MANUSCRIPT

FOR

"LIVE VIA SATELLITE"

MEMORANDUM

To: Distribution

From: Robert W. Hunter RWH

Date: January 20, 1988

Subject: Completed Manuscript of Book on COMSAT Labs

Attached for your reading is the completed manuscript of a book on COMSAT Labs that has been in production for more than one year.

We are now working with the author to find a commercial publisher. Our goal is to see this book for sale on the street, in hard bound copy, during our 25th anniversary year.

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LIVE VIA SATELLITE

The story of COMSAT Laboratories and the technologies
that changed the way the world communicates

By Anthony Michael Tedeschi

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PREFACE

On Sunday, December 14, 1986, choirs of children in North and South America sang a song for peace in Central America. The broadcast was carried as a teleconference to more than 100 locations in the Western Hemisphere from Alaska to the tip of Argentina.

Ten days later, Dirk Van Der Loo, a lab technician in the Washington, D.C. area dialed his mother in The Netherlands, to wish her Merry Christmas. Within seconds the phone was ringing at the family's home on the opposite side of the Atlantic.

On April 29, 1981, the tanker Arco Juneau with a full load of Alaskan crude was struck by gale force winds off the Canadian west cost, near the Port Charlotte Islands. A crewman was swept down the length of the deck by heavy seas, sustaining compound fractures above and below the left knee, two broken arms and a broken jaw. A ship-to-shore link-up allowed medical crewmen aboard the tanker to gain life-saving advice from the Public Health Services Hospital in San Francisco. Doctors later credited the long-distance collaboration among medical personnel with saving the crewman's leg, if not his life.

Every year from April to October, baseball-crazed fans gather each day at the Lucky Seven restaurant and bar in Santo Domingo in the Dominican Republic where they sit, transfixed by rows of television sets playing as many as six games simultaneously, broadcast from major league baseball parks in the United States and Canada.

The common thread in each of these vignettes lies at the end of Shawnee Lane in Clarksburg, Maryland. It is COMSAT Laboratories, the research and development arm of the Communications Satellite Corporation, where during the last two decades, scientists, engineers and technicians have changed the way the world communicates.

It is an odd trip, the 35 miles from nearby Washington, DC to the labs. All but the final mile is by super-highway, past the Washington area's version of Silicon Valley. Modern buildings housing corporations with names like Quantex, Spectrum and MA/COM line both sides of Route 270, punctuated by the requisite golf course, the business-traveler hotels and the fast-food restaurants. But a change takes place a few miles from COMSAT Labs. Here the road dissolves into a rural amalgam of hay bales, run-down service stations, weathered clapboard houses and eerie Victorian mansions. When they decided to build the labs in the late 1960s, they opted for a campus atmosphere. That would be more conducive to the kind of thinking required to solve the complex problems which lay ahead for the hundreds of people who would eventually devote the better part of their waking hours to this facility.

As you pull into the parking lot of the 400,000-square-foot complex, you are immediately confronted with a visual synopsis of what went on here. Large antennas of various sizes and shapes point skyward. A display area near the main entrance contains models of each generation of communications satellite. There is an overall sense of space and light at the 200-acre site.

"I remember talking to the architects," said Wilbur L. Pritchard, the first director of the labs. "I said let's get a laboratory in which everyone has a window. And let's make all the offices the same size. You don't often get a chance to have influence over the little irritants."

COMSAT Labs is a facility of long, open corridors and individual test labs crammed with equipment, vacuum chambers with sinister-looking foam spikes and offices sporting an array of personal computers. It is meeting rooms, screening rooms, and "clean" rooms. And it is people -- bright, dedicated people, with an incredible command of their particular subject matter, the courage of their convictions and the stubbornness to persevere when the faint of heart would have thrown in the towel. But more than anything COMSAT Labs is people with the love of a challenge, brought together by the excitement of a chance to break new ground and the understanding that if you did solve the unsolvable, your ideas would germinate into reality, become part of the hardware, the software, the systems -- the solution . . . and you would have had a direct effect on people's lives.

In many ways, the story of COMSAT Labs involves the conquest of the "little irritants" and in the process the reshaping of the big picture -- a macro view of the world. While "the man in the street" may not be familiar with developments such as Time Division Multiple Access, Single Channel Per Carrier, the Echo Canceller, the Hydrogen-Nickel Oxide Battery or the Multi-Beam Antenna, during the period since the launch of the first commercial communications satellite in 1965, the world has become familiar with television "live via satellite," direct-dial telephone service to the most obscure corners of the earth, lightning-fast data transmissions to and from anywhere, links to ships at sea or between conferences in corporate board rooms.

On August 31, 1962, President John F. Kennedy signed the Communications Satellite Act, which said in part that it would be the policy of the United States "to establish, in conjunction and in cooperation with other countries . . . a commercial communications satellite system . . . which will contribute to world peace and understanding."

This is the story of the place where the gauntlet of that challenge was taken up and the world was altered in the process.

CHAPTER ONE: TAKING ON THE CHALLENGE

In late November of 1962, Dr. Joseph Charyk was awakened in the middle of the night by a phone call. Charyk, who was undersecretary of the Air Force in the Kennedy Administration, had indicated to his superiors that he would like to seek opportunities outside the government. The caller was Philip L. Graham, of the influential *Washington Post* publishing family, who was on special assignment for the Administration. He'd just been advised of Dr. Charyk's availability. Being an impulsive man, Graham decided he had to talk to the undersecretary immediately about a top position with a company being formed to put in place an international communications satellite system. Graham was chairman of the board of incorporators for the Communications Satellite Corporation. Undersecretaries of military departments don't take phone calls in the middle of the night lightly, so it took Dr. Charyk a few moments to ascertain that this was not an emergency.

Graham got right to the point. Charyk had discussed his upcoming departure with Deputy Secretary of Defense Roswell Gilpatrick, and Gilpatrick had suggested, among other things that Graham was looking for people to staff key positions at COMSAT. Gilpatrick had spoken to Graham about Charyk's availability and Graham was interested in pursuing the matter. He asked Dr. Charyk if they could meet in Los Angeles the following day. Charyk agreed. He flew out to L.A. and the two men had breakfast together at the Beverly Hills Hotel, where Graham was staying, then walked around the grounds.

"He said [the board of incorporators] had the responsibility to set in motion this new corporation," Dr. Charyk explained, "and that he thought it was going to be one of the greatest things that has ever happened.

It's impact on the world was going to be profound, because it was going to provide a linkage between all of the countries of the world and would dramatically change the nature of the world."

Graham said he'd been impressed with Charyk's work at the Pentagon -- where he had been in charge of key Department of Defense satellite programs. Graham told the out-going undersecretary he would be an excellent choice for chief operating officer. They would also have to find a chief executive officer, Graham said, but he indicated that would be an easier task.

Charyk said he'd think about it and went back to Washington, but Graham, a persistent man, didn't allow him much peace. After a succession of phone calls, meetings, even trips abroad, Dr. Charyk accepted the offer of the board. Then he played a hand in helping to bring in Leo Welch, a former chief executive officer at Esso (Exxon) Corporation, as the first chairman of the board and chief executive officer.

On February 1, 1963, COMSAT was born, officially, with the issuance of its certificate of incorporation by the District of Columbia. A little over a month later on March 10, the board of directors made the elections of Welch and Charyk official and the enormous task of putting together the new company and fulfilling its charter of a global communications satellite system was begun.

One of the early concerns involved AT&T. Although the giant communications company, which had dominated the industry for so many years was represented on the COMSAT board of directors, there were questions about whether AT&T, with its vested interest in transoceanic cables, would merely pay lip service to the concept of a global satellite communications network, or whether "Ma Bell" would put its substantial clout behind the new venture. On December 10, 1963, Leo Welch made public a letter he had received from James Dingman, executive vice president of AT&T, which Welch felt spoke to this concern, and the answer was an endorsement by AT&T. Dingman said, among other things, "the point can be stressed that we see a place, and a need, for both cable and satellite communications." He emphasized that if a satellite was successfully launched and made operational by early 1967, AT&T would prefer to use circuits on the satellite rather than place additional cables beneath the ocean, although he added that the appropriate communications agencies in other countries would have to be willing to use the satellite as well. Dingman said, "Diversity of routes and facility types is the best method of assuring service integrity and that is one of the major reasons for our interest in utilizing satellite circuits for overseas service as soon as possible. The high capacity cable will have many important applications but we see no basic reason why it should prevent satellite usage from reaching economical and profitable levels."

It was an important vote of confidence. The support of AT&T in general, and Dingman specifically, would serve COMSAT well at other critical points in COMSAT's early history.

One of the early priorities for the new company was the creation of an international communications consortium and that became the full-time job of John A. Johnson, who joined COMSAT in April of 1964 as vice president, international. Johnson had been general counsel at NASA since its founding in 1958.

"He had the assignment from me to bring the message of satellite communications to the rest of the world," Dr. Charyk said. "to open a dialogue with countries of all stripes for the purpose of telling them about the promise of satellites, and encouraging their participation."

Johnson understood that even the earliest negotiations would set the tone of how the entire international environment would be structured. "My job, was to help create the international organizational mechanism which would enable COMSAT to carry out its statutory mission to be the U.S. participant in the establishment and operation of a global commercial communications satellite system," he said. "We agreed from the outset that what was necessary was to look at this thing from a global point of view, with a satellite system in which ownership would be shared in some yet-to-be-defined manner. The definition of that form of ownership, in its final form, took the better part of a decade, but the concept was developed quite quickly and we then had a series of negotiations with the Europeans, Japan, Canada and Australia."

The first critical meeting took place in Karlsruhe, West Germany, in December of 1963. It was a meeting of the European Conference of Post and Telecommunications Administrations (CEPT). While many of the Europeans had expressed a desire for caution in what they saw as eagerness by the U.S. to move too rapidly into space, they were, however, intensely interested in the new COMSAT entity and had invited Johnson and Charyk to the meeting. AT&T's Dingman, also attended.

"We were able to make it clear to the Europeans that we were going ahead with the construction of the first commercial communications satellite and that we were doing this without awaiting any further progress in the actual conclusion of international agreements," Johnson said.

Once again, it was a forthright and unequivocal statement by Dingman that held sway.

"AT&T's support of our venture and their intention to make use of satellite communications was very significant in conveying a sense of seriousness and urgency to all the PTT administrations of Europe," Johnson said.

While the Europeans were getting their ducks in a row, and agreeing to speak with one voice despite any differences among them, COMSAT began lining up allies in the Canadians, Australians and Japanese -- the only countries outside of Europe with serious interests in satellite communications at the time.

"We could not tolerate the situation where we would have a stand-off," Dr. Charyk said, "with the United States on the one hand and Europe acting as a bloc."

Ultimately it was this alliance with Canada, Australia and Japan that broke any deadlock, because it didn't permit the Europeans, acting as a unit, to frustrate action. But the real questions centered around the terms and conditions of the international agreement. How would decisions be made? How could decisions be frustrated? What were the voting rights? What were the financial terms of the agreement?

"We were very much concerned about the economics of the thing," Dr. Charyk said. "We were not going to enter into any agreement where the terms and conditions would prevent the enterprise from operating in a sensible, businesslike fashion."

There was also an effort to bring the Soviet Union into the fold. In the spring of 1964, representatives of COMSAT and the U.S. government met with a Soviet delegation in Geneva. The talks, however, were not successful.

John Johnson recalled the session ending with the Soviet delegate reading "a harsh statement which had obviously been produced in Moscow and which had little relevance to our presentations. He said that the whole effort was premature, the implication being that the technology was not yet ready for application to a global system. In addition, he blasted our plans as being a means of extending a capitalistic imperialism and monopoly around the world."

Then an odd thing happened. The Russian put down the document he'd been reading and changed his tone entirely.

"He expressed, in very gracious words his appreciation for all they had heard," Johnson said, "and said he hoped that at some future time, we could renew the experience."

At a meeting in London during late July of 1964, final arrangements for the participation quotas in the new international body were hammered out, the meeting ending at two o'clock in the morning in the suite of COMSAT CEO Welch. The negotiating had brought results. In announcing a meeting of the minds, Welch described the agreement as a "very important chapter" in the development of a global space communications system.

The New York Times reported, "the evolution, in the opinion of (COMSAT) corporation and Administration officials, has taken place with remarkable rapidity and smoothness over the last six months."

On August 20, 1964, the International Telecommunications Satellite Consortium (INTELSAT) was created under international agreements for interim arrangements. COMSAT, which had a 61 percent investment in the new consortium, was named the manager. The European investment quota was 30.5 percent (exactly half of COMSAT's) and the remaining 8.5 percent was divided up among Canada, Japan and Australia.

". . . The INTELSAT Agreement and the INTELSAT Special Agreement, which were signed into effect on an interim basis . . . reflected a compromise between divergent national viewpoints," wrote former INTELSAT Director General Santiago Astrain in "The INTELSAT Global Satellite System." ". . . The Agreements were structured to allow participation either by governments or private enterprises designated by their governments. INTELSAT was created on the basis of commercial operating procedures, but, just as significantly, it was premised on the principle that all charges would be nondiscriminatory and the the same charges would apply to all users for the same service, regardless of their traffic requirements."

The agreements were then opened up to other countries who might want to join. It was only a matter of weeks before Israel sent word that it wanted in.

"The State Department put out a press release announcing that Israel had signed the agreements," Johnson said, "and within 24 hours I had a call from the Washington office of the League of Arab States. They wanted to know what this new organization was all about. And so we had some very interesting meetings with representatives of that office and a number of Arab nations with the result that the entire group of Arab states very quickly came into INTELSAT, bringing its members to over 30."

Within a decade the number grew to more than 100.

While all this negotiating was going on at the international level, COMSAT was frantically preparing to float its first issue of common stock.

"The company hasn't taken in a nickel yet, probably won't turn a profit for years, and doesn't even have a product to show potential customers," began the lead-in to the Newsweek cover story, March 16, 1964. "But with all those drawbacks, investors will be standing in line when $200 million worth of Communications Satellite Corp. stock is offered to the public."

While the company was leaning towards a satellite design that would involve high-orbiting satellites synchronized to the rotation of earth, a need for $200 million dollars was decided upon to provide enough funds in the event that this geosynchronous concept did not prove viable. The alternative approach involved a medium-altitude system, requiring two-dozen or more satellites orbiting at once, plus sophisticated earth stations that could track and communicate with the satellites as they crossed the sky -- a far-more expensive proposition than the geosynchronous approach.

"We had to raise enough money so that if we were wrong, we could still get to the point where we could demonstrate something," Dr. Charyk said. "If we were going to go the medium-altitude route, $200 million was not nearly enough. But, we thought that $200 million would at least be enough that you could demonstrate something. We felt that it was essential that you raise enough money so that you could actually demonstrate the viability of a system before you had to go back for additional dollars."

Two months before the public offering, The New York Times reported brokers predicting so great a demand for the stock that many would entertain requests to buy only from favored customers. The stock offering was to be the largest since the Ford Motor Company had gone public eight years before. It was inspiring a tremendous amount of grass roots interest.

In a random sampling, The Wall Street Journal found, "a Chicago housewife buying it because it's 'the patriotic duty of every American.' . . . a Dallas bank employee ordered some because it's 'something you can leave for your kids and really give them something.'. . . a San Francisco radiator repairman placed an order because 'it might pay off and I like to help and support pioneers anyway . . . '"

Of the 10 million shares of stock in the original issue, half were offered to authorized communications carriers, the other half to the general public. The results of the carrier offering were made public on May 28, five days prior to the public half of the offering. The carrier issue was a huge success. More than 160 communications companies, from the giants of the industry to much smaller firms, had over-subscribed the issue. At $20 per share, $100 million was raised, with AT&T emerging as the largest shareholder at $85 million. ITT bought $21 million, GTE $7 million, RCA $5 million.

The public offering was no less a success. Sold via hundreds of brokers across the country, the stock came on the market at $20 per share and rose to $27 per share within minutes. While AT&T had emerged as the largest stockholder, Wall Street analysts estimated that the COMSAT family included several hundred thousand shareholders.

"Quick profits were a motive for some people," The New York Times reported. "A man who could garner 40 shares at the offering price, might have sold his stock within the first half hour of trading and realized a short-term profit of around $250 on an $800 investment."

While the stock issue held the headlines on the business pages and the creation of the international consortium was the subject of a score of major articles in domestic and international publications, the real story of satellite communications was beginning in the laboratories and manufacturing facilities that would put the hardware in place, which in turn would make commercial satellite communications a reality. And that story begins with a tiny metal barrel about the size of an oil drum and an experiment that would chart the course for the future of communications satellites in space.

CHAPTER TWO: THE EARLY BIRD CAPTURES THE IMAGINATION

"The greatest innovations are often simple in principle. All Early Bird does in essence is pick up a microwave signal sent from one ground station and relay it to another a long distance away. But the potential effect could be as far-reaching as the invention of the telegraph." Fortune magazine, October 1965.

In the late afternoon of April 5, 1965, a young engineer named Simon Bennett stood atop the gantry alongside a Thor Delta rocket, more than 10 stories above the launching pad at Cape Kennedy, Florida. Bennett and his team were performing the final tests before the launching of an experimental satellite that would play a pivotal role in world communications. The satellite, built by Hughes Aircraft Company, was known officially as HS-303, but it had been nicknamed "Early Bird," by an information officer in a shoot-from-the-hip answer to a reporter's question. The name would stick and become part of satellite lexicon.

Among other things, Early Bird was designed to provide answers to some critical questions about satellite communications. It weighed only eighty-five pounds, which was about all that could be lifted into high orbit by the rocket power of the day. And this satellite was bound for a high orbit indeed -- 22,300 miles above the earth, the altitude at which a satellite assumes a geosynchronous orbit, i.e. a stationary position relative to the revolving earth. The altitude was such that the Delta rocket had to be augmented with three solid-fuel boosters to provide the additional thrust needed to put the satellite into transfer orbit, from which it would be boosted into geosynchronous orbit.

The crew testing the satellite on this particular launching of an experimental satellite that would play a pivotal role in world communications. The satellite, built by Hughes Aircraft Company, was known officially as HS-303, but it had been nicknamed "Early Bird," by an information officer in a shoot-from-the-hip answer to a reporter's question. The name would stick and become part of satellite lexicon.

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The crew testing the satellite on this particular afternoon in early spring were employees of Communications Satellite Corporation, or COMSAT, a brand new corporation spawned by the Communications Satellite Act of 1962. They were performing tests on the microwave radio systems aboard Early Bird to make sure they would work as advertised and adjusting the on-board antenna.

