronics and antenna system spinning in the opposite direction to maintain continuous stability and pointing accuracy to the desired subsatellite point on the world below. Since submarine cable systems were still at less than 100 voice circuit capacity and no live television transmission capacity, this design with 1200 voice circuits plus color television channels would vault satellite communications into a dominant technological position.

This design was advancing forward when the U.S. government, and NASA in particular, came forward and said they needed to have satellite capability to communicate with ships at sea that would be tracking and communicating with the Gemini space launches that were the predecessor U.S. manned space program to the Apollo moon mission. They offered to compensate Intelsat for the cost of launching, on an accelerated schedule, a satellite that

Figure 3. *The AT&T designed 30-m Andover, Maine Earth station as photographed in 1966 (courtesy of Comsat Legacy Project).*

could provide communications to a ship in the Atlantic Ocean off the coast of Africa so as to maintain communications. After considerable debate within the Intelsat Board (then still known as the ICSC) with the Swiss Delegate, Dr. Reinhart Steiner, in particular, making strong interventions that U.S. interests were overriding the best interests of Intelsat, the decision was made to have an "intermediate" Intelsat II satellite constructed and launched. This satellite would, unlike Early Bird, be able to support multi-destination uplinks and downlinks, but otherwise would be much like Intelsat I (Early Bird).

John Johnson, the former NASA general counsel, the prime author of the Comsat Act of 1962, and now Chairman of the ICSC as a Vice President of Comsat, was left to defend the action, and to indicate that no time would be lost on the 1200 voice circuit satellite and that in the interim Intelsat would gain valuable experience with multidestination service and increased revenues. Thus, what were known as the Intelsat II satellites were indeed built and deployed in 1967. These were manufactured by Hughes and launched on Delta rockets. This decision was made despite several ICSC representatives demurring on the wisdom of proceeding in this manner [16].

The Intelsat intergovernmental agreement and the Special Agreement among the operating entities were rather unique in that they set commercial principles for the Intelsat organization. Contract awards were to be based on best price and performance with international participation only to be considered if all other elements were equal. The Early Bird (Intelsat I) contract had been awarded to Hughes Aircraft prior to the formal creation of Intelsat. The accelerated program to meet NASA needs also went to Hughes since the so-called Intelsat II program was only a slightly modified version of Intelsat I. Thus, what became known as the Intelsat III satellites — the larger-capacity "spinner" satellites with a higher-gain antenna and increased power — were the first true international competitive spacecraft contract award by Intelsat. After approving a formal performance specification, international bidding, and a review by the Technical and Finance Subcommittees, the ICSC decided to award the Intelsat III contract to the American firm of TRW.

This Intelsat 3 series was less than the stunning success for which Intelsat had hoped. Matt Gordon, the public relations head for Comsat, acting as Intelsat manager, decided that names like Intelsat 1 (F-1) (for flight model), and Intelsat II (F-1) and (F-2) had, in a word, a lack of "pizzazz." He convinced Comsat management and the ICSC that the first Intelsat III, which was to be launched in 1968 just prior to the Mexico City Olympics, should be called "Olympico." It was a great public relations idea, but there turned out to be a major flaw in the plan. The first Intelsat III was a launch failure. After that embarrassment, it was decided to just give Intelsat satellites number designations.

Then, after the Intelsat III satellites had been up a short while another disaster occurred. The key to the de-spun platform was the satellite antenna that constantly pointed to Earth. This depended on a very sophisticated rotating bearing and power transfer assembly (BAPTA) that transferred power between the outside drum with the solar cells and the crucial interior reverse spinning satellite antenna system. The disaster was that the bearing system froze up on one of the Intelsat III satellites. This satellite essentially became instantly useless.