"This whole launch thing was very new to me," Bennett said, "and a tremendous challenge. I had never been to a launch site before."

The crew wore special clothes, overshoes and anti-static straps, because with the solid-fuel booster rockets already in place for the launch scheduled for the following morning, they didn't want to risk any kind of a spark.

April is part of the "shoulder season" for the resort areas of Florida and the Caribbean. It is that time of year between winter and summer when visitors are fewest because of the prevalent thunderstorms that spring up, and at this particular moment, one of them sprung.

As he saw the dense black clouds rolling in, Bennett ordered his crew down from the gantry. "You didn't really know if lightning could do something," he said.

There was a small problem. The elevator was overloaded with test equipment, so it wouldn't move.

"These elevators were external to the gantry," Bennett explained, "and they didn't always run, so _we_ had to run all the way down."

For the scientist and engineers of COMSAT, it seemed they were always doing things on a dead run. In this case the lightning did nothing, the tests continued and the systems performed perfectly. The satellite was pronounced ready.

A few months earlier, President Lyndon Johnson had called the concept of commercial communications satellites, "sky trails to progress in commerce, business, trade and in relationships and understanding among peoples . . . . The objectives of the United States are to provide orbital messengers, not only of words, speech and pictures, but of thought and hope."

At the time, the only means of transoceanic communications were undersea telephone cables, completed across the Atlantic in 1956 and the Pacific in 1964. But transoceanic telephone calls followed odd routings, often dictated by present or prior political allegiances. For example, a call between Senegal and Nigeria, two African neighbors, was routed through France and the United Kingdom, two colonial powers in Africa. A call between American Samoa and Tahiti was via Oakland, California, hundreds of miles away from either.

The alternative to cables, was microwave radio, but such microwave transmissions would not work over great distances, because radio waves travel in a straight line. They do not bend to follow the curvature of the earth. While Guglielmo Marconi had managed a trans-oceanic telegraphy signal in 1901, the success of the experiment was dependent upon the ability of the ionized regions of the earth's atmosphere to reflect long-wave radio signals. While this did usher in an era of medium-frequency radio communications, the performance was not reliable and consistent, good-quality telephone services not achievable. To send an effective microwave signal across an ocean, you would need relay towers at approximately 30-mile intervals, or a single tower almost 500 miles high, positioned at the half-way point. Obviously, neither solution is feasible, much less practical.

With the advent of the space age, the idea of the communications satellite was born. Although there were a growing number of people who could see the value of a communications satellite system, there were some very basic disagreements as to how to implement such a system. The most hotly contested issue involved the choice between a geosynchronous orbit versus a system of lower-orbiting -- or medium-altitude -- satellites. AT&T had already put the much-heralded TELSTAR into medium orbit. But in order to achieve continuous communications using satellites like TELSTAR, you would need a series of 25 or 30 satellites, because in anything but a geosynchronous orbit, the satellite and the earth are not rotating in unison. Therefore, satellites in sub-synchronous orbit are only "visible" to a pair of communications stations for a short period of time -- the time after the satellite "rises" over the horizon and before it "sets."

Using medium-altitude satellites creates further complications. When a medium-orbiting satellite begins to set, as seen by a pair of earth stations that are communicating with each other, it is necessary to re-route traffic quickly to the next satellite as it rises above the horizon to avoid disrupting communications. To do that requires a suitable period of overlap between the outgoing and incoming satellites. This, in turn, requires synchronized tracking by pairs of antennas at each earth station to set up the "hand-over" without a period of outage -- one antenna tracking the final moments of the first satellite, while the second picks up the first moments of the incoming satellite. Forecasted costs for redundancies such as these were enormous.

On the other hand, to establish a global communications system via geosynchronous orbit would require only three satellites: one each above the Atlantic, Pacific and Indian Oceans. There were difficult problems to be solved, but the simplicity of the concept, and the potential cost savings were attractive. Geosynchronous began to win proponents.

the special experimental endeavor would be conducted on a non-profit basis after a request from the State Department which felt that it would be "in the national interest that this project be undertaken."

The live TV feed to the United States was via a U.S. Navy earth station at Point Mugu, California, modified by COMSAT specifically for the telecast. On their end, the Japanese built a special earth station at Kashima, 50 miles northeast of Tokyo. The TV feed would go via microwave link from Tokyo to Kashima, then up to the satellite over the Pacific, back down to Point Mugu, then via microwave to the Los Angeles test board in the Bell System for distribution to U.S. television and other participants in the project. The audio portion of the transmission was via undersea cable, since the image transmission required the full capacity of SYNCOM III.

Scientists and engineers at COMSAT had a number of concerns about the experiment, the principal being that SYNCOM III had not been designed for television, so the company made it clear in its announcements that "the quality will not be as good as that of the satellites in

The idea of the geosynchronous orbit first gained attention in a memorandum written by a British technical officer at the close of World War II. That officer, Arthur C. Clarke, who later achieved worldwide celebrity status as a science fiction writer, explored the idea in a memorandum titled, " The Space Station: Its Radio Applications." He expanded upon the idea in October, 1945, in an article for a magazine called Wireless World. Clarke went no further, however, because he didn't feel the technology to launch such a satellite would be available in his lifetime and, in any event, he was busy writing his first novel.

However, it would be less than 20 years before the concept was demonstrated, in 1964, a year before Early Bird. Live television transmission via satellite had been the subject of a successful experiment during the Olympic Games in Tokyo that year, when COMSAT coordinated the arrangements to broadcast the games, utilizing an orbiting geosynchronous satellite called SYNCOM III, built for the government by the Hughes Aircraft Company. In announcing plans to broadcast the games, COMSAT said the global commercial communications satellite system. The global commercial communications satellites will be far more powerful with much greater bandwidth to accommodate telephone, telegraph, facsimile, data transmission or TV signals of internationally accepted standards."

They need not have worried so much. Jack Gould, writing in The New York Times, called the telecast of the opening ceremonies, " a triumph of electronic technology that was almost breathtaking in its implications for global communications . . . in every way markedly superior to the previous international TV experiments by TELSTAR satellites over the Atlantic Ocean." The Times reviewer also lauded the quality of the images and the fact that the telecasts lasted longer than those done previously via TELSTAR.

Despite the success of the Olympics experiment, however, important questions remained unanswered, the two most critical of which were: What do you do about the delay and the echo in telephone conversations which were expected to provide the bulk of the traffic in satellite communications? And, could you get the necessary lifetime out of a high-altitude satellite?

As for the question of life-span, scientists would try to simulate conditions of heat and cold in a deep vacuum and experiment with the type and amount of propellants needed to make on-going adjustments of the satellite's position, but those questions could be answered only over time. The problems of delay and echo, were more immediate.

With a satellite at 22,300 miles above the earth, the human voice, carried on a microwave radio broadcast at the speed of light (186,000 miles per second), would take a quarter of a second to travel from the speaker to the distant listener. During the process, the transformers that combine the send and receive circuits at all local telephone exchanges generated an echo of the speaker's voice. For the relatively short distances of most earth-bound conversations, the echo was received so quickly that it was not noticeable. But via satellite communication, the echo would make the return trip to the party who was speaking about a half-second after he or she had spoken. It can make a conversation all but impossible. The problem, far less noticeable in long-distance terrestrial telephone conversations, was dealt with using echo suppressors which open the leg of the circuit that is not active, thereby cutting off the echo, but these devices often operated imperfectly or made for choppy conversations over satellite circuits because of the long response time.

The debate raged. "If a medium-altitude system were built, with its 25 to 30 relatively simple satellites, it would be prudent to first launch a prototype model prior to manufacturing the total quantity," said Sydney Metzger, first manager of COMSAT's engineering division. "That satellite, even if successful, would prove out the design, but would be of no operational value until most of the others were launched. If we launched a single synchronous satellite as an experiment to test the effects of time delay and echo . . . and the satellite design as a whole was successful, it could be used operationally without launching additional satellites."

On March 4, 1964, COMSAT announced it had made a decision to go geosynchronous and test the echo via the existing system of echo suppressors. It applied to the Federal Communications Commission for authority to "construct and place in orbit an experimental-operational synchronous satellite in the spring of 1965 . . . with the capability for up to 240 high-quality telephone voice circuits, or alternatively for message traffic, facsimile, or black-and-white television . . . a light-weight spacecraft with a minimum operational expectancy of one year, but with on-board spacecraft control aimed to keep it on station for three years."

The company, however, recognized that the subject of orbit would be a matter of experimentation, so as late as 10 months before the launch, COMSAT was keeping an open mind on the matter. Despite the fact that Hughes Aircraft had been awarded a contract to build a geosynchronous satellite, COMSAT announced on June 8, 1964, that it had awarded engineering design studies to AT&T and RCA for a random-orbit, medium-altitude design; and Thompson Ramo Wooldridge and ITT for a phased-orbit medium-altitude design.

Two weeks later on June 22, COMSAT announced that it had reached agreement with AT&T to modify the huge cassegrain horn antenna at Andover, Maine, to enable the antenna to work with synchronous satellites. Services necessary for the operation of the Andover station would continue to be provided by AT&T. The earth segments of the experiment would include Andover and European stations at Goonhilly Downs in the United Kingdom; Pleumeur-Bodou, France; Raisting, West Germany; and Fucino, Italy.

Two days before Christmas in 1964, COMSAT announced a contract with NASA to launch the new satellite, now dubbed "Early Bird." NASA was to provide thrust-augmented Delta type vehicles, be responsible for preparations and the conduct of the launch and the injection of the satellite into transfer orbit. COMSAT agreed to pay on the order of $3.5 million for NASA's services, whether the launch were successful or not. The launch was targeted for the latter part of March.

Emotions ran high as the launch date approached.

"If this thing didn't work, the repercussions could be terribly profound," said COMSAT President Joseph Charyk, "-- not only nationally, but internationally -- since now you'd had other countries who had been talked into participating in this thing on the basis that we could do it. Getting the satellite into synchronous orbit, then putting voice traffic through it, was a terribly important step in the development of the whole concept. A failure would be a pretty solid negative blow. So there was great tension."

There were other causes for tension. For example, even if the launch went without a hitch, there was concern that they would not be able to "find" the satellite, once it separated from the launch vehicle.

"The launch vehicles were not as accurate [as they are today]," said Robert Briskman, who was manager of telemetry tracking and control for COMSAT at the time. "That created uncertainty over exactly where and when the satellite would be first visible at Andover. Would we have enough orbital data and be able to compute it well enough that we could point this very narrow beam at

Andover and find the satellite. If we didn't find it the first time, the likelihood of us ever finding it again became fairly small."

Among those who would be watching closely were members of the business community. The Washington Post reported, "stock brokers expect a wide fluctuation in the price of COMSAT stock, depending upon whether the Early Bird launch succeeds or fails."

In early March, there was real cause for apprehension when transistors being used in the communications package failed repeatedly. All the transistors of the type that failed had to be systematically replaced and the launch delayed from late March to early April. By mid-March the transistor retest was deemed satisfactory, and the satellite was shipped from Hughes's plant in California to Cape Kennedy. The launch was scheduled for April 6.

To most of the outside world, the idea of the historic experiment in space began to gain a kind of dramatic momentum. In the days immediately preceding the launch, the hottest ticket in town read:

Leo D. Welch Chairman

and

Joseph V. Charyk President

of

Communications Satellite Corporation

request the pleasure of your company at a

special closed circuit television viewing

of the launch of the first

Commercial Communications Satellite

"Early Bird"

Tuesday, April 6th at 5:30 p.m.

Corporation Offices

1900 L Street, N.W.,

RSVP . . .

Among those accepting the invitation were Arthur C. Clarke, Vice President Hubert Humphrey, who also served as chairman of the National Space Council, and Minnesota Senator Walter Mondale.

On April 3, the COMSAT press office issued an announcement of a news briefing to take place at 4 p.m. on the launch day and invited journalists from major publications and news services, domestic and foreign. A closed-circuit, two-way TV hook-up was installed that connected COMSAT headquarters with the Cape Kennedy launch site.

By 6 p.m. on April 6, VIPs and media were in place and the countdown was being monitored.

Shortly after COMSAT Chairman Welch told the fidgeting gathering, "we hope you are not going to be disappointed," the countdown was held at T minus 11 minutes when, it was discovered that the automatic fueling system for the second-stage rocket engines was not functioning properly. Switching to manual took about 15 minutes and the countdown was resumed.

At 6:48 p.m., the thrust-assisted Thor Delta rocket carrying Early Bird sat for a moment atop a plume of flame, then lifted flawlessly off the launch pad at Cape Kennedy. The correspondent for _The London Times_, an eye-witness, described the launch thusly: "The light was just fading and it presented an awe-inspiring sight as, illuminated by searchlights, the base of the 71-ton launcher erupted suddenly into a brilliant orange colour which soon changed to a red as the vehicle appeared to saunter lazily skywards. As it quickened its pace, it emitted a thick, whitish trail which was tinged pink as it caught the last rays of the sun."

Seventy seconds later, the three solid-fuel boosters burned out and fell away, while the first-stage engine continued to burn, pushing the tiny satellite further away from earth. Less than two minutes later, the second-stage rocket fired and within 20 seconds the nose fairings protecting Early Bird from the elements in the early phases of the launch, were jettisoned. At 138 miles above the earth, the satellite began spinning, then coasted for about 15 minutes until it separated from the third and final stage engine. Early Bird had assumed its elliptical transfer orbit, swooping down to within 195 miles of the earth's surface, then swinging out to its first apogee of 23,000 miles at 49 minutes after midnight.

After lift-off, Welch had told the group, "we will all sleep better tonight."

Humphrey broke the tension by joking, "now we'll be able to call everybody. I don't know if this is a good thing or not. We have enough telephone calls in the office already." Then, he added, "it is indeed an early bird and thank goodness it looks like an eagle."

The gathering broke up. There now began an agonizing three-day period while scientists prepared for the critical maneuver of boosting Early Bird into its synchronized orbit.

CHAPTER THREE: ACHIEVING HIGH ORBIT

James B. Potts, COMSAT's manager of terrestrial interface, was stationed with his crew at Andover, Maine monitoring the progress of Early Bird. COMSAT had leased the big cassegrain horn antenna there from AT&T and had contracted with Bell Labs for extensive modifications so that the necessary telemetry, tracking and control functions could be performed. The critical segments of Potts's assignment would be the three-day period from the launch until the satellite achieved geosynchronous orbit. NASA's role ended with the achievement of transfer orbit, at which point COMSAT assumed responsibility for the success or failure of a number of key operations that "could have had disastrous long-term effects," Potts explained, then added. "Maybe we weren't smart enough to be scared."

By launch time, they had pointed the big horn south toward Cape Kennedy, just above the horizon, to see if they could monitor the lift-off, via VHF radio signals which would be transmitted during the launch. "We picked up the VHF signals as the launch cleared the horizon, and we knew the satellite had survived the launch," Potts said.

Early Bird's first apogee would be over the Indian Ocean, so the COMSAT team would have to wait for the second apogee to perform the first critical test, which would involve locking onto the satellite, then sending a command to turn on the microwave beacons. Instructions were to activate the command switch at Andover for two seconds. When the moment arrived, the switch was activated. There was no verification from the satellite. Step one hadn't worked!

"Expectant silence, turned to stunned silence," Potts said. "Did we miss something in the procedure? Had the transmitter failed?"

One of the Hughes engineers suggested that they had not executed the command for a long-enough period. They tried it again. The beacons responded. There was a microwave signal -- and many sighs of relief.

The firing of the apogee motor would not occur for three days and it was too much to expect the team to wait that long for something exciting to happen. They began muttering about checking out the communications package by sending up a television signal.

"Sid Metzger was the instigator," Potts said. "We had a small TV camera, something like you see in stores as a monitor to protect against shoplifting. We also had some pictures out of the press folder -- one of a bird caricature and one of an artist's rendition of Early Bird itself."

They set up a loop transmission, up to the satellite, then back down to Andover, then waited for the satellite to come within range. The loop worked. Instant exhilaration. They snapped some Polaroids of the return pictures on the TV monitor.

The _Washington_ _Post_ picked up on the story of the unscheduled, unauthorized act on the part of "over-eager" engineers, but also reported on the excellent quality of the picture.

For the next three days, COMSAT engineers prepared for what would be the critical spacecraft maneuver: the boost into geosynchronous orbit. The sixth apogee was chosen for the kick into high orbit for several reasons. A firing at an earlier apogee would require additional use of precious fuel needed to make in-orbit adjustments during Early Bird's functional lifespan. A later firing would subject the solar panels to an extended exposure to potentially damaging rays as the spacecraft passed through the Van Allen Belt in lower orbit. Again, this might shorten its lifespan.

On the morning of the appointed day, April 9, the control building at Andover was jammed with team members from COMSAT, Bell Labs, Western Electric and Hughes. Anticipation and tension ran in equal measure as the satellite approached its sixth apogee. At 08:40:25, a signal was sent from the earth station at Andover and a small engine aboard the satellite fired its peroxide propellant as it reached the high point of the transfer orbit. A perfect burn kicked Early Bird into a circular path 22,300 miles above the Equator. Its orbit was then synchronized with that of the earth and it was positioned at 27.5 degrees west longitude off the east coast of Brazil. It was a moment that created "a very special memory" for Jim Potts and the select few who watched it happen first-hand.

Back in Washington, COMSAT engineers monitored the goings-on from their new Control Center at 2100 L Street. Arnold W. Meyers described it as a "jack-of-all-trades facility" built for the limited capabilities projected for the early satellites. "Constructed in less than one year, the center was designed with the idea that the acquisition, handling and processing of information would have to be a largely manual rather than electronic affair," he said. "Grease pencils and sliding plexiglass panels were the methods and materials of the day . . . not video displays . . . The expertise we lacked in operating satellite systems was made up for by our enthusiasm over the opportunity to play a part in making history."

Nonetheless, the center functioned effectively, coordinating time on the satellite between earth stations in the U.S. and Canada, on one side of the Atlantic, with those in the U.K., France, Germany and Italy, on the other side.

"Simplicity of operations stands out . . . as the important aspect of Control Center," Meyers said. "The teamwork of the staff was excellent and amid the hectic pace there was no time for second-guessing and worrying."

During the week of April 15, engineers at Andover tested the satellite with TV transmissions from Andover-to-Early Bird-to-Andover and telephone tests between Andover and COMSAT headquarters in downtown Washington. Then, in preparation for live TV broadcasts in early May, engineers ran tests to align the earth station antennas in Maine and those in Europe to work with the satellite. Live transmissions were sent from Andover to Goonhilly Downs in England, Pleumeur-Bodou in France, and Raisting in Germany, while the Europeans returned test patterns and film segments.