Emergency meetings of the ICSC, plus a meeting of the ICSC Technical Subcommittee, where I was then serving as Secretary in 1969, were convened with great urgency. Meetings of the ICSC Technical Committee lasted past midnight amid heated discussions. Engineers from Ball Aerospace were called to discuss the problem, since it was they that had designed and manufactured the bearing system as a subcontractor to TRW. These engineers and Comsat personnel explained how they could re-engineer the bearings to provide greater tolerances between the bearing and the bearing housing, and also change the lubricants. The design changes were rapidly approved, and the rest of the Intelsat III satellites were successfully launched. These actually performed well and met all specifications. In June 1969, just before the moon landing, Intelsat engineers commanded an Intelsat III satellite to fire its thrusters in order to transfer this satellite from the Pacific to the Indian Ocean. As of a few weeks before the July 1969 moon landing, Intelsat, for the first time since its creation in 1964, had achieved its goal of achieving truly global communications.

Thus, there were now Intelsat satellites spanning not only the Atlantic and Pacific Oceans, but the Indian Ocean as well. Suddenly the globe was fully connected via a network of satellites for global communications across all the continents. Over 500 million people across the world were able to watch the Moon Landing in July 1969 — live via satellite. The signal came back from the moon to an Australian radio telescope; from there it was relayed to an Australian Intelsat Earth station at Carnarvon, and from there around the world on Intelsat satellites. Intelsat had become truly global less than two weeks before. As a small part of the overall process, I must confess I felt an element of pride for what Comsat and Intelsat had accomplished.

Despite TRW's recovery, they did not receive another spacecraft contract from Intelsat in the decades that followed. The next generation of satellites, the Intelsat IV and IVA, went back to the "proven supplier" Hughes Aircraft. As we moved from the Intelsat III series of satellites to the IV series, the whole vision of what Intelsat was and hoped to be changed in significant ways. Early Bird (Intelsat I) was one small experimental satellite of some 240 voice circuits and could provide limited television capacity only when all voice service was surrendered. With the Intelsat IV series in the 1970s, we deployed eight satellites, each with 4000 two-way voice circuits and two television channels, and the IVA that followed had 6000 voice circuits. Then the Intelsat Vs, with three-axis body stabilization and large solar array wings, had a capacity of 12,000 voice circuits plus television channels. These huge increases in capacity restructured our thinking about service options, and we began offering domestic transponder leases, first with Algeria and then with scores of other countries.

International telephone, data, and television capacity in the 1970s was now expanding exponentially, and costs were dropping rapidly. We were moving from analog to digital services that were much more cost efficient. We were approving ever smaller and more cost-efficient Earth stations whose costs were dropping even faster than the per circuit cost of a satellite channel. We had set the stage for the worldwide deployment of over 100,000 very small aperture terminals (VSATs) around the globe on international, regional, and domestic systems that we see today.

Two other fundamental shifts in the satellite industry also occurred in the 1970s. National satellite systems began to be deployed. The U.S.S.R.-based Molniya satellite system deployed in the 1960s along with Intelsat was used to combine the various Soviet Socialist Republics and other Communist countries such as Cuba, and thus was a sort of Cold War alternative to Intelsat. The Canadian satellite system, known as Anik (Inuit for "brother"), was thus the first truly domestic satellite system, but other systems followed in the United States, Japan, various European countries, Australia, and even developing countries like Indonesia. Intelsat, starting with Algeria, began leasing spare capacity on a transponder-by-transponder basis to meet the needs of countries lacking the level of traffic needed to support the deployment of complete satellite networks. Today, scores of countries still lease capacity from Intelsat and other satellite systems to meet domestic needs.

Perhaps even more significantly as we moved into the 1980s, satellite systems were designed to meet mobile satellite communications needs. The so-called "Marisat" system was designed, built, and deployed to meet the communications needs of the U.S. Navy. The Comsat General Corporation, which operated this satellite, also used additional capacity to meet commercial maritime communications needs. Also, Intelsat decided to include maritime satellite packages on three of the Intelsat V series of satellites to meet maritime communications needs. Furthermore, the European Space Agency designed some of its Experimental Communications Satellites (ECS) to provide maritime mobile satellite services as well. These satellites were known as the Maritime ECS series or MARECS satellites. When the Inmarsat Organization was formed in 1979 (initially called the International Maritime Satellite Organization) it combined the Marisat system, the Intelsat V maritime communications Subsystem (IS V MCS) and the MARECS satellites to operate the first truly global commercial maritime satellite network.