On Sunday, May 2, broadcasters in North America and

Europe pooled their resources for an inaugural, one-hour TV program, called "This is Early Bird," which was viewed by an estimated audience of 300 million people. The following day, Monday, May 3, COMSAT made more than 14 hours of Early Bird time available to TV stations in an effort to demonstrate the capability of satellites for use in international TV journalism. All three network morning shows took advantage of the opportunity.

NBC kicked things off during the "Today Show," from 7 to 9 a.m. with host Hugh Downs broadcasting live from London, and included segments from Paris, Rome and Amsterdam.

CBS utilized the time during its Morning News program from 10 to 10:30 a.m. with anchorman Mike Wallace and reports from correspondents in European capitals. Then from 12:30 to 2 p.m. CBS hosted a "Town Meeting of the World," a two-way round-table discussion concerning the War in Vietnam, telecast between New York and London. Those discussing the situation were U.S. Senator Barry Goldwater and Secretary of State Dean Rusk on one side of the Atlantic and Former British Prime Minister Sir Alec

Douglas-Home and Foreign Secretary Michael Stewart on the other. It was the first of many telecasts that brought the Vietnam War into the living rooms of the world over the next several years.

ABC used its time on Early Bird for news segments, featuring correspondent Peter Jennings broadcasting from London. All three networks, broadcast news segments from across the Atlantic on their evening news programs, as did the Canadian Broadcasting Corporation, with its newscaster Earl Cameron reporting from London. European television also took advantage of the opportunity via France's ORTF, Italy's RAI, Britain's ITV, as did United Press International and the European Broadcasting Union.

Among other things, the day's flurry of activity gave birth to the now-familiar phrase, "Live Via Satellite."

On Monday, May 17, COMSAT made Early Bird available to the networks once again, during regular programming, for the first transmission of color. The inaugural color broadcast was for an NBC segment called "A New Look at Olde England," originating in London. The event was scheduled to coincide with the 100th anniversary of the founding of the International Telecommunications Union.

The outside world was impressed with the new satellite. _TV Guide_ reported that Early Bird "appears to be capable of doing just about anything except eating a worm."

With things going so well, COMSAT filed, on May 28, a tariff to use Early Bird for transmission of voice, record, data, telephoto, facsimile, and television on a commercial basis. It was, of course, the first tariff of its kind filed with the FCC and was designated FCC No. 1. The tariff would take effect on June 27, unless the FCC took action to halt or alter it.

Use of the satellite required some tricky scheduling. Since Early Bird did not have the capability to provide simultaneous voice and television channels, voice-grade channels were made available on a lease basis for periods of one month, on a 16-hour, seven-day-a-week schedule. COMSAT made provisions for customers to surrender voice channels to accommodate TV, when decisions were made to make TV channels available. The company said the carriers would have to make their own arrangements with their European counterparts to complete the communications path. COMSAT promised that with additional satellites in orbit, it would be in a better position to provide for the use of TV on a less intricate and more regular basis.

Initial rates for satellite transmission were $4,200 per month for a two-way leased voice-grade channel; one-way transmission of black-and-white TV signals was $2,400 for the first 30 minutes, $475 for each succeeding 15 minutes.

On June 8, COMSAT filed with the FCC for the appropriate licenses to operate Early Bird commercially. To support the application, COMSAT included, among other things, the satellite's performance test results and the Andover earth station test results, both of which exceeded expectations. During the following three days, Early Bird continued to demonstrate its versatility by collaborating with ITT, RCA, and Western Union to transmit, telegraphy, facsimile, telex, photographs and data. Then, on June 15, the satellite was used to provide a space link for high-speed transmission of weather data and maps for the U.S. Weather Service between its headquarters in Washington and the French National Weather Center in Paris.

On June 28, Early Bird faced its next critical test. How would the telephone voice circuits work? In other words, would the delay and echo problems make conversation difficult, if not impossible? COMSAT engineers were confident that the echo suppressors would prove adequate. Consequently, arrangements were made for President Lyndon Johnson to exchange telephone greetings via the satellite with fellow heads of state on the opposite side of the Atlantic. Aside from President Johnson, speaking from the White House, other participants included former President Eisenhower, plus the Prime Ministers of Great Britain and Canada, and the Chancellor of West Germany, among others.

In addition to the two-way communication between heads of state, 12 phone booths, which had been set up at Washington's Mayflower Hotel, accommodated calls between other high-level members of government and industry on both sides of the ocean. The ceremony officially inaugurated commercial service, which provided service between the U.S. and Canada, on the one hand, and 10 European countries on the opposite side of the Atlantic.

Although, this initial test of Early Bird's voice capabilities was bally-hooed with much fanfair, the on-going question of the quality of these communications in day-to-day use still remained. As Sid Metzger put it, "if the problems of time delay and echo proved unacceptable to the telephone user, any cost advantage over the other system would be of only academic interest."

AT&T leased 60 of the 240 circuits aboard the satellite and began sampling user reaction, with call-backs to the United Kingdom, France, Italy, Germany and Scandanavia. This six-month user-test period was a bit apprehensive for the people at COMSAT who had made the decision to go geosynchronous.

"If the conclusion had been that this was not satisfactory, the consequences would have been pretty serious," Dr. Charyk said, "because at this stage of the game, we would have had to look to other kinds of systems. The financial and other consequences of that would have been very significant."

Those who were in favor of the synchronous orbit found the sampling questions to be a bit leading -- i.e. Was there anything wrong with your call? As opposed to, how would you rate this call? Nevertheless, the testing showed a high level of user acceptance and proved the viability of the concept. As Early Bird proceeded to provide positive answers to the questions about the geosynchronous orbit, it was made an operational satellite and work on the next generation of satellites proceeded with a higher level of confidence.

Recognition for the accomplishments of the satellite continued. At the Emmy Award ceremonies in June of 1966, COMSAT Technical VP Siegfried Reiger accepted a special Emmy from Rod Serling, president of the National Academy of Television Arts and Sciences. Serling called the Early Bird experiment, "a significant advancement in television research and development."

It had been just five years since President Kennedy had addressed a joint session of Congress and asked for an extensive, three-pronged space program that would land a man on the moon before the end of the decade, develop the rocket engines to launch satellites far into space, and put in place a world communications system via satellites. "The 1961 statement was based largely on prediction and promise -- very little on the results of development or on demonstrated technology," Burton I. Edelson wrote in "The INTELSAT Global Satellite System" for the American Institute of Aeronautics and Astronautics. Dr. Edelson, who was the second director of COMSAT Labs, went on to say, "At the time, no active satellite had flown to test voice or video transmission; no spacecraft had ever been put in geostationary orbit; no data on reliable operation of electronic devices or rotating mechanisms in space were available; and some considerable doubt existed as to the acceptability of long-delay transmission paths for commercial service. Still, engineers and managers pushed onward; and as each problem unfolded, they seemed somehow to find a solution."

In 1983, Emeric Podraczky, director of engineering for INTELSAT, co-authored a chapter also for the American Institute of Aeronautics and Astronautics, with Joseph Pelton, director of strategic policy formulation for INTELSAT, that traced the development of the INTELSAT satellites. By then, Early Bird had been renamed INTELSAT I. With the benefit of almost 20 years of hindsight, the two men said of the Early Bird experiment, the "project proved many things but, most fundamentally, it proved that a working network of a geosynchronous spacecraft plus earth stations could provide a high-capacity, reliable communications link between North American and Europe."

COMSAT scientists and engineers had hoped for a lifespan of a year and a half, based on what they might expect from mechanical valves operating in a vacuum. They got more than three-and-a-half years before the hydrogen peroxide propellant in the attitude-control motors began to turn to water and Early Bird drifted into what was to become a kind of burial ground for old satellites above the Indian ocean. But by then, the second-generation of satellites was already in orbit and world communications was unalterably changed.

CHAPTER FOUR: SOME ODD PLACES FOR A HIGH-TECH LAB

> 20 March 1967. Effective immediately, the correct designation for the research and development center will be COMSAT Laboratories. This title appears to give the proper connotation for the purpose and function to be performed and will provide a meaningful identification outside the corporation. The change in title, now, will provide a gradual transition and acceptance prior to complete implementation of our present plans.
>
> -- Memo for Siegfried Reiger,
> Vice President, Technical

Tregaron was an odd place for the origins of a laboratory that would have as its mission, state-of-the-art technology for communications satellites. A mansion of near-baronial proportions, it was set on a hillside in northwest Washington, in a bucolic location, where squirrels and birds came to the windows in summer, and you could watch children sledding on the hill in winter. Once the home of a former U.S. Ambassador to Moscow, the antiquated building seemed a more-suitable location for the lab of a Dr. Watson or even Dr. Jekyll, than the site of a space-age corporation. The sun dial out front, shaped in a medieval representation of the earth, appeared a failed attempt to hint at the nature of what was to go on inside.

"It was really a very unusual building," explained Dr. Charyk, who was COMSAT's newly appointed president when the corporation moved into Tregaron on February 15, 1963. "The only thing that was fairly clear was that the dining room would be the boardroom."

Dr. Charyk put his office upstairs, in the master bedroom, where flowering vines entwined around the windows. CEO Leo Welch moved into the library on the first floor, which opened onto a terrace overlooking the garden. The kitchen was designated as the copy room, supplies were kept in a steam bath (inoperable) and some test equipment was set up in one of the bathrooms.

The _Washington Star_ said of the whole thing, "Such untidiness may shock those in Washington society who remember the late Ambassador Joseph E. Davies estate in its heyday, but those connected with Tregaron's present occupant could not be less concerned . . . the setting is at least in keeping with the unusual nature of the new corporation it houses."

Dr. Charyk remembered Tregaron as a place where the concept for an unusual team was born. "It was pretty clear from the outset that we had to have within COMSAT a group of individuals and resources that would permit us to get the best technical judgment on the key questions," he said. "There were the questions of time-delay, the question of lifetime -- particularly of the different kinds of components, the batteries, the tubes, etc. The amount of data was very limited, therefore we were going to have to have resident experts who were on top of what was going on in the field -- what was known, what was not known, what additional experimentation might be necessary, in what areas, what kinds of questions would be addressed and so on. There would have to be a collection of people from different disciplines because satellites brought together combinations that normally would not have worked together. This cadre of people would be essential to us making the right kind of technical decisions. So there was, very early in the game, an emphasis on trying to get a collection of people who had exposure to the kinds of problems that were involved, who were very knowledgeable of what was going on in those areas and could pool their knowledge in order to make the best possible technical assessments. Now, it was clear that this was also going to be a continuing requirement regardless of what happened in round one, unless the whole thing went belly up."

The unusual tandem of new company and old building had no shortage of applicants, however. Hundreds of resumes began pouring in, to the point where a secretary had to be hired just to sort through and process the inquiries and employment applications.

The first such "hire" was a new vice president-technical, Siegfried Reiger, a man absolutely convinced of the doability of the system.

"He was one of the most confident people that this could be done and I think he was oriented in the direction of the geosynchronous orbit, almost from the outset," Dr. Charyk said. "At Rand, he had done studies on the feasibility of the different kinds of communication satellite systems, and he had talked to most of the people in the field who were knowledgeable about the status of the technology. Therefore I put a lot of faith in him and the kind of information he had been able to bring together from many different sources."

By most accounts, Reiger was a brilliant man, who understood the underlying technology and had a good judgment as to the way the technology would be heading -- a real driver.

"He did not suffer fools lightly," Dr. Charyk said. "He admired people who had a strong technical position, provided it was founded on a strong technical foundation, but he would not tolerate discussions when he felt you were arguing for the sake of arguing and didn't have the technological backup to justify the position. He would interrogate people roughly, so some people might have viewed him as being a pretty rough, brutal type of a person. There were others in whom he had a great deal of faith, those with a high level of technical ability and whose opinions therefore he would respect. He hoped to envelop those people in pursuing the work that was needed to be done."

He had another characteristic symptomatic of "doers," he hated bureaucracy.

"He was totally intolerant of rules, regulations and procedures," Dr. Charyk explained. "Whatever was necessary to get the job done, he felt should be done and it shouldn't be inhibited by paper reports and forms and things of that sort. So, anyone who had anything to do with the business management or the bureaucracy did not get along very well with him because he treated them as fools."

Emeric Podraczky was not a paper-pusher. He was one of the first of a long line of foreign-born scientists and engineers who would add a distinctly international tone to COMSAT's research and development efforts over the years. Podraczky was born in Switzerland of a Swiss mother and a Hungarian father.

"The early years of my life were spent in France," he said. "My mother tongue is French. But in 1939, we got stuck in Hungary on a visit at the breakout of the second World War, so we stayed there and I learned Hungarian. That's where most of my education took place; that's where I went to the University. In 1956, I was involved in the Hungarian uprising, and eventually became a refugee."

Podraczky his wife and two-month-old daughter crossed the border into Austria and were refugees in Vienna. They settled next in Canada where he joined RCA Victor, and they eventually became Canadian citizens.

Satellites had fascinated Podraczky at a very early age.

"In Hungary I was leader of a research group in telecommunication equipment at the Telecommunication Research Institute," he said. "So when I joined RCA in Canada, I got involved in microwave radio relay systems, and I proposed that the future was orbit state microwave radio relay systems. I was put in charge of a group which was designing solid-state microwave radio systems which were very new at that time."

Podraczky was ploughing new ground. The transistor had been invented only a few years earlier. But NASA, itself only a few years old, had already issued a request for proposal (RFP) for a communications satellite that would require the use of the new solid-state devices. RCA, one of the bidders, searched its staff for expertise in microwave utilizing solid-state components.

"They found me in Canada," Podraczky said. "RCA got the contract, and I ended up doing the microwave hardware for the satellite, the repeater as it was called. I designed it in Canada. It was the first significant Canadian contribution to the space age and eventually that satellite, RELAY, was launched. It worked beautifully. It was launched a few months after TELSTAR and therefore did not have quite the same smash, but it was a highly successful satellite. It lasted much longer than the TELSTAR satellite. It was fundamentally a better design."

Meanwhile, back in the U.S., the Communications Satellite Act had been passed, COMSAT formed, and the new company started to look for people who had some knowledge of communications satellites.

"One day I got a call at RCA, from Sid Metzger whom I knew from his RCA days," Podraczky explained. "He asked me if I would come to Washington for an interview. So I came down to a Tregaron in 1963."

Podraczky was made an offer and accepted.

"Once you get the bug of the satellite business, you like it," he said. "It's very hard work but it's very exciting to pioneer. That was the biggest attraction. It was a new field. There were a lot of unknowns. We needed to find solutions to problems that sometimes you didn't even understand."

Podraczky was in his early 30s, RCA in Canada did not appear to have any more satellite projects on the immediate horizon and COMSAT had said, in effect, make this your life's work.

At Tregaron, he and Jim Potts set up shop in what had once been a ballet room at the old mansion. "The wall was full of mirrors," Podraczky recalled, "which was a strange sort of atmosphere." But the big house which had gone unoccupied for years, plus the need to deal with the winter chill and the bizarre mirrored room became the ingredients for a near-disaster. "When the heating system was turned on," Podraczky continued, "--those good, old-fashion radiators -- the heat did something to the glue and the mirrors came crashing down one morning. So we lost our mirrored view."

After getting himself established, Podraczky knew he would need some highly qualified assistance. He remembered a young engineer he'd met at the Andover earth station during his work at RCA with the RELAY satellite, Simon Bennett.

"While I was working on RELAY, they had sent up a command to turn on the repeaters, but they appeared not to come on," Bennett recalled. "I was running strip-chart recordings of the received signal, and at the instant that they sent the command, I saw just a very momentary blip on the strip chart."

Bennett heard on his headset that the repeaters had failed to come on, but he thought otherwise. "I tore off the strip-chart, ran into the other room and showed it to Emeric. "Look," I said, "it did come on, but it turned itself off."

It was important to Podraczky that the repeater had come on, if only for an instant, because it indicated that there was a problem in the command circuitry, not in his repeater. Podraczky never forgot the bearer of that good news, and a year later he offered Bennett a job at COMSAT.

Bennett joined the company in December of 1963.

"They were anxious to have me come because they were about to issue the contract to Hughes for Early Bird," he recalled, "and they were anxious to get some staff on board to do some of the analysis and follow the progress of that work."

His hiring brought the total number of staff to 13 people. He moved into an office up in the attic and started working on transmission plans for Early Bird.

"Those were very interesting days because we were so small that all the decisions and considerations were made with immediate contact to top management," Bennett explained. "There was no difficulty getting ideas across because things were moving very, very fast."

The 1964 Olympics experiment using SYNCOM III was the first great challenge, and they set about getting ready for that.

"We were pretty confident that everything would work," Bennett recalled," but neither Emeric nor I had been used to working with a satellite transponder that used what's known as a hard limiter which kind of clips the tops and bottoms of the signals. I had to do some analysis to see what kind of distortion this would cause to the signals and it turned out it would be fine the way we were using it."

While there was a close-knit feeling that went with the coziness of Tregaron, COMSAT quickly outgrew the quarters and moved into all five floors (plus basement) of a new office building at 2100 L Street, N.W. It was somewhat more accommodating to the mission of the corporation.

"We were a bit closer to reality," explained Sid Metzger. "We even had a launch control center, located in a corner ground floor area, originally planned by the builder for use as a retail shop."

While this new control center included telephone and telegraph lines to Cape Kennedy as well as the earth station at Andover, the telemetry tracking and control data still had to be copied manually from a teletype printout. Soon a small microwave lab was set up in the basement, and a computer was added to assist with mathematical problems and design models.

There were still the space constraints. Here again, one of the technicians had established himself in a bathroom with a telephone, and was even negotiating with vendors in these cramped quarters. Others made do with shared space crammed with various kinds of test setups. The equipment pool was very small.

Basically it was what Emeric Podraczky called, "the seed of a laboratory." Podraczky had put together a budget of what it would take to set up a small lab so they could do multiple-access and transmission measurements. He convinced Technical VP Sig Reiger to let him start it up with a few benches and some basic necessities.

"I borrowed equipment from friends at RCA and from NASA, and bought some," he said. "Then I set up a little measurement facility, in which we tested the chosen multiple-access system, frequency division multiple access." There were two or three other engineers helping him out.

As the role of COMSAT grew and more satellites began taking their places in geosynchronous orbit, spotted strategically above the earth, the need for a permanent lab of appropriate proportions and suitably equipped and staffed was becoming a paramount concern. The company had outgrown 2100 L Street and now occupied space in two buildings with some offices at 1900 L and others, including the technical departments at 1835 K Street. Again, the quarters would be temporary. Meanwhile, the company was looking for sites for a permanent lab in the Maryland and Virginia countrysides, ideally not more than 30 minutes from downtown

Washington, where the corporate headquarters would be built at L'Enfant Plaza. Serious consideration was given sites in Rosslyn, Virginia and a plot in Maryland, just beyond the District of Columbia, where the Beltway intersected Route 270. Both were rejected as too small, the thinking being that it was important to maintain a campus atmosphere and a sense of openness. Representatives on the board of directors who had been part of similar real estate exercises with other companies warned against selecting land in areas that were destined to become congested. The corporation began looking at a site consisting of 200 acres of land in Clarksburg, Maryland.

COMSAT also began searching around for the best person to lead such an effort. The man they settled on was Wilbur L. Pritchard, an engineer with long-time experience in communications, who had headed up two labs for Raytheon. The higher-ups at COMSAT were familiar with Pritchard. He had been a bit of a thorn in their sides.

"For a while, there was a considerable debate between COMSAT and all the members of the communications community as to whether or not COMSAT should try to do both military and commercial satellite communication, using the same satellites," Pritchard said. "There were some people at COMSAT who were very much in favor of this. There were some people on the outside -- especially me -- who were very much opposed to it, thought it was not a good idea, either for COMSAT or for the military."

Pritchard, who was with Aerospace Corporation in California at the time, felt the satellites had sufficiently different requirements, so there just couldn't be a satisfactory compromise. Both would suffer. The satellites either would be unprofitable and no good commercially, or wouldn't do the job required by the military. The decision was made to develop separate satellites.

"Many people participated in that decision," Pritchard said, "and I like to think that I was one of the major parties who influenced getting it to go correctly, as it did. I think everyone in retrospect knows that decision was correct."

During the course of this debate within the communications community, he got to know the people at COMSAT very well. Despite the fact that for many of them the relationship with Pritchard had been an adversarial one, there was no denying that Pritchard knew his craft and the attitude became one of if we can't beat him, let's have him join us.

The approach to Pritchard was somewhat fortuitous. Siegfried Reiger had known Pritchard since they had both done work for the Air Force, a decade earlier, Pritchard as an engineer for Aerospace Corporation, Reiger with Cambridge Research Center. Reiger respected Pritchard's work, both as an engineer and as a manager. So, when the two of them ended up at the same press conference during a communications industry function in 1967, Reiger passed Pritchard a note. It said, "Would you like to be director of COMSAT Labs?"

"I just wrote on it, 'Yes. Let's talk about it,' and passed it back to him," Pritchard recalled.

The two men met later in the bar.

"We'd like to start a laboratory," Reiger said, "but we have no facilities, no programs, no people -- nothing. Just the idea." Then he repeated his offer, "do you want to be director?"

Pritchard answered, "are you going to do it, seriously?"

Reiger said, "yes."

Pritchard questioned, "does Charyk know about it?"

"Yes."

"I'll take it," Pritchard said.

It was only after saying yes that Pritchard discussed salary. "It turned out I was getting paid only $2,000 a year less than Reiger was at the time," he said, "so I went for no change in salary, and I didn't care, because it was a job I wanted. I thought it was a real challenge to create a laboratory from scratch, in a field I worked in, satellite communication. What better job could I ask for? I didn't give a damn what he was going to pay me."

Pritchard got going in earnest in the spring of 1967, putting together the teams of scientists, engineers and technicians who would become the backbone of COMSAT Laboratories, while he also paid close attention to the design of the physical plant.

"This was my third lab, but it was the first time I ever had a chance to have anything to do with the architecture of the place, and with hiring all the people," he said. "Almost everybody was hired by me. Some people got transferred into it, and had been with COMSAT before, but the great number of people at COMSAT in that period were hired by me."

Things at the time had turned a bit tense for COMSAT. It was shortly after the first launch of the new INTELSAT II series of satellites. Buoyed by the success of Early Bird, now renamed INTELSAT I, COMSAT watched as Chapter II began as flawlessly as Chapter I. The satellite approached its transfer apogee with emotions running high, but with the firing of the apogee motor, they came crashing down. The motor blew apart. Subsequent investigation and analysis have attributed the problem to ice formations in the hydrogen peroxide fuel system. Pritchard therefore was entering an environment where the last program had been a failure. However, he had been hired by Reiger to build and staff a laboratory and that is what he set out to do.

There had been opposition to COMSAT's making such a heavy commitment to a lab, one line of thinking being that COMSAT should serve only an operational role, doing nothing fundamentally new or original in the way of technical work, but simply buying satellites, buying earth stations, and staffed with a few technical people to put it all together.

"This is a view that's only held by non-engineering people," Pritchard explained, "never held by engineering people. When I say engineering and non-engineering, I don't care what people's degrees are. I care about what kind of work they've really done, because sometimes people have degrees in engineering and never work as engineers, and don't know what engineering is. They just studied engineering in college and then went on to do other things. They are not engineers. On the other hand, the reverse happens, too. Sometimes people don't study engineering, they study the other things, but they get into engineering and they learn it and they teach it, and they work at it. They are engineers."

Pritchard felt no engineer, at least no good engineer, could ever stand by and just buy things, even if the things being bought were satellites and earth stations. Furthermore, he felt that even good engineers who spent years not doing anything but writing specs and talking to contractors, lost their touch.

He put his feelings on the record. "A top R&D man is a kind of amphibian," he wrote in the March 1969 issue of R/D magazine, "he doesn't have to be in the lab all the time, but he begins to get uncomfortable if he's kept in an office too long."

A true scientist breathes science, Pritchard contended and science was like a language, he emphasized. "You've got to work at engineering, and you have got to have creative technical work to do. That's the biggest reason for a laboratory. The laboratory let's you keep good technical people around, doing creative, technical work."

Pritchard had a lot to offer the people who would listen to his pitch. They would get into a program that would offer a challenge most people never get in their lifetimes -- the opportunity to pioneer. It was not merely a matter of operating within a certain narrow discipline. He was looking for people who could hear opportunity knocking -- no, pounding -- on the door. He looked for people who were technically oriented. He didn't look at college degrees; he listened to the way people answered questions during the interview. He wanted people who could design, who could build, who could solve the complex mathematical and engineering problems that lay ahead. He did not want people who would rather be in project management or operations or marketing.

Most of the people he selected joined the labs from outside the company. But there were those, already on staff, who wanted to be part of the new team, preparing to move out to Maryland farm country. Emeric Podraczky was one of them.

"I didn't choose him," Pritchard recalled, "he chose himself. The first day I was there, he came to see me. He said, 'hey Bill, I think I'd like to be in a laboratory.' I said, 'you're on!'"

Christoph Mahle was a microwave radio specialist living in Zurich at the time. Like many of those Pritchard was looking at, Mahle was a self-described "multi-national." The holder of an Austrian passport, Mahle was born in West Germany and grew up in Brazil, but returned to Europe to study engineering.

"I wanted to work in hardware that had to do with space, satellites, radio astronomy, anything like that," he said. "There was nothing going on in this field in Europe, in the practical sense, so I wrote lots of letters and sent lots of resumes, and with COMSAT, it eventually clicked. I was interviewed by Bill Pritchard, who came to London for this purpose."

Mahle was hired. Step-by-step, Pritchard continued to build his team.

"The technologies that we would be involved in were really dictated by communications satellite systems, which consisted of several different elements," said Burton Edelson, who was Pritchard's deputy and the second director of the labs, "satellites, earth stations, and transmission systems and the different scientific and engineering disciplines. A satellite system is a radio link that goes from earth to the satellite and then back to earth. So we had to have a radio research laboratory. There was also base-band equipment, which involves modulation and coding and transmission, etc., so we called that communication processing -- which came into being just at the time of the digital revolution, so it became preeminent in digital communications. There was obviously a requirement for spacecraft technologies in mechanical engineering, power system engineering and propulsion. There was an underlying requirement for applied science, solid-state physics, etc."

Edelson pointed out that there was a valuable infusion of Japanese know-how at the time, especially with the arrival of Dr. Tadahiro Sekimoto, an assignee of a new program that INTELSAT had instituted in conjunction with the labs that would allow foreign experts to come and work at COMSAT.

The initial organizational structure divided the

R&D mission of COMSAT Labs into five laboratories: Microwave Technology, headed by Louis Pollack; Communications Processing, headed by Dr. Sekimoto; Systems, under Emeric Podraczky; Spacecraft Technology, with Fred Esch in charge; Applied Science, headed by Edmund Rittner.

Meanwhile, efforts were proceeding to find a permanent home for the laboratories.

CHAPTER FIVE: THE CAMPUS AT CLARKSBURG

The concept of the laboratory was Sig Reiger's. He really had a gut feeling that we needed a research and development capability and pushed for it. The support for the labs came largely from the three AT&T directors who were on COMSAT's board and who were knowledgeable about the communications industry. COMSAT Labs was patterned very much after Bell Labs."

-- Burton Edelson,
Second Director, COMSAT Labs

Early Bird had proved out the viability of the geosynchronous orbit, but it was only a start. NASA had approached COMSAT concerning the need to put in place a communications satellite program that would help fill gaps in the manned spaceflight program. Negotiations between NASA, COMSAT and INTELSAT had resulted in a go-ahead on the INTELSAT II, as a satellite design similar to Early Bird, but larger -- about three times its size and twice the in-orbit weight. The INTELSAT II generation would not only replace Early Bird over the Atlantic, but include sister satellites over the Pacific and Indian Oceans to create three regions within which all countries of the world could be linked via satellite.

Launch dates were set for October 26, 1966 for the Pacific Ocean satellite, November 23 for an Atlantic satellite to join Early Bird. As the launches approached expectations ran high. The Pacific satellite's designated location was to be about a thousand miles east of the Gilbert Islands, but positioning it would be tricky. So COMSAT was reserving a decision on whether to go for the Pacific orbit on the first launch or wait for the second one. If an Atlantic positioning was decided upon, the new satellite would be placed above the West Coast of Africa.

The October 26 launch went flawlessly and the satellite achieved transfer orbit. Within 24 hours a decision was made to go for a Pacific positioning and the satellite was nicknamed Lani Bird -- Lani being the Hawaiian word for "heavenly."

"Looney Bird"

Lani Bird would usher in several firsts. UPI reported that the satellite would provide the first live TV coverage of the Vietnam War, and might even be ready for election coverage from Hawaii on November 8. The New York Times also anticipated improved telephone service across the Pacific. However, the optimism was brought to an abrupt end on October 29, when the satellite failed to achieve geosynchronous orbit. The apogee kick motor failed to function properly.

Simon Bennett and his crew were already in place near Paumalu in Hawaii to put Lani Bird through its first series of in-orbit tests. The crew had gone out days earlier to set up and calibrate the equipment, then wait for a go-ahead. Word that the satellite had assumed a kind of cigar-shaped orbit, swinging from an apogee of 22,300 miles to a perigee of 1,800 miles was a terrible disappointment. The beach and the lovely Hawaiian climate were no consolation.

"Everybody was trying to look at all the telemetry data from both the satellite and the rocket, in Washington and at the Cape," Bennett said. "Meanwhile, I'm sitting in Hawaii dying to find out more about the satellite. I was thinking, if I can test the transponder and find out if that's working or not: one, it's a new design; two, if it's working, it means nothing serious -- no explosion occurred on the satellite, no damage -- and that would all be very important information."

Bennett kept calling but he couldn't get people's attention in Washington. They had other concerns. Meanwhile, the patience of his boss, Marty Votaw, the project manager, was beginning to wear thin. Finally Votaw got on the phone and said, "listen, Bennett, the uniform of the day is a bathing suit. You and your team go to the beach and when we need you, we'll call you."

They did eventually test the transponder and it was fine, which proved out the new design.

The experience pointed out how little was really understood about the environment in which the satellites would operate, and how dependent the whole was on the sum of its parts. That, in turn, reinforced the need for an expanded, integrated R&D program, and the facilities to make such a program work.

"We tried to focus on what would be needed on a long term basis if we were going to be properly able to carry out our mission to be the most knowledgeable group of technical people in the world in the subject of communications satellites," Dr. Charyk explained. "So the focus was clearly to make sure that worldwide this would be known as the group of people who knew more about communication satellites than anybody else. We talked to a lot of outside people from RCA, from Bell Labs, a lot of research institutions, about their estimate of the technology in different areas. We had a small group of people study what kind of a laboratory we should have, what the size of it should be. It was clear that there was going to be some sort of a minimal size. If you were smaller than that, you just wouldn't be effective and you probably couldn't afford something much bigger than that. So, we attempted to make a judgment as to what this critical mass should be, what it would cost and to basically take the position that that was an essential element if COMSAT were to carry out its statutory mission. When we ultimately got into regulatory discussions, it was always our position that having this kind of a capability was fundamental to our statutory role and therefore was clearly an allowable expense in determining our rates."

On November 1, 1966, COMSAT announced that the company had signed agreements to purchase 210 acres of land on Interstate 70-S (Now Route 270) in Montgomery County, Maryland as the site for a research and development center. The news release stated that the new facility would be to "conduct advanced research on satellite communications with an initial staffing of about 200 persons, half of them scientists and engineers."

On February 24, 1967, the company selected Daniel, Mann, Johnson and Mendenhall, a Los Angeles-based architecture and engineering firm to design the facility, which was expected to include about 250,000 square feet of working space. The design contract was for $450,000.

On December 27, 1967, a contract was signed with the J.W. Bateson Construction company of Dallas for $7.9 million to build the new facility. Bateson was authorized to begin at once.

Bill Pritchard who had been named director of COMSAT Labs in May of 1967, was overseer during the entire construction process and saw to it that the design and construction of the new facility reflected what his experience running other labs had taught him was needed.

"I watched every nut and bolt go up," Pritchard said. "In fact, the steel framework of COMSAT Labs was bolted together, not riveted."

After a little more than 20 months from ground-breaking, the new COMSAT Labs opened its doors on September 10, 1969. The staff, most of whom had been hired directly by Pritchard, went to work at the spanking new labs and offices, with the overall mission of fine-tuning the hardware of the global satellite system now in place and operating in the skies far above the earth. One was a newly retired military officer, who, at the age of 41 was just beginning to hit his full stride in the satellite business.

In the mid-'60s, Burton Edelson was in London finishing up a tour of duty as a lieutenant commander with the Navy. He was helping to establish the NATO communications satellite system and the British military communications satellite system known as SKYNET. The United States had provided the impetus to develop and build these systems and Ford Aerospace, then known as Philco, built the satellites and the earth stations.

"The technical expert behind all that was Bill Pritchard, who was director of communications at Aerospace Corporation for the U.S. Air Force," Dr. Edelson explained. "Bill made many trips to England where he helped me to promote U.S. industrial capability to build satellite systems. On one of his trips over, I mentioned that I was going to complete my 20 years in the Navy and I thought that I would leave the service and go into civilian life."

Pritchard, who at the time was still being considered for the director's position at COMSAT Laboratories, said if he got the job he wanted Edelson to be deputy director. Edelson said he would definitely be interested.

"I actually had my job offer to come to COMSAT written on Aerospace stationery," he said.

On December 31, 1967 Lieutenant Commander Edelson retired from the Navy and on January 1, 1968, he became the number two man a COMSAT Labs, joining the company while the technical functions were still playing musical buildings in downtown Washington and the labs were an empty plot of land in Maryland. Edelson got right into the middle of everything with Pritchard, working on the design of the building, the layout of the laboratories, the selection of hardware, software, and most importantly the humans who would create the professional personality of the new facility.

"I was kind of the general manager of the labs," he explained. "We quickly divided up the responsibilities because we were good friends and we'd worked together before. Bill was responsible for all policy, personally hiring the top people, and providing the tie with the rest of the company. COMSAT Labs had the in-depth technical capability, and the labs' most urgent role at the time was to support the development of INTELSAT II and INTELSAT III. The latter, INTELSAT III, was in great technical trouble. The contractors, TRW and ITT, didn't have the experience that Hughes had with SYNCOM, and INTELSATs I and II, and they were having a great deal of trouble developing the satellite. So the labs, during 1968 and 1969, were very much devoted to providing engineering support for the development of INTELSAT III."

The trouble they were having with INTELSAT III had a great deal of influence on the labs, causing COMSAT scientists and engineers to get more and more technically involved with what was being built for the satellites. And the director got directly involved as well.

"It meant that Bill was almost 90% involved in that," Edelson explained, "while I was very much devoted to developing and setting up the administrative organization of the labs and the R&D programs and dealing with our potentially great customer, INTELSAT. COMSAT as manager of INTELSAT was organizing programs, and in my particular case, the INTELSAT Research and Development Program."

COMSAT Labs worked very closely with the technical committee at INTELSAT to come up with a research and development program that would develop new spacecraft technology, develop new transmission techniques, improve the INTELSAT system in one or more ways, either by making communications more effective through lower costs or higher quality or new types of services. The program grew into a multi-million dollar revenue producer for the new labs.

One of the great problems of any high-tech company, however, is to tie research and development into operations.

"COMSAT had that problem, too," Dr. Edelson said, "but in early days we made the bridge very often. We had a very strong engineering capability and we tied the engineering division very closely to the labs. Because the development of the satellites was in trouble, particularly INTELSAT III, this tie became very close and there were people going back and forth all the time. For more than a year Bill Pritchard had a regular Thursday meeting out at TRW and he flew from Los Angeles to Washington to Nutley, N.J. and back every week."

Meanwhile they grew the size of the lab from some 200 employees who moved into the building at Clarksburg to twice that many within two years.

"One of our programs was Corporate R&D," Dr. Edelson explained, "which was a jurisdictional research and development program and it helped to support COMSAT's three roles in INTELSAT, -- as one of the owners, as operator of earth stations, and as management contractor. Research that we did to support any one of those three roles was considered jurisdictional. Therefore, the research that we did was capitalized, put in the rate base and amortized over a five-year period. All the equipment and facilities that were used for that would be considered in our rate base as well."

With all the new programs underway, there was some sorting out to do.

"There was some amount of confusion as to the details of who was to do what," said Christoph Mahle, one of the new labs' new engineers, "but there was overall a very profound sense of mission. The attitude was this company and this laboratory is here to get an international satellite system going and up there and working as well as we can do it, and this seemed attractive to some of the best engineering minds in the whole world."

While there was already fierce competition for engineering excellence among the staff, among the managers, there was, at the same time, a very friendly and collegial atmosphere.