One of the challenges Intelsat sought to meet as they deployed larger and more powerful satellites was to find a new set of technologies that would allow more cost-effective communications for the thin-route traffic associated with developing and island countries. These new thin-route services were called SPADE (for single channel per carrier [SPC] demand assigned services). SPADE was followed by the simpler SPC services. These new digital services, introduced on the Intelsat system in the 1970s, were followed in the 1980s by the world's first satellite-based time-division multiple access (TDMA) service [17].

All of these new digital satellite services and their specifications (i.e. SPADE, SPC, and TDMA) came out of the Comsat Labs. Dr. John Puente and Andy Werth took the lead in developing the SPACE and SPC specifications. Dr. Tadahiro Sekimoto, also then at Comsat Laboratories on loan from NEC, Japan, took the lead in developing the TDMA specifications. These three men rapidly elevated to much greater fame and fortune. Puente and Werth took the lead in forming the Digital Communications Company (DCC) that became MA Com. MA Com eventually evolved into the corporation known today as Hughes Network Systems (HNS). Dr. Sekimoto returned to Japan, and became the President and Chairman of NEC.

THE PAST, THE PRESENT, AND THE FUTURE

As one looks back on the past 50 years of satellite communications development, those early years were quite remarkable. In this short initial period of commercial satellite services the total amount of global communications capacity went from a few hundred voice circuits to many tens of thousands. Likewise, during this period the in-orbit capacity increased by hundreds of times, and the cost of service dropped by more than a factor of ten. Technological advances of these early years included:

- Moving from low Earth orbit launches to geosynchronous satellite operations
- Transitioning from low-gain nearly omni antennas to high-gain satellite antennas
- Shrinking the size of Earth station giants from 30 m antennas to increasingly smaller ground units
- Moving away from "all analog operations" to TDMA and SPC digital systems
- Leaving behind inefficient FM carriers for thin international links to more efficient SPADE and SPC operations
- Abandoning satellite designs with non-stabilized platforms with no "antenna pointing capability" to "spinners" and now on to 3-axis body stabilized satellites with much greater pointing accuracy and the ability to support more efficient solar arrays
- Transitioning from exclusive reliance on wide-coverage but low-power global beams to higher-power and more efficient spot beam, and to cross polarization for frequency reuse
- Shifting away from quite inefficient power-limited satellites to today's frequency limited satellites
- Moving from no frequency reuse capabilities to highly efficient multiple frequency reuse capabilities through cross-polarization and spot beam separation techniques

All in all, the first years of satellite communications were an exciting time of enormous technological innovation, international political innovation, and organizational change. Satellite manufacturers and launch service providers worked closely with Intelsat to achieve rapid innovation and still maintain reliability. In the 1980s and the years that followed, we have seen other tremendous changes in the satellite industry. We have seen the evolution of mobile satellite communications that started with Marisat to today's networks that provide cost-effective maritime, aeronautical, and land mobile services. We have seen the evolution of direct broadcast satellite systems that provide hundreds of high definition TV channels directly to small dish receivers mounted on the homes of subscribers that range in size from 80 cm down to 35 cm in size. We have seen the evolution of more and more sophisticated satellites for remote sensing and space navigation. These new space industries are themselves a billion dollar industry and have become a part of our everyday lives.

Clearly, today we have moved quite far in the world of commercial satellite operations. There are today around 20,000 satellite television channels in operation worldwide-many of these support HDTV service. Millions of satellite voice and data circuits are in service around the globe in over 200 countries and territories. The Inmarsat I-4, Thuraya, New Iridium and Globalstar mobile satellite networks today provide mobile services around the globe. These satellite services connect to user terminals that have shrunk down in size from the multi-ton, huge 30-meter earth stations of the 1960s staffed 24 hours a day by dozens of employees to actual hand-held battery-powered units operated by individuals.

In short, the era of satellite communications, now going on fifty years in length, has in many ways only just begun. Perhaps one day we will see broadband commercial satellite systems operating to support telecommunications services for the Moon and Mars. But the excitement of the early years will be hard to beat.

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