With the staff selections going well and the nuts and bolts in place, they began to outfit the lab. They brought in equipment of all kinds to help them design the satellite systems, then test their performance, both in the lab and in orbit.

"Testing a satellite to see if it's going to work or not in outer space is no joke," Pritchard explained.

"That is one complicated and expensive business, because you have to simulate outer space. That means you've got to simulate the high vacuum -- and it really is a high vacuum -- and the solar energy. You do this in what are called thermal vacuum chambers. You have to simulate the temperatures and the vacuum at the same time. It is not a minor operation and of course you have all kinds of chambers."

They built large chambers to test whole satellites, smaller chambers to test systems, still smaller ones to test specific components. Overall, the testing of antennas, all the components and sub-systems, and finally the entire satellite itself, was an operation requiring many millions of dollars in test equipment.

"A satellite is a complicated business," Pritchard went on. "It doesn't only have the communications equipment. It's got propulsion. It's got temperature-control equipment, because it's got to operate at a congenial temperature for everything. It's got the attitude control system."

The attitude control system was both critical and fraught with problems. "You have to have some way of keeping a satellite so that its antennas are pointed at that area of the earth that you want to communicate with," he said. "You have to keep your solar panels pointed at the sun, because all commercial communications satellites use solar energy. So you've got the double attitude control problem to stay pointed at the sun and to stay pointed at the earth."

In many of the five new divisions at the Labs, groups were developing whole new technologies.

"The laboratory pioneered the tremendous improvements in solar cells," Pritchard said, citing some specific examples. "Solar cell improvement is translated into tens of millions of dollars. Originally, they were converting less than eight percent of solar energy into electricity. We doubled it to about fifteen percent. We did a lot of work in attitude control and understanding the dynamics of attitude control. This is a very sophisticated, highly mathematical, theoretical subject but the results are dramatic."

Aside from the challenge of positioning the satellites properly with respect to the earth and the sun, there is also the problem of the satellite's tendency to tumble. A major contributor to instability is the fuel that is on board, which is a double-edged sword. It is needed to make constant corrections of the satellite's position, but it has a tendency to slosh during these corrections.

"A satellite carries a lot of fuel," Pritchard explained. "As long as a tank is full of fuel, it is okay. But when you start to use up some of the fuel, and you get any motion of the satellite, the fuel sloshes, which de-stabilizes the satellite even more, which makes it slosh some more, and pretty soon you can have a tumbling satellite."

This process can be analyzed to some extent mathematically. It can also be modeled on computers, and it can be simulated experimentally. The engineers in COMSAT's Spacecraft Division did all three of those things at the labs to understand what was going on with the fuel.

Then there was the matter of the eclipses. The satellite goes into eclipse when it gets into the shadow of the earth. Thus shielded from the sun, it has no solar power. With the satellite in geosynchronous orbit above the equator it is in view of the sun during the summer when the sun is far north of equator and during the winter, when it is far south. During a six-week period in the spring and a similar period in the fall, while the sun approaches and then passes the plane of the equator, the earth casts its shadow upon the satellite during part of each 24-hour period. To avoid an interruption in service, it must carry batteries.

"The batteries on a satellite are about as agreeable as they are in your automobile," Pritchard said. "They are heavy, expensive, and they are not the world's most reliable devices. You've got to charge them. You've got all the charging circuits and regulating circuits and you've got a structure to carry and the fuel to keep it in orbit. It is a chain-reaction of money. Each thing leads to something else, and everything costs money."

COMSAT Labs made big improvements in batteries, the crowning achievement of which was the hydrogen-nickel oxide battery. It's development was something Pritchard attributed to serendipity.

"We didn't start out to design nickel-hydrogen batteries," he explained. "We started out to design hydrogen-oxygen fuel cells. The shuttle, and the moon trips used hydrogen-oxygen fuel cells. If you keep hydrogen and oxygen separate, then bring them together carefully, you generate water and electricity. So it is a great way of storing a lot of electrical energy."

The reaction, however, can be very explosive. So the two gases must be brought together in a carefully controlled process. But, the hydrogen-oxygen fuel cells allow you to carry a lot more energy per weight than the more common batteries. Pritchard had thought in terms of using the fuel cells as storage devices on communications satellites.

"In the process of trying to develop the specific technology, we came across -- by accident but were alert enough to notice it -- the realization that hydrogen and nickel made a fine battery and was a lot safer than hydrogen and oxygen."

Pier Luigi Bargellini had been a top communications expert in Italy, during a career that began prior to World War II. After the war, he emigrated to the United States, taught for almost 20 years at the University of Pennsylvania and worked during that period on R&D projects. He'd met Pritchard at the Aerospace Corporation in Los Angeles and stayed in touch. In 1968, Pritchard made Bargellini senior scientist and assistant to the director at the Labs. Bargellini was impressed with the team that Pritchard had put together for the move to Clarksburg.

"He surely did a magnificent job in forging an instrument which was really unique in the world," Bargellini said. "I left the University of Pennsylvania, where I had a tenured position. I was well-established and I enjoyed teaching and consulting. It was very risky to leave the position which I had had for more than 18 years. But I told my wife, if I don't do it -- take advantage of this opportunity -- it will never come again. It was 1968, and I was already 54."

The opportunity that Bargellini saw, like so many of his colleagues, was that for decades, space would be the dominant factor in communications.

"I had been in communications all my life," he said. "I'd been on cable ships repairing submarine cables, telegraph ones. I had seen telecommunications move from VLF to LF to HF, VHF and UHF. Satellites were going to redefine communications. I felt it was going to be fun. I was right. It was fun because the technical challenge was considerable. There was a great deal of enthusiasm. Good men had been chosen and there was a vibrant atmosphere. We almost felt that we had a mission. Major breakthroughs were accomplished at the technical level in all areas. Communications satellites were such a novel art, notwithstanding the know-how of the manufacturers. The continuous interface between COMSAT and the manufacturers was absolutely essential. We moved the art forward in a number of areas. We had the opportunity of seeing the payoff in terms of continued improvements in the series of INTELSAT satellites."

In 1971, they established the COMSAT Technical Review, the first journal exclusively devoted to satellite communications technology and systems, which grew to be recognized internationally as the leading periodical in the field.

"The first four years of INTELSAT operations after the launch of Early Bird were years of dramatic progress, wrote Santiago Astrain, Former Director General, INTELSAT in The INTELSAT Global Satellite System. "The number of earth station-to-earth station pathways grew from one to 20. The number of half-circuits in operation grew from 150 to 1142, representing, in effect, an eight-fold increase. The number of hours of television transmissions increased . . . and, perhaps most significantly, the total communications capacity increased more than ten-fold. At the end of 1968, INTELSAT had a system capability of some 2,400 two-way voice circuits and four television channels. This dramatic shift in only four years' time enabled INTELSAT to reduce its utilization charges by some 35 percent. By the end of 1968, therefore, INTELSAT had already established itself as the predominant international overseas telecommunications facility, providing two-thirds of the world's overseas service."

CHAPTER SIX: THE CALIFORNIA CONNECTION

One day during the summer of 1966, Irv Dostis sat at his desk contemplating his fate. He had been on the job with COMSAT at 2100 L Street in Washington for two months, getting acquainted with his new duties. At least he was trying to. Things were a bit loosely defined. Dostis got up from his desk and walked into his boss's office. "What am I supposed to be doing?" he asked.

"Well, we were thinking about that," he was told. "Actually, you're really supposed to be in California."

"Oh?"

"You're only going out there for a little while," the young engineer was reassured. "Don't worry, Irv. You'll be back before you know it."

It was a critical period during the development phase of the early satellites. Hughes Aircraft, the primary contractor, had just finished work on Early Bird (INTELSAT I) and had started work on INTELSAT II. COMSAT was putting a team in place out at the contractor's facility to monitor the development of the next generation of satellites and assist in their design.

So Dostis left Washington and returned to his home in New Jersey, now a man with a mission. He gathered some personal effects then headed out for his temporary assignment in California. The timing was not good. There was a major airline strike. When he got to New York, there were no flights. So, Dostis camped out in the airport for three days and three nights. It wasn't the greatest of accommodations and it was having a psychological effect on him.

"While I was sleeping in the airport, I kept thinking, this is a bad omen," he said. "I just joined this company and I can't even get out to the place where I'm supposed to be working."

But Dostis, like so many of his contemporaries, was not disposed to shrink from a challenge, and an airline strike could not be more than a temporary inconvenience. He persevered. After hanging out at the airport, turning scroungy and battling aggravation, finally, he got a seat. It was a smooth flight to California.

Filled with a sense of accomplishment at finally having made it to work, Dostis paraded in to meet his new boss, Martin Votaw, who was the COMSAT project engineer on site at Hughes. Votaw stopped him dead in his tracks.

"Where have you been?" Votaw said. "You're late."

To the people who worked for COMSAT Labs in those early days, it seemed like they were always late for something. There was indeed a great deal to be accomplished. And much of the effort was directed at getting the hardware in place. For the satellites, that meant working closely with the manufacturers. Hughes had the working model of a geosynchronous satellite at the time -- SYNCOM II --and that intrigued the technical people at COMSAT. Hughes offered to build a commercial version that would have a wider bandwidth, higher power and higher antenna gain. So, in September of 1963, COMSAT sent a team out to the Hughes plant in El Segundo, California to open a dialog. Votaw wrote of the experience in the 20th anniversary issue of COMSAT magazine in 1983:

> After these discussion were concluded, Sig Reiger [then COMSAT director of systems analysis] asked, "What specifications are you prepared to meet?"
>
> One of the Hughes people responded, "No specifications. This is a straight commercial arrangement, like a TV set. You don't expect specifications when you buy a TV set, do you?"
>
> Reiger responded, "I had specifications on my swimming pool." Then Reiger left the room and after a well-placed phone call came back and said, "No specifications. No contract. If you want to continue the discussions tomorrow, we'll come back with a list of parameters to be specified, and you fill in the performance numbers that you are willing to meet."

The COMSAT group retired to Reiger's residence in Los Angeles and hammered out a list of a dozen parameters, which were presented to, and accepted by, the Hughes negotiating team the next day. Hughes agreed to fill in the appropriate numbers and the discussions would continue.

Since one of the major concerns early on was whether a satellite would enjoy a long-enough lifetime functioning in high orbit, COMSAT was concerned that a contractor not push a product out the door that merely met the specs. The company wanted to provide some incentive, secure some guarantee, that the product would live out a projected lifespan, high above the earth where repairs were not possible. Consequently a fixed-price concept was decided upon, with back-ended, or in-orbit, incentives. It put pressure on the contractor to build something that worked -- and lasted.

At the time, the accepted method of letting contracts was on a cost-plus basis. In simple terms, that meant the profit on a contract was fixed, but cost overruns were added to the price. COMSAT fixed the price. On the other hand, to prevent the contractor from simply choosing the cheapest solution, the in-orbit incentives were added. These incentives could increase a fee by as much as 30 percent.

"Your fee was going to be a function of lifetime," Dr. Charyk said. "Not only would you not get a fee if the thing didn't work, but you might not even get your costs back. [On the other hand] the lifetime of the satellite was a determination of the magnitude of your fee -- and you could get fees much larger. In theory, we could pay you any kind of fee. We were prepared to play this game to the hilt."

"This operating philosophy was at the root of the very big technical success that we had with the INTELSAT system," Chris Mahle said. "If you look at the record, broadly, the INTELSAT satellites and other satellites COMSAT has been involved with have had some aches and pains, but by and large they have performed very, very well in orbit, and the overall price tag was not outrageous, when you compare it with some other systems. We said all right, the spacecraft contractor is building hardware for money, so we give him a specification. As soon as the piece meets the specification, he's going to ship it. If he doesn't understand why it behaves the way it behaves, that's not part of the contract. Maybe something in there will make this thing quit after a year in orbit and we can't repair it."

That's where the scientists back at the labs on the east coast provided some invaluable backup.

"The Labs was always a resource that was available to support the programs," Simon Bennett explained. "We used the Labs quite a bit, to do off-line investigations, to assess hardware that was delivered by the contractor, for performance measurements, to figure out how to write specifications for new satellites. We'd figure out what we needed, then ask the labs, 'is that feasible?'"

For example, if the California contingent wanted to know whether it was feasible to achieve a certain filter characteristic that approached the ideal, the labs would do development work, show that yes such a thing was feasible, then the engineers in place at the contractor could, with confidence, specify it that way. They also used the labs for problem solution. Sometimes that meant long-distance coordination; other times it meant trips back and forth on the red-eye flights between coasts.

"We had the charter of really understanding why the circuits worked the way they worked," Mahle said. "We had the time and money to know circuit design and circuit functioning better than the guy who was building it for money. And so, we made it our job to look at every circuit they built. We typically built a similar test model at the laboratory just to understand what makes it tick. What are the pitfalls? What might you do wrong, that will stop working after a year or two in orbit? I think we did it very, very successfully."

And they had to do it against deadlines.

Richard Mott came to COMSAT Labs out of college in 1966 and rose from technician to engineer to staff scientist. He recalled the deadline pressures. "We had to be timely in our inputs to change or have an effect on Hughes's design and to make recommendations that weren't after the fact. And that was really COMSAT's role in general, and the labs' role in particular, during all those years. It was one of riding herd on satellite contracts for INTELSAT, to make sure first that the contract concept was correct and finally when the contract was let that the house selected to build the satellites was honest, did their best work, used the best technology for the job, and maintained the contract specifications. To do that we would think up experiments, even think up designs and actually build them in house and beat the contractor over the head with this alternate design if it were better than the contractor's design. If we could do that early enough we couldn't force the contractor to use our design but we could embarrass him or her into a better design. If we were late, the contractor of course then had the option to say 'well, this is going to affect my schedule; this design works but it's not as efficient as ours and we're not obligated to use your design.'"

While Hughes was receptive to the idea of the fixed-price contract, the company was not overly enthusiastic about COMSAT moving a contingent of people into the plant.

"The idea of having a live-in crew monitoring every facet of the satellite development, that Hughes did not like," Charyk added. "They basically said that was a way of increasing the cost of the program, slowing the program down and was totally unnecessary."

It fell to Votaw and this crew to change the contractor's perception of this new west coast division, called Spacecraft Engineering.

"I managed a group of people who were engineers with a fair amount of experience in the various technical areas of the satellite," he said. "We monitored the production of the satellite and decided whether or not the satellite was satisfactory to ship."

It was a process that took some getting used to, not only on the part of the manufacturer, but by the new players in COMSAT's west coast office.

"The first thing that happened," Irv Dostis said, "was the guys I was working with took me out to look at this new gadget that we were building, which was a satellite. It was half the size of a round kitchen table, and had one or two little boxes that I looked at and I said 'that's what I'm going to be working on? Holy mackerel, what did I get myself into?' Well, the story gets to be real exciting real fast, because by the time we started getting into things and started looking at the development of all of the items, the thing that became clear is that there were probably no more than half a dozen of us out there at the time and we never had the luxury of arguing about who was in charge of one area or another area. There were so few of us that whenever somebody needed help, you had to help, because there was nobody else around. So all of us became a little bit more general than probably we would have ever been if we had stayed back on the east coast."

As time went by, and the weeks turned into months the west coast assignment began to take on a permanence that the COMSAT contingent working there began to accept. And the relationship with the manufacturer became better defined as well. The COMSAT crew found that despite the fact that the spacecraft manufacturer was certainly expert at building things, the manufacturer had to achieve its profit objective, which in its most basic terms boiled down to: How do you build the satellite at the lowest cost, while still satisfying the requirements, and getting it out the door on time.

"Our objectives were a lot different," Dostis said. "We were going to have to operate it for a number of years and we wanted to make sure it really worked. We weren't worried about just getting it delivered to us, we wanted to make sure it worked right."

The difference between the COMSAT contingent and other monitoring organizations was that most quality assurance people would have a list of procedures and would check if the procedures were followed and the numbers were right.

"Very rarely would you get a quality assurance person that understood the type of design of a particular item," Dostis said. "Now for the first time the spacecraft manufacturer was looking into the face of a guy who was looking over his shoulder that knew, probably as well he did, how to design the unit. It was probably resented very much at the beginning, but I think as time went on, they began to realize that it was a real asset."

The COMSAT people floated, observing many aspects of the operation at the manufacturing plant. With the technical skill they had and the ability to move through the organization, they were able to spot things that weren't exactly right, things that weren't getting coordinated right, measurements that really weren't matching up properly, correlations between different measurements and different organizations . . . and it all brought a new flavor to the system. In other words, here were a group of people, highly skilled technically, who -- although they could generate a significant amount of trouble for the manufacturer -- could also produce a significant amount of added information and added reliability, could approve products and help in a lot of ways that nobody anticipated at first, and do a lot of the analysis work that was really required to make the satellite successful. But they had to draw the line somewhere, because, in the final analysis, it was the manufacturer who was going to take the heat if the satellite wasn't right.

"It was tricky ground, a tightrope operation," Dostis emphasized, "but the way it was set up and the way we operated was that, we have a contract and the contract requires certain performance characteristics. We can stop the contract at any time the performance is not right. However, if there are things that don't look like they're right, even though they do meet the objective, we could try to convince them to do something different. Nobody is going to do something for goodness if it's going to cost them money, because that is their profit margin and it's not fair to ask them to do that. However, if there was a risk to the long-range capability of the spacecraft or there was a danger that something could get in trouble later on, where it would be more expensive to repair, then you had to convince the people to do that."

It was tricky business because they were dealing on an engineer-to-engineer basis, with no contractual leverage to force the manufacturer to see it their way. That's where the laboratories came in.

Dostis explained. "We would look at these devices and say, 'we think that's not exactly right.' We would call up our friends at the labs and say: 'We think we see something that doesn't look right. You guys see if you can simulate it or set it up. We'll tell you what we want you guys check and see if it makes sense.'"

Sometimes the tests at COMSAT Labs would indicate a change was required. Other times, they would reinforce the correctness of the manufacturer's design. It was a kind of gratis consulting service that worked to the benefit of both COMSAT and the manufacturer. There were many times, during the construction of the early satellites, when both the manufacturer and COMSAT crews went without a day off for months. And this kind of shared hardship helped cement the working relationship, which continued to develop into mutual respect and that mutual respect grew.

"People said, 'well you were lucky; the company that you worked with was smart,'" Dostis said. "But we worked with Ford, we worked with TRW, we worked with ITT, we worked with Hughes Aircraft. Every one of them developed that kind of relationship with us."

When additional on-site support was needed, experts from the labs, headed for California. "I visited Hughes a lot at that time," said Chris Mahle, an expert in microwave technology, "helping to look over Hughes's shoulder, to understand how the individual circuits would work. We had a good friendly competition of engineering excellence with Hughes."

Mahle cited the design of multi-cavity filters as an example of how the friendly competition worked.

"Nobody at the time could design multi-cavity filters that came out exactly as predicted theoretically," he said. "We needed these filters to perform like the theory and when they didn't we said, 'hey, let's find out why, then make them better.' We pushed the state of the art very substantially in a very short time."

Filters select out part of the frequency spectrum, let that part pass and reject everything else. The desired effect in a satellite is similar to the effect you seek when you tune a radio to a particular frequency. You want to hear only the radio station at that particular frequency, nothing else. The function of a filter is to shut out all the other frequencies on either side of the selected frequency. On the INTELSAT IV satellite, for example, the assigned microwave radio band was sub-divided into 12 channels. The 12 channels would go through individual transmitters and then be combined to go to the antenna. To keep adjacent channels from interfering which each other, two antennas were installed on the satellite. Channels 1, 3, 5, 7, 9, and 11 went to one antenna; channels 2, 4, 6, 8, 10, and 12 went to the other. The solution was viable as long as the antennas weighed only a few pounds. The design of later satellites called for antenna systems that were big and complex, more than a hundred pounds. Weight, of course is a limiting parameter in a satellite. To eliminate one antenna required a whole new kind of filter.

"The specifications on those filters were pushing the state of the art," Mahle said. "Nobody could build these filters, and we and Hughes together learned how to do it. We had done a lot of research and work on filters and we said well we think we can make a multiplexor that will allow you to combine adjacent channels. We did indeed put a crash effort together and in something like eight months we demonstrated the feasibility of this."

The new filter design paid back years later by making the launch of INTELSAT V possible on an Atlas Centaur rocket instead of a Titan III, a very substantial savings in the cost of the launch.

"I use this example when the accountants say to me, 'R&D, is just money poured down the drain,'" Mahle explained. "You invest today, then 10 or 15 years later you reap the benefits."

The intensity of the work made for some lighter moments.

Dostis and a crew were testing INTELSAT II in a thermal vacuum chamber, a big metal can that has a steel bottom on it, which closes tight with wedges that permit a high vacuum. They were engrossed in their work, but there was a very distracting element.

"All these building maintenance guys from Hughes are walking around," Dostis said, "looking around the floor, in the drain pipes -- all over. We don't know what they're looking for. We're measuring the satellite.

They walk around; they disappear; they come back; they disappear."

All of a sudden, everything in the satellite went off.

"All the signals go off," Dostis explained, "and we're sitting there looking at each other and wondering, what the heck is going on? We start checking our equipment, but we can't find anything wrong. We're saying, 'holy mackerel, we had a major failure and we don't know what it was.' We're all sitting there thinking, 'God, this satellite is really in trouble.'"

When they cracked the locks of the vacuum chamber it was not an in-rush of air that greeted them, but a deluge of water.

"Oh," the chief of the maintenance crew said, "that's were the water is."

A cooling pipe had broken in the vacuum chamber, which drained the water in the tank on the roof into the chamber. Since the search by the maintenance people did not turn up evidence of where the water had gone, they filled the tank again. It proceeded to drain, a second time, into the vacuum chamber.

"Well, what was more interesting," Dostis said, "is we're sitting there scratching our heads, saying, 'now we have a couple of million dollar satellite in here which is all blown to hell.' And a Hughes spacecraft engineer we're working with says, 'hey, maybe what we ought to do is just get all the water out of the chamber and put a vacuum on it. The vacuum will take all the water out and dry it. So we said, 'that sounds like a good idea.'"

It took many hours to re-establish the vacuum, but that did get all the water out, and when they turned everything back on, it all worked.

"You know, you look at it and you say that's pretty ingenious," Dostis recalled. "Nine out of ten people wouldn't have thought of it. And if this one guy hadn't, we would have had a complete loss. That was the first experience I had that showed me you better turn your brain on when you're testing satellites, because if you don't, all kinds of bad things can happen."

There were a lot of complex problems ahead, that had to be solved to increase the lifespan, efficiency and effectiveness of the satellites and a lot of smart people were going to have to turn on a lot of brain power to put it all in place.

CHAPTER SEVEN: GOING DIGITAL

When John Puente was hired by COMSAT in 1963 as one of the company's first dozen employees, he -- like his colleagues and many of the scientists and engineers yet-to-be hired -- was very excited about the opportunity to ply his particular expertise along a new and as yet largely unexplored frontier. Puente was one of the country's first digital communications experts. He'd been exposed to electronics in general and radar in particular during a stint in the U.S. Air Force, extended from two to three years by the outbreak of the Korean War in 1950. Trained as a radar technician, Puente was hooked. After his discharge, he used the G.I. Bill to earn a degree in electrical engineering from Brooklyn Polytechnic Institute in New York, then went on for a masters at Stevens Institute of Technology in Hoboken, New Jersey. While in college, he worked nights as a technician, first at Bell Laboratories then at ITT. After earning his degrees, IBM offered him a job in the Washington, D.C. area, which he accepted.

"I designed one of the first modems for land lines for IBM," he explained. "Of course that kind of work was being done at other parts of IBM too, but I was in the communications department, which was a new department at that time."

Friends and colleagues started talking about the new communications satellite company and Puente began to listen. COMSAT was looking for a digital engineer and there weren't too many people with that kind of digital background in 1963. Puente felt his training at IBM and his expertise in radar would make him uniquely qualified to work for the new company. Radar was not that much different from satellite communications, in the sense that you were dealing with a very weak signal from very far away. Puente was interviewed by Sid Metzger and Emeric Podraczky but was having difficulty making up his mind because he was, after all, working for IBM and he liked his job.

"Then Joe Charyk made me an offer I couldn't refuse," Puente recalled. "He made the whole satellite business sound so interesting. It was absolutely risk because no one had launched a commercial satellite. It was very challenging and it just intrigued me."

His first office was in the attic at the Tregaron mansion, where the young cadre of engineers around him were deeply involved in utilizing their various skills. Puente began to get frustrated. A design engineer, he kept trying to create digital systems for satellite communications but there was early resistance to going digital. Part of the problem derived from the nature of the backgrounds of his colleagues. Most of the people at COMSAT were analog-oriented, their backgrounds based in FM transmission. Analog transmissions were quite adequate for the early satellites and, at this point in time, less expensive than digital systems.

An analog system carried a voice signal on a continuous, non-discreet basis. A digital system put the signal into a neat little discreet package. The packaging relied on the binary number system used in computer memories.

"You take the analog signal and convert it into numbers," Puente explained. "Take a sample and say all right, the signal at this moment in time is 10 units. Now I'm going to write a binary number, which is a computer number, and say this binary number represents 10. Then I take another sample of the signal and I say this binary number represents 8. Now on the other side (the receive side), all I ever get are numbers. I take the numbers, convert them back to the samples, and put the signal back together again. All I do is send numbers and they're all digital numbers, 1s and 0s. They have a beginning and an end. In other words it's discreet."

They could process numbers, store numbers, change numbers. The potential was very exciting. Like the geosynchronous orbit, this digital concept seemed the embodiment of simplicity itself.

"I could switch a number," Puente explained, "put this number here and this number there. I could use digital switching devices, that really work on 1s and 0s -- the switch is either open or closed. The signal that you've converted to digital makes it easier to do a whole lot of processing."

The economics didn't support him, however, because digital systems were a new concept and their costs hadn't come down yet. They didn't yet have the methods to mass-produce large chips and integrated circuits. So it was hard to justify going to digital with analog being so much cheaper. It had to be a transition over time, especially in the heavy traffic, point-to-point systems they were working with, where even today analog is a very economic solution.

"Still I always felt the world had to go digital," Puente says. "I felt fiber optics were coming, switches were going digital, computers were getting cheaper, digital was getting cheaper every year. The economics were going to change on a systems-wide basis. So getting all signals, whether it's video, voice or data into a digital number scheme was the right way to go."

With his firm convictions of a future that was digital-based, Puente began to take his frustrations out on paper. He wrote reams of internal memos that got the "that's nice, but..." treatment.

Enter Tadahiro Sekimoto, INTELSAT assignee from Nippon Electric Company (NEC) in Japan. Sekimoto, among other things, had been reading Puente's memos. When Sekimoto began to push for digital systems, literally on his way in the front door, it was as if the concept had gained an unbiased third-party endorsement. He was placed in charge of a newly created Communications Processing Laboratory and Puente went to work for him. They became close working partners and life-long friends.

The first thing of major significance that the new Communications Processing Lab did was design a system called SPADE -- Single-channel-per-carrier Pulse-code-modulation multiple-Access Demand-assignment Equipment. Puente felt he needed an acronym for that mouth full if he were going to continue to put his thoughts down on paper. SPADE was designed to bring smaller countries into the satellite universe.

"In the early days of INTELSAT, earth stations cost five-, ten-, fifteen-million dollars," he said. "For these smaller countries with their low traffic, we had to come up with a system concept which was much lower cost -- i.e. a million-dollar earth station. SPADE allowed you to use a smaller earth station and get sufficient traffic into your country to make you a partner, a real partner."

But there was opposition to the concept.

"I never really understood it at the time," Puente said, "why people were giving us such a hard time. Why couldn't we get this kind of system in? The arguments against it were always technical. 'Single-channel FM is better than single-channel digital.' Okay, but why debate the concept?"

What he found out was technical decisions were sometimes driven by political considerations. The traffic patterns around the world were controlled by the larger countries. Puente's system was for the benefit of smaller countries. Under existing systems, smaller countries had to transit their traffic through the larger, more highly developed countries. Under SPADE, you could by-pass these circuitous traffic patterns, but the larger countries lost revenue. While such a hierarchy of communications may have been necessary when international communications were in their infancy, satellites and systems like SPADE had the potential to make them obsolete.

"Going through that hierarchy, every administration got a piece of the call," Puente explained, "that's why calls used to cost $12 a minute. The most profitable business was the international. When TAT I, the first transatlantic cable, was put across the ocean, it cost roughly 100 million dollars, and carried 36 circuits. It was designed to last 20 years. When satellites went up, that traffic pattern started to change rather rapidly because all of a sudden things were easy."

The beauty of SPADE was you could take the satellite system as it was and convert to digital on the ground, you didn't have to do anything to the spacecraft.

The satellite could remain a simple repeater in the sky. Even at this early stage, consideration was given to designing a system where the switching would be done aboard the satellite, but that of course would be far riskier.

"It's a big risk because it's up in space and you can't fix it in space," Puente emphasized. "But you could do a lot of it on the ground and you could make that whole satellite look like a digital switch, even though the satellite remained basically dumb, a simple repeater."

The new SPADE system received the enthusiastic support of Bill Pritchard, who was director of the Labs at the time. "What we really needed was a different way of operating a satellite system, in which anybody could have one circuit, not 12 or 24," Pritchard emphasized. "We needed a module of one, so that small countries could call anywhere. The SPADE system had a pool of a couple of thousand circuits. If you wanted to call someone else, you got on and there was a signalling channel. You sent a signal in effect saying, 'hey I got a call for you.' If you got a response saying 'yes the call is okay,' you took a pair of frequencies, one going and one coming, and you used it to talk. When you were finished you returned the frequencies to the pool. The other way, with preassigned channels, you had a lot of idle channels all the time. This way you could do something they do with airplanes; you could over-book them. You could handle an awful lot of traffic, if you've got 2,000 available channels. What's more, if you add up all the power of the 2,000, it's much more then you really have got, but you don't care about that, because you know they are not going to be used all at once."

SPADE was tested, approved by INTELSAT and was rolled out as a system for smaller countries. The digital revolution in satellite communications had begun. And that led to other applications.

An obvious satellite use of digital systems was the transmission of data from the growing number of computer users. With that in mind, COMSAT Labs' digital wizards created the wherewithal to transmit such data. And that ultimately became COMSAT's DIGISAT service rolled out for the general public at a demonstration at COMSAT's new L'Enfant Plaza visitors center in early 1975.

Utilizing the single channel per carrier (SCPC) equipment designed and developed at the labs, COMSAT had first introduced a high-speed 50 kilobits per second international service, but it only had viable applications for heavy users. With the new DIGISAT service, COMSAT brought mainstream users in the 2.4, 4.8 and 9.6 kilobits per second range into its potential markets. It represented a significant economic breakthrough, utilizing the more efficient digital transmission capabilities unique to satellite systems. Via SCPC and the allocation of time segments through Time Division Multiplexing, COMSAT could handle, digitally, volume that would require the equivalent of 12 voice-grade channels, utilizing conventional FM techniques.

One of the early members of the team in the new Communications Processing Lab (CPL) working with Dr. Sekimoto and Puente was Dr. Joseph Campanella, a life-long native of the Washington, D.C. area, who had earned engineering degrees from Catholic University and the

University of Maryland. Dr. Sekimoto had hired him to head up a signal processing research branch of CPL to deal with analog and digital signal processing. Dr. Campanella came from a background in digital signal processing and pattern-recognition applied to speech and other types of signals, including units called Vocoders, created for the military.

CPL had become an exciting place to work in the late 1960s. There were numerous projects underway that would ultimately lead to significant new communications applications for the next generations of satellites. For example, the early work in Time Division Multiple Access (TDMA) had begun (see Chapter Nine) and there was some exciting work being done with television.

""Under the leadership of Dr. Len Golding, the digital TV branch of CPL performed pioneering efforts in the digital compression of broadcast-quality TV," Dr. Campanella said. "The system was referred to as DITEC, an acronym of Digital TV Compression. The concept was based on sampling of TV chrominance (color) and luminance (brightness) signals and a use of a special scheme for coding sharp edges."

The result of the compression was full-motion TV pictures at a transmission rate of only 32 Mbits/sec as opposed to the 120 Mbits/sec that would be required to achieve equivalent quality without DITEC. That meant the equivalent in quality via much less of the satellite system's capacity.

Digital was now solidly on the move as the method of choice for many of the new communications systems. John Puente's insistence that digital was the way to go had gotten a foot in the door with SPADE. It then wedged the door open as an integral element in many new developments at the labs, eventually becoming part of systems in voice, data, and video -- in the satellites and earth stations. The future of satellite systems was getting more exciting and more challenging with each passing day.

CHAPTER EIGHT: DEFEATING THE ECHO

The dramatic decision to develop the global communications satellite network at the geostationary level brought the echo problem immediately to the fore. While the question of whether existing echo suppressors could provide at least an acceptable level of quality was answered almost immediately, the scientists at COMSAT Labs were not satisfied. Echo suppression, they felt, was simply a short-term solution. They would settle for no less than cancellation. Tests run at the labs in the late 1960s compared echo suppressors of different manufacturers in an effort to establish technical parameters for existing suppliers who were producing suppressors that ranged in quality from good to downright unacceptable.

Meanwhile, recognizing the inherent limitations of echo suppressors and the serious impact poor quality would have on the opinion of the customers using the satellite links for telephone calls, COMSAT initiated what was to become a very successful program to improve the quality of long propagation delay circuits, conducted in the Communications Processing Lab (CPL).

At that time Michael Onufry was working with Fairchild-Hiller Corporation in Rockville, Maryland, where he was unhappy about a personnel situation that had developed during the merger of staffs between the company's Maryland and New York offices. His career path led him to COMSAT in April of 1966. Onufry had been an expert in voice communications in the analog area at a time when the movement was to digital processing. He became part of the movement. He went to work almost immediately on the echo problem in the signal processing research branch of CPL.

"Another engineer, Don Kutch, and I worked together with echo control, in testing echo suppressors and looking at the subjective effects of propagation delay," Onufry recalled. "We conducted some experiments trying to simulate the satellite delay by using the FDM carrier system and a tape recorder. The carrier system was specially modified, and we were able to take the modulated carrier (the signal) from the FDM system, put it into the analog tape recorder and use the separation between the record and play-back heads by going through it a number of times to simulate the satellite propagation delay. Then we conducted some subjective experiments to see what the effect of this delay was on people talking over a circuit that was patched through the thing."

They were not surprised to find that the delay was not the problem; the echo was. They began to look into better ways of controlling the echo.

The echo was created as follows. In basic terms, the telephone in a person's home or office is connected to the nearest switching office of the telephone company by a single twisted pair of wires that serve for both transmit and receive. At the telephone switching office there's a transformer called a hybrid, which takes the transmit and receive speech and separates it into two different paths. This energy is now carried through the entire telephone system along separate paths, one pair of wires for transmit, another for receive. The hybrid tries to maintain a kind of balance in impedance, i.e. match the impedance of the receive channel to that of the user's telephone. The nature of the telephone system makes this all but impossible since different users have lines that are dissimilar, depending upon their distance and route from the local exchange. Thus the hybrid can become unbalanced and the energy from the receive side leaks across into the transmit side. Then the person who is talking may experience an echo of his or her own voice. When the distance between the two parties is short, the echo comes back so quickly that it's masked by the talker's speech and he or she doesn't hear the echo. But as the distance increases, there is first a hollow sound, then an intelligible echo, which depending upon the length of the delay, can make conversation all but impossible. When the signals travel on a satellite circuit, the delay is such -- about half a second -- that if there is no echo control, it can begin to interfere with the thought process and even cause some people to start to stutter.

The commonly used echo suppressor was a voice-activated switch which detected the arrival of the receive speech and simply opened a switch in the return path, which prevented the echo from reaching the person who was talking. That was fine so long as only one person was talking. When the second party wanted to interrupt, you had problems. For one thing the person who shouted the loudest gained control of the voice-activated switch. If you didn't shout loud enough, segments of your speech would get cut out, a phenomenon known as chopping. If you did speak loud enough to gain control of the switch, your speech would get through, but so would the echo. You were damned if you shouted, damned if you didn't.

The international communications agencies had defined a specification for an echo suppressor and COMSAT Labs tested suppressors against that spec, then put them through subjective testing to gauge user acceptance of the different models. Manufacturers of inferior models were told to get them up to standards. Bad echo control would reflect badly upon the entire concept of geosynchronous satellites. They had to come up with a better mousetrap.

Among other things, echo control was important to providing technical reasons for modifying the appropriate specs of the ITU's Consultative Committee on Telephone and Telegraph (CCITT). One concept that had promise was to create a model of the terminating echo path, pass the speech on the receive end through this model and subtract out the echo. If the model did its job of creating a perfect replica of the echo, it could be subtracted from the transmit-side signal and precisely cancel the echo. This method would not interrupt the speech transmission path the way suppressors did and therefore was not prone to chopping.

"At the time, a Japanese engineer, working for Nippon Electric Company, had reported on an experimental, digitally implemented device called the blockless echo suppressor, which actually did this job," Dr. Joseph

Campanella explained. "However, it developed its impulse response by pulsing the echo path before the talker started to speak. But, with this method, once the conversation began, the echo path could not be conveniently corrected and changes in the echo path -- which could take place during a conversation -- would spoil the cancellation. The method was also subject to noise in the echo path, which created errors."

At the same time, Dr. Campanella had been studying experimental computer simulation work done at Bell Labs on feedback control of a device called the transversal filter, using a technique know as "the maximum rate of descent convergence." He felt this technique could be applied to the blockless echo suppressor. The seeds were planted that would result in the development of the echo canceller.

Dr. Campanella and Mike Onufry presented their idea to INTELSAT in early 1968 and gained support to develop an experimental model. They were joined in their efforts by Dr. Henry Suyderhoud, whose experience at Bell Labs was perfect for the task of designing and building a real-time echo canceller. At Bell Labs, Suyderhoud had worked with transversal filters, manually applying coefficients, which he adjusted using a headset, then applied an analog multiplication process to show that there was some control of echo that could be obtained by simply tuning the device.

Results of the team's work bore fruit almost immediately when at the 1968 Mar del Plata Plenary, the CCITT modified its regs to say that satellite circuits were fully acceptable for international telephony for circuits with a mean, one-way propagation delay as great as 400 milliseconds. The revised recommendation noted that echo cancellers were under development and promised to improve quality even further. The change caused Post, Telephone and Telegraph administrations around the world to take notice. World satellite circuits had become fully acceptable as a form of telephone communications in the eyes of the PTTs.

Under INTELSAT sponsorship, a specification was prepared to procure an echo canceller, using adaptive processing which involved the marriage of impulse response modeling, convolution with the received signal and maximum rate of descent convergence to automatically adjust the impulse response coefficients continuously using the actual receive and transmit signals encountered in the telephone circuit. A contract was awarded to Nippon Electric and NEC implemented this adaptive process with its blockless echo suppressor to produce the first real-time echo canceller. The end product had one rack of power supplies and two other racks of equipment associated with it. It took up most of a good-sized wall.

"And this was to control the echo on one end of the telephone circuit," Onufry said. "You would need one of these things at both ends. It was an extremely long way from a practical reality at that point."

But it worked. Its principal shortcomings were it required almost a second to develop the computer model of the echo, and it provided only 14 db of speech cancellation when they needed about 50 db for complete cancellation of the echo. It was a good first step -- but only a first step.

"The way the device worked was if you're talking to me, the device that protects you against echo is at my end of the circuit," Onufry said. "So your speech arriving to me would come into the receive input of the echo control device and that speech signal, combined with the actual echo signal that results from it, was used to develop the model inside the canceller in an adaptive process."

They looked at the sign bit of samples of the echo signal and the sign bit of samples of the speech signal, examined the correlation and through this cross-correlation process described the echo path impulse response. The impulse response called the "model" could be used to create a replica of the echo from the received signal by a mathematical process called convolution.

"Once you have the model," Onufry explained, "you process the speech through it, and generate the estimate of the echo. When we encode speech in a digital format, we sample it 8,000 times a second in order to be able to reproduce the amount of band-width that we have in a telephone channel. Then we encode each of those samples at 8 bits per sample, so it takes 64,000 bits per second for one telephone channel. The samples are stored inside the echo canceller where they are used as input to the echo estimating process."

In order to generate the estimate of the echo -- just one sample -- you must take a sample of speech and multiply it by a mathematical coefficient and store that product, then take the next sample of speech and multiply it by the next coefficient, sum those two products and continue that process typically through 256 coefficients. The sampling occurred every 125 microseconds or 8,000 times a second. That was more than 2 million multiplications plus 2 million additions each second.

So they had this first echo canceller . . . and all these racks of equipment . . . and a long way to go.

"We said well the first thing we have to do is make it adapt faster," Onufry said. "One second to develop the model was too long. When people would start talking, they would hear echo for too long at the beginning of the call and that was not acceptable."

The team was spending all of its time working with the new device, trying to come up with ways of improving it. They got the modeling delay down to one-third of a second.

"But we found we couldn't do anything about improving the amount of cancellation that it provided because the system was noise-limited," Onufry explained. "There was too much electrical noise picked up through the combination of the analog and digital circuitry, the length of wires and the way it was put together. So at that point we decided the best thing to do would be to build another device and switch to all digital."

They started building their own unit, while INTELSAT issued another request for proposal. Dr. Campanella, Onufry and Suyderhoud drafted the INTELSAT RFPs. Meanwhile the COMSAT Labs team continued working to develop a canceller of its own. They decided to go digital all the way.

"We continued to be concerned with the problems of what to do when both people talked at the same time," Onufry explained. "How do we prevent the model from getting contaminated? Also how fast did the device have to track in order to be satisfactory? How much cancellation did we need in order to have it work adequately? We didn't even know what the character of the impulse response was in the telephone system. So, we were probing to find out all of these things."

At this point, Dr. Campanella introduced another novel concept, which he called the "electronic black hole," to overcome the fact that a canceller cannot reduce the echo to zero and a whisper of echo may remain. The electronic black hole was easily implemented by not passing signal values that fall below a specified level. Any residue of echo of amplitudes less than this pre-set level were eliminated, i.e. get sucked into the black hole.

Meanwhile, satellite users were making do with echo suppressors. Subjective call-back testing resulted in the satellite circuits getting generally satisfactory ratings but invariably finishing lower than undersea cable circuits in the opinion of the end-users. The reason given most often was echo control.

"If both people try to talk at the same time, you might hear a burst of echo or you might have a loss of some information because the echo suppressor cut out the speech," Onufry said. "And if the echo suppressor wasn't adjusted properly, these problems could be aggravated. Twenty-five to thirty percent of those called would say, 'yes, I had some difficulty.'"

However, people making international calls were predisposed to know that the call was not going to be as good as if they called a sister in Brooklyn or Oak Park. It was also felt that a bit of education wouldn't hurt the cause, while the work on the canceller proceeded.

"We were going out to electronic shows and exhibits and demonstrating what the effect of delay was," Onufry said. "One of the demonstrations that we used was the 'COMSAT Double-Hopper,' via the Etam, West Virginia earth station. We actually simulated the effect of two satellite circuits in tandem and had people talk through it. We would ask their opinions of the quality of the circuit and we would also interview them to see what their normal usage of the telephone system was. Were they occasional users, for local calls only or business long-distance calls, international calls, etc. Surprisingly, we found that the rating of the circuit was independent of the user's background. In other words, whether people made a lot of international calls or not, the rating came out about the same for the mean opinion score."

Then, in the early 1970s, COMSAT Labs built the first version of an echo canceller they felt they could field test. A model dubbed "The Refrigerator," it was a single rack about four and a half feet tall. The parts for it cost in the neighborhood of $40,000.

"Since we were concerned about how fast we needed to develop the model of the echo," Onufry said, "we had a mode in it that was controlled by a single switch, whereby we could cause it to do this processing two times between each of the 125 microsecond sampling intervals. We were able to drop the time it took to develop the model to under 100 milliseconds, which turned out to be faster than what we actually needed. The ultimate specifications required it to happen in less than 1/4th of a second for a noise signal. And we were able to get up to about 25 to 30 db of cancellation."

COMSAT Labs built two of the new echo cancelers and there were two other units that were developed by NEC. They went to INTELSAT and asked if the consortium would like to participate in a field trial. That created a problem.

"Six other countries said yes," Onufry recalled, "and we didn't see a political way to weed out, so we went to all of them."

They chose New York-London for the first test, preceded by a two-week course for foreign technicians who would be participating, so they understood how the canceller worked and could at least perform some minor trouble-shooting should there be malfunctions during the field test. The other tests were Brazil to France, Hawaii to Australia, Hawaii to Japan, Brazil to Germany.

"The field-testing process took almost two years," Onufry said, "with shipping and moving the equipment around and the trips that were involved. But it showed that the concept of echo cancellation did in fact work. It provided better echo control than the echo suppressors."

With the success of the field trials, COMSAT Labs began to seek ways to reduce the size of the device and improve its efficiency.

"We went to time-sharing schemes and we had a central processor that worked on six different channels," Onufry explained. "You would switch from the processor to the operating unit and try to gain improvements in size that way. We looked at an approach utilizing differential encoding rather than just straight pulse code modulation to try and save bits and reduce the size of the hardware in the processing. We looked at a logarithmic implementation of the multiplier, where instead of doing a full parallel multiply, you converted it to a logarithm and did a simple addition of two numbers. Throughout all of this, there was very close interaction between Dr. Campanella, Henry Suyderhoud and myself. I was in the lab implementing things and making changes and bouncing ideas off of them, because I had worked for Henry, who was manager at that time, and Dr. Campanella had moved up to director of CPL."

Dr. Campanella still maintained close contact with the echo canceller development. In the spring of 1974, he became very concerned about implementing an echo canceller that could be effective and economical. He assigned to the project Dr. Otakar Horna, a digital circuit design expert, and gave him the assignment to redesign the canceller using log representations of the input and output signals and of the internal processing steps. Dr. Horna, along with a summer student, worked intensely on this project and by the end of the hot weather had a working -- albeit hay-wired -- echo canceller on the bench, a major breakthrough.

"We had gone from our large rack to something that was about three times the size of a tape recorder," Onufry said. "We built a limited number of these under the authorization of Dr. Edelson, who was the Director of the Labs at the time, and we sold them to companies like RCA and Western Union. We said, 'here, take them into your lab, test them, do what you want to with them and see how they work.' The response that came back overwhelmed us. We started getting back orders for 300 units."

The demand for the echo cancelers led to the creation of a marketing arm. The unit was a hot seller. but all the customers seemed to want different versions.

"They wanted different bells and whistles and they wanted different monitoring schemes that fit with their own maintenance aspects," Onufry recalled. "So each unit required a different design."

The basic unit was called the COMSAT Labs Echo Canceller (CLEC) Model 2000 and it represented the conquest of the echo problem. The biggest question about the viability of satellite voice communications had been answered. Future acceptance was assured and the scientists who had worked to solve the complicated echo problem could now turn their energies to other areas.

The work of COMSAT Labs on the echo canceller was directly responsible for bringing the process from a computer-programmed mathematical curiosity to a practical, economical telephone system component that replaced the earlier echo suppressor in all telephone service in the U.S. and was replacing echo suppressors world wide. COMSAT carried its message to the CCITT and spear-headed the acceptance of Recommendation G.165 for the echo canceller.

"It had been a cycle that started with the conception of the idea and proceeded all the way through to seeing it standardized and then rolled out into wide-spread applications," Onufry said. "It had been very interesting and represented the work of a dedicated team."

CHAPTER NINE: GETTING THE MOST OUT OF WHAT YOU'VE GOT

The on-going challenge with satellites was how do you cram the most capacity into a limited space? From the outset, COMSAT Laboratories tackled the problems of developing systems to get more and more traffic into a given amount of bandwidth. Inefficient use of capacity was endemic to terrestrial-based systems common at the time. For example, circuits were assigned to carriers and were available only to the assignees whether they were fully utilized or not.

"When satellite communications started internationally, it used a lot of the communication technology of microwave radio, and long distance telephony, which was natural," explained Bill Pritchard, first director of COMSAT Labs. "Telephone circuits have been, since the 1920's, bundled together in groups. They put each of them in a different carrier frequency and they bundle them together in groups of 12, 24, 60, 120. Then there was a hierarchy of groups, master groups, or super groups. The way the satellite business evolved to begin with was that each earth station was assigned its own carrier frequency, a bandwidth and a channel assignment. It was given so many channels that it could transmit on. That worked fine between the United States and England and France and Italy and Germany, because they had plenty of traffic, which was growing quickly as people caught on to the desirability of long-distance telephone service and the high quality of the satellite circuits."

But there was a lot of inefficient use of this new capacity. And that had to be remedied. One possible solution would be to make assigned frequencies work more efficiently but that involved solving some inherent problems.

In the late 1960s, Francois T. Assal was working on his Ph. D. in electrical engineering, while serving as a professor at the City University of New York. He loved the job, he wanted to complete work on his doctorate, but he was getting itchy. He'd read about the formation of COMSAT Labs and that they were looking for people. He decided to go visit.

"I spoke to Lou Pollack [head of the Microwave Technology Lab]," Assal said, "and he made me an offer."

Assal went home to think about it. He was faced with a difficult choice. There were a number of key factors, some pulling against each other. Assal, a native Tunisian, had moved to Israel as a young man, met an American woman and they were married. He moved to the U.S. with his young family, and of course, had to consider them in any decision he made. Education, he knew, would be important to his future, and joining COMSAT Labs would mean putting his academic work on hold. On the other hand, he knew he was faced with the kind of opportunity that did not come along very often. At the same time, managers at COMSAT had developed this persistence for going after people they wanted.

"I don't know how Pollack managed to get my inlaws' phone number," Assal said, "but he called me there one night and he said that he was waiting for an answer."

Assal told Pollack he had decided to join.

By his own description, a pencil-and-paper kind of theoretician, Assal was immediately put on the satellite capacity problem. "My first assignment was to try to come up with a solution for maximizing the capacity of the satellite, by bringing the carriers as close together as possible."

That involved designing filters the likes of which had never been designed before.

The transmission system in use at the time was of the analog type, modulated in one of two ways: by amplitude or frequency, the same system which creates the AM or FM of a common radio. But, as Bill Pritchard pointed out, the efficient way to deal with signals in a satellite of limited bandwidth is to bunch them in groups of 12, 24, 60, or more, a method known as multiplexing. However, when you put signals in spatial proximity within a given bandwidth, they interfered with each other. Common practice was to minimize this interference by keeping the frequency of the signals far enough apart. That, however, wasted bandwidth. To bring signals closer together, filters were needed that would keep the signals separate.

The problems were complex.

"If you don't do anything in the transmission, you will have adjacent-channel interference," Assal explained, "one channel will be coupling into the other. If you try to limit this on the receive end, it doesn't do you any good because the interference took place on the transmission side, it's already there. So you have a little bit of a tail that will effect your signal."

Filtering individual carriers benefits adjacent carriers while creating problems for the carrier being filtered. So the challenge was to design filters that were very sharp, while equalizing their effects on all carriers, demonstrating that they did in fact work -- then convincing international partners to accept them. It was a whole new modus operandi for a man who had just come from the staid surroundings of academia.

As part of a team working on the filter problem, Assal worked long hours, went home for dinner and to share some time with his wife and children, then came back to the labs to work some more. When he had a design that he felt solved the problem, he presented it to his boss who said, "that looks great, Francois, now build it."

Assal was stunned. In the past, he'd put it down on paper and that was the end of his involvement. When he needed something built, a technician was assigned to him. Now, he was faced with the prospect of proving -- himself -- that the new filter could be built. It took some new-found manual dexterity, but he did it and demonstrated it. That, however, turned out to be just another battle in the war. Next a contractor was chosen, Airborne Instrument Laboratories (AIL), and he had to work with the contractor to show them how to build it, in order to demonstrate to the technical committee of INTELSAT that the filters could be produced at the manufacturing level.

"I showed them that in fact you could achieve the performance as specified and satisfy all the requirements for communication, using these filters," he said.

The most tangible result was that by allowing the carriers to be placed closer together, they increased the capacity of the satellite by a whopping 20%. That translated into additional revenue which in turn improved the performance of the satellite at the bottom line.

The work on microwave filters continued in earnest. Novel electrical and mechanical designs resulted in substantial weight and volume reductions, making it possible to increase communications capacity for a given total spacecraft mass. At COMSAT Labs, the work done in this field by Drs. Ali Atia and Albert Williams became well known nationally and internationally.

While the filters were being improved, scientists and engineers at COMSAT Labs were looking at the larger question of multiple access. They felt that a system that allocated capacity on the satellite as a function of time, as opposed to frequency would be far more efficient, so they began experimenting with a concept called Time Division Multiple Access (TDMA).

Until the advent of TDMA, all satellites operated with continuously transmitted carriers, each assigned a different frequency. In order to maximize capacity on a frequency-division basis each transponder in the satellite was assigned up to 10 carriers. But this technique resulted in intermodulation distortion. To minimize this type of carrier-coupling distortion, the power output of the transponder needed to be reduced. However, this was an inefficient use of the satellite's limited power. If capacity on the satellite could be allocated as a function of time, i.e. one carrier per transponder during a given unit of time, then the power output could be held at its maximum without incurring this distortion, since during any specific time period there would be only one carrier assigned to the transponder. This, in effect would permit multiple access to the satellite, but as a function of time, not frequency. The signals to be transmitted were encoded into "bits," the digital language of a computer, then collected into a unit called a "burst" and the burst assigned a time segment during which it was "fired" at the satellite.

"Each earth station would transmit its messages as a burst," Dr. Joseph Campanella, chief scientist at COMSAT Labs explained. "Instead of tuning in frequency, the earth station would tune in time, and be given a specific time to transmit its burst. Every station transmitted at a different time so that when the bursts arrived at the satellite, they arrived one after the other and didn't overlap. TDMA was the discipline that permitted us to do that."

This transmission of bursts all happened during a very small fraction of a second. So the matter of synchronization was critical to the question of TDMA's viability. If you were to divide the satellite's capacity into segments allotted to earth stations on the basis of time -- very tiny segments of time -- the synchronization between the satellite and the earth station would have to be incredibly accurate. The first tests to determine whether such critical synchronization was achievable outside of the laboratory was an experiment called MATE conducted over the Atlantic in 1966.

"We were using a Canadian station and making believe it was three stations in one," said William G. Schmidt who was manager of TDMA project in the Communications Processing Lab. "We used Early Bird and it was very successful. Coming back we said, 'well, what's the follow-on?' 'How do we prove it further?' That was the birth of a system that became MAT I, a TDMA system."

The early systems were very carefully synchronized. Each earth station had to know exactly where the satellite was when it let loose its bursts of digitized conversation. The calculations were very complex. For each earth station the distance to the satellite was different, and many people in the technical world felt the problems with synchronization would be a nightmare too horrible to confront.

"They felt you wouldn't know the distance to the satellite well enough to have any capacity," Schmidt explained. "They felt that maybe only 50% of the time would the satellite be overhead for synchronization, so the outstanding contribution of this system was the solution of the synchronization problem."

It also proved that they could compress the bursts between very, very small gaps.

"We proved that with the synchronization scheme you could effectively know the distance to the satellite to a much higher degree than that obtainable from any other measurement technology that had been around," Schmidt said. "The final result was a TDMA system that used something in the order of 10 nanoseconds as the gap between the bursts, which means that you knew within ten feet the position of a satellite at 22,000 plus miles away, doing a 'lazy eight,' in orbit."

The validation of the burst synchronization approach created a potential for a tremendous increase in the efficient use of the satellite's capacity. It meant that the members of the Communications Processing Laboratory could push full-speed ahead in developing the new system.

They moved into the phase they called MAT I, which utilized higher speeds and, for the first time, demand assignment.

"Burst length determined capacity," Schmidt explained, "so a demand-assigned TDMA system has extendable bursts. You get your capacity when you need it, as opposed to being assigned it whether you use it or not."

An important advantage of TDMA was it allowed flexibility of capacity at an earth station simply by changing the duration of the burst allotted to the station. If the station had little traffic, it was given a short burst; in the case of heavy traffic, a long burst was used. It was very easy to do as a function of time.

For example, the stations on the European side of the Atlantic begin their day earlier. So when they begin talking to each other, they are using 'fat' bursts. As their day proceeds into evening, they get into a period of lighter usage, their bursts get thinner. They are moved in the TDMA frame to make room for the fatter bursts on the North American side of the ocean because people there are in the middle of their day and their demand is greater; they take up the greater amount of space allotted earlier to the other earth stations.

"So, the ability to automatically move bursts and still keep communications going is the key to a demand-assigned TDMA system," Schmidt said. "MAT I was the first demand-assigned TDMA system."

The typical frame in the INTELSAT-TDMA system was two milliseconds long.

"And in that two millisecond frame we had as many as 10 stations," Dr. Campanella said, "each of them having a burst duration of nominally 200 microseconds, average -- some longer, some shorter, depending on the balance of traffic."

A TDMA transponder aboard an INTELSAT satellite, operating at 120 million bits per second could handle the equivalent of 3,000 telephone conversations at once.

"In Frequency Division Multiple Access (FDMA), you couldn't do that very easily," Dr. Campanella explained. "You had to change the bandwidth of the carriers to change the capacity. That meant you had to go in and change the filters. A lot of things had to be done which were very costly. This was avoided by TDMA because it gave us flexibility. It's the reason why TDMA has proven to be an interesting technique."

The earliest applications of TDMA were with satellites that utilized regional or global beams, i.e. send and receive beams that covered broad expanses of the earth.

"When we built the first TDMA system under INTELSAT funding," Dr. Campanella explained, "it was used to experimentally demonstrate the complete TDMA transmission on tests conducted in the Pacific Ocean. These tests actually demonstrated many features, very early on, which were very important: the ability of multiple stations to synchronize the traffic to the satellite and to carry end-to-end digital communications, but they also demonstrated the ability to adapt the capacity of the stations for demand assigned traffic management."

Once the basic features of TDMA were shown to be viable, the teams at COMSAT Labs began to refine and improve the concept. For example, the TDMA team felt that one of the drawbacks of the concept derived from the need to allow the system to operate even in situations where stations were in different beams of the satellite. Beams on the satellite were normally interconnected in a fixed manner. What that meant was that a signal sent via a specific up-beam to the satellite would follow a pre-determined down-beam to its destination. That would result in situations where time, i.e. capacity, went unused. Unused capacity was the enemy of Bill Schmidt and his team.

The decision was made to propose putting the switchboard in the sky, aboard the satellite. The concept, called "Satellite-Switched" TDMA, or SS-TDMA, was published by Schmidt as a paper for the first INTELSAT International Conference on Digital Satellite Communications held in 1969 in London. The idea was to give the satellite a rapidly acting switchboard that cycled through a series of connections tailored to traffic distribution and demand, resulting in an extremely efficient use of its capacity.

Dr. Campanella likened the concept to giving earth stations "windows" to the rest of the world.

"Let's say one connection allows your earth station satellite, but even the six meters per second that the satellite moved within its orbital "box."

Allocating capacity as a function of time and digitally packaging those segments into bursts which were then directed via satellite switching was not the be-all, end-all. The braintrust at COMSAT Labs was troubled by an inherent inefficiency in telephone conversations, the dead time on the circuit, during which one or both parties weren't saying anything. Since a telephone conversation requires both a send and a receive circuit, one line is not being used for half the time, i.e. when one party is listening to the other party. Then there are periods when neither are talking, natural pauses in the conversation. Statistically, a channel (i.e. either half of the circuit) is active less than 40 percent of the time.

COMSAT Labs developed a way to release the other 60 percent of time for use by active talkers. The technique called Low Rate Encoded/Digital Speech Interpolation (LRE/DSI) exploits the statistical properties of speech so that more than one conversation can be transmitted over one circuit, a kind of time-sharing of circuits by active talkers.

Dr. Campanella, along with fellow engineer Joe Sciulli, explored a concept that had been used on analog circuits to add capacity to undersea cables. When employed with digital circuits, however, it caused clapping at the beginnings of speech spurts.

"We wanted to do the job better by using the features associated with the implementation of the interpolation process on digital circuits," Dr. Campanella explained. "We came up with a concept called Speech Predictive Coding (SPEC), which interpolated the individual pulse-code-modulated speech samples of the active talkers, based on the short-term predictability of the samples. This method totally avoided the clipping problem and replaced it with a mild increase in what is called quantizing error."

They built and demonstrated implementations of the device that clearly showed improved quality.

A 240-channel DSI terminal operates with independent transmit and receive sides, each independently synchronized to a TDMA terminal. The DSI encoder utilizes a voice switch to detect the presence of speech on a terrestrial channel, a telephone line. When the switch determines that a channel is carrying the voice of an active talker, an assignment processor in the unit begins searching a satellite channel pool for an available channel. When one has been found, an assignment message is transmitted to the DSI decoder and the active terrestrial channel is connected to the selected satellite transmission channel, which in turn is connected to the specified terrestrial channel on the receive end.

When the spurt of speech ends, the selected satellite channel is returned to a pool of channels and made available for the next active talker. The system allows a 2:1 capacity enhancement, i.e. using only 120 channels to carry the voices of 240 telephone users.

Low Rate Encoding, developed in tandem with DSI, allows the speech to be encoded at 32 kilobits per second, instead of the standard 64 kbits/sec, providing an additional 2:1 advantage, i.e. allowing two voice signals to be packaged into the same capacity that formerly carried only one.

"The LRE/DSI system was custom-designed and a good example of the type of problem-solving we do at the labs," said Dr. John Evans, Director of COMSAT Labs. He pointed out that each new development was at the same time a valuable research tool for developing the next level of improvements for a system, and foresaw the possibility of an 8:1 gain through further improvements in encoding.

The sheer physical capacity of each generation of INTELSAT satellites increased from 240 circuits on Early Bird to 15,000 circuits on INTELSAT V-A -- to 120,000 circuits on INTELSAT VI. Developments at COMSAT Labs stretched that existing capacity many times over with the likes of demand assignment, TDMA, LRE/DSI -- to the point where capacity, once one of the critical limiting factors in satellite operations, had become an all-but-eliminated problem. The life-limiting factor for satellites had become, almost exclusively, a matter of getting and keeping the satellite in its proper orbit and extending the lifespans of its power and back-up power supplies. COMSAT had solutions to the many elements of those problems as well.

CHAPTER TEN: KEEPING THE BIRDS IN THE AIR

In the staffing of a laboratory there often occurs a kind of lemming effect. Scientists, engineers and technicians from existing laboratories find themselves following to a former leader to his new home. The motivation is often a renewed interest in their work, intensified by the new challenges of the new lab, the respect they'd held for the former leader and the desire to work with former colleagues who have jumped ship in favor of those new challenges offered by the new operation. In the staffing of the Spacecraft Laboratory at the new COMSAT Labs, such a phenomenon took place. Many of the original staff members followed the division's new leader, Fred Esch, over from the Applied Physics Laboratory of Johns Hopkins University. These people had been in the satellite business, albeit mostly military satellites, at APL, and they joined a cadre that Esch was assembling which would form the core of the Spacecraft Laboratory for years to come.

Esch had met Martin Votaw in 1964 when Votaw was working on a double-decker satellite for NRL. Esch was the payload engineer on the project. A mutual respect developed and when Votaw was selected to be head of engineering at COMSAT, Votaw asked Esch to join him as head of a key division.

Esch came to COMSAT in 1965, at a time when the technical activities were located at 2100 L Street, in downtown Washington. "I joined with the understanding that there would be a laboratory formed," he said. "Sid Metzger was very much in favor of creating a laboratory as was his boss, Sig Reiger, and Dr. Charyk. The technical activities at the time were mostly just monitoring work of on-going programs."

Esch began to reshape the monitoring function and add more creative responsibilities. He formed a group he called the Spacecraft Techniques Department, which was later to become the Spacecraft Division and most recently, the Applied Technologies Division. At the time, a limited amount of laboratory work was going on, but the principals of COMSAT were anxious to get on with setting up a laboratory and creating the new technology that would define the satellites and earth stations of the future. But most of the emphasis and attention was concentrated in the communications and electronics areas. Esch saw that as a blessing in disguise.

"We enjoyed a situation where the rest of the company was not all that concerned with the spacecraft and left us alone," he said. "Most of the people involved with COMSAT at the time had electronics or communications backgrounds."

The Spacecraft people had to establish their own objectives and set their own courses.

"We did a lot in terms of laying out plans and identifying areas of interest to investigate," Esch said. "People were building kits for test instrumentation. Somebody had located a used lathe and a drill press, and that composed the machine shop at the time."

It was the laboratory-in-the-garage scenario, played out in the middle of Washington.

"But we proceeded to influence the company to set up a budget for doing some laboratory work and started to form several groups pursuing various technology investigations," Esch said. "At that time, we were located in a downtown office building which wasn't the most convenient place to adapt to the kind of laboratory activity that we were pursuing, so we had to make a lot of adjustments as we went along. We were very cramped with people sitting in the aisles and were faced with problems like inadequate electrical service. We had to do a lot of gerry-rigging and ran electrical lines where we'd have gotten written up for all sorts of unauthorized systems."

The completion of the new laboratory facilities in Clarksburg, Maryland, was "heaven," according to Esch. And he and his people turned to the challenges at hand. While it was the development, construction, installation and operation of the communications packages that was the focus of attention, the size and lifespan of the spacecraft itself were critical limiting factors, determining what could and could not be done with these dramatic new satellites.

"In order to hold the satellites in geostationary orbit and to keep them pointed properly, you had to use on-board propulsion," Esch said. "Early on, the propulsion system was hydrogen peroxide that was decomposed in the catalytic thruster. It was a very sensitive system and temperamental to say the least. We had a lot of problems with the early satellites in that regard. We were trying to set up experimental investigations into how to best operate those systems and also to find new systems more reliable and with a greater assurance of longer life."

Then there was the electrical power supply. On-going power was supplied by solar cells which provided a very low efficiency in terms of the amount of sunlight they converted to usable power -- about eight percent. Further, during those times of the year when the spacecraft passed through the earth's shadow for more than an hour at a time -- the spring and fall equinoxes

-- the communications systems needed a back-up source of power to maintain continuous service.

"We focused a lot of attention on the problem of energy conversion in the silicon solar cells," Esch explained, "the manner in which they were mounted and interconnected, the substances with which they were covered, sunlight filters, etc. We looked for alternatives such as cadmium sulfide cells which were far more rugged for some applications, but far less efficient, and they had some characteristics that were not very attractive in terms of using them for long-life satellites."

Undaunted, they set about the task of improving the efficiency, durability and lifespan of the solar cells.

Richard Arndt came to COMSAT Labs because he was "a scientist who likes to get my hands dirty." Arndt, who rose to become senior scientist for the Microelectronics Division of the Labs, remembered the early days as being fraught with unknowns about the lifespan of a satellite in high orbit. Along with the very real delay and echo problems, early concern about the economic viability of geosynchronous satellites centered around how much lifespan you could get out of them. One of the major concerns was whether radiation effects would do them in. Arndt had been a specialist in radiation effects at Brookhaven National Laboratory on Long Island.

"Satellites were still pretty unusual things," he said, "so there was a good deal of concern for the survivability of a spacecraft with respect to the radiation environment. Consequently, we had built up a rather small, rather good group of people who were specialists in both working with the damage resulting from the radiation itself, as well as trying to measure and predict what the radiation environment was going to be. The radiation effects were of particular concern for the solar cells, because they are on the outside of the satellite and they take the brunt of all the radiation that's out there. Being the primary supplier of the power, it was very critical."

There was also the question of what effects radiation might have on the electronic components of the communications package. Since the early satellites had to make maximum use of volume and weight for the communications packages, there was no room for equipment whose mission would be purely measurement and therefore little, if any, data fed back for analysis purposes.

"You just had to guess by the seat of your pants," Arndt explained. "While the NASA people were doing a lot of monitoring of the environment, not much of it was at synchronous altitude. So you had to more or less guess what the whole long-term environment on a synchro-satellite was going to be, based upon just a few excursions through that part of the zone by NASA. You had to be very intuitive to take this minute amount of data, guess what the synchronous, or communications satellite environment was going to be, and based upon that, predict what the lifetime of the solar cells was going to be."

So Arndt and his group simulated, on earth, what they thought the environment in space would be like, integrated that data with what little real data they got from NASA, put the two together and came up with surprisingly good estimates of what the degradation in the solar power output would be as a function of time.

"What we found was that electrons that are trapped in the magnetic field [around the earth] bombard the solar cells and create a defect in the silicon host material. That defect acts as a capture site for the light-generated electrons so that they don't wind up generating the power that you need. As a result, over a period of time, the maximum power that you can get out of a solar cell drops off."

Methods were devised to protect the solar cell by adding an extra layer of quartz to its surface. But that decreased the conversion efficiency of sunlight to solar power, which meant you had to make up the difference by putting more solar cells on the spacecraft -- and that ate up a percentage of the valuable weight limitation.

They decided to concentrate on ways of making a given solar cell more efficient, i.e. they had to do better than the eight percent that the best solar cells in use at the time converted to usable power. First they set about improving the responsivity of the cells across the full spectrum of light.

"The earlier versions were not very sensitive to the short wave-length or blue end of the light spectrum," Arndt explained. "The first advance COMSAT Labs made was to make cells sensitive to that wave-length. Consequently, you were able to convert about 30 percent more of the solar energy into electrical energy."

Next, they sought to reduce reflection from the surface of the solar cell.

"I mean if you're shining light and most of it comes back off, it's not doing you any good," Arndt said. "So we made an improvement that permitted more of the light to get into the silicon material itself. That made another big jump in the efficiency."

There were other, more subtle improvements, until the early 1980s when the labs succeeded in developing a very thin cell.

"You'd like to make a solar cell as thin as possible for two reasons," Arndt explained. "One is less mass you have to haul up. Secondly, the thinner the solar cell, the less susceptible it is to the radiation damage."

But a thin solar cell is very difficult to make, because a piece of silicon, only about 2/1000ths of an inch thick, can curl up like a potato chip. So if you make a very thin cell then try to apply it to a flat surface, there's a good chance you will break it in the process.

"We came up with an idea that has an integral reinforcement on it," Arndt explained. "On the backside, it looks like a waffle; on the front side it's flat as a pancake."

Overall, the effort led to major improvements in the solar cells that have benefitted many segments of society, including commercial and consumer interests. COMSAT Labs became the premier lab in improving the efficiency of certain solar cells. Within eight years, the scientists at COMSAT Labs had doubled the efficiency of the cells to more than 16%.

"We had gotten out onto the learning curve," Arndt said, "to a point where the returns were not paying back the investment in research anymore. The satellites would last longer and you could put more payload on for the same weight of solar array."

The back-up source of power for the solar panels was batteries and with the early satellites, the batteries were of the conventional nickel-cadmium variety. They were designed to last up to seven years, but in actual use generally lasted less. In the early 1970s, the INTELSAT IV satellites were the workhorses of the fleet. They contained the nickel-cadmium batteries and were not getting the predicted seven years, i.e. the batteries were <u>the</u> life-limiting factor on the IVs and IV-As. After about five or six years in orbit, traveling wave tube (TWT) amplifiers had to be turned off to reduce the load on the battery during eclipse operation. Approximately half of the TWTs were eventually turned off on all the INTELSAT IVs, resulting in a substantial reduction from the original 4,000- or 6,000-circuit capacity.

Scientists at COMSAT Labs took on the challenge of extending the life-span potential of satellites by developing better, longer-lasting batteries. At the time, fuel cells, such as hydrogen/oxygen combinations, seemed most promising for sheer advanced energy-storing capabilities. The problem, and it was a big one, was their tendency to explode during periods of extended use. Experimentation with fuel cells and hybrid systems, however, led to the discovery of the beneficial properties of a hydrogen-nickel oxide marriage. For one thing, you could overcharge such a cell or discharge it without damaging the battery.

Members of a team headed by Dr. Edmund Rittner and James Dunlop built the first sealed nickel-hydrogen cells in early 1970 and they were tested at the labs. The results were promising, but the potential was not appealing enough to the original contractor, selected to manufacture the batteries, so its management decided to drop the project. Convinced they were on to something, the COMSAT team took over the project completely, designing pressure vessels, electrode stacks, seals, weld rings and other necessary components for a complete system. Then they took the design to Eagle Picher, another battery manufacturer. By 1975, they'd convinced the Navy to include the battery aboard a navigation satellite called NTS-2.

"A hydrogen-nickel oxide battery, fabricated by the Naval Research Laboratory, used seven COMSAT-supplied cells in a series," Dunlop explained. Two of the batteries made up the energy storage system flown on NTS-2."

The satellite was launched in June of 1977, with the prototype hydrogen-nickel oxide battery aboard. The final design was a hybrid system combining the best features of the fuel cell and the nickel-cadmium secondary battery. The fuel cell hydrogen electrode and the nickel-hydroxide positive electrode were two of the most reliable and stable secondary electrodes existing at the time. Combining the two electrodes into an electro-chemical cell led to many advantages, with the major one being the improvement in life expectancy, two to four times that of the nickel-cadmium cell. There was also the significant advantage of a reduction in mass, increasing the usable energy density by two-fold. The launch of the Navy satellite marked the culmination of more than 10 years of battery research and development at

COMSAT Labs, and it rewarded the confidence of the battery team by operating effectively well into the late 1980s.

By 1978, with actual field test data from the Navy satellite in hand COMSAT Laboratories scientists proposed to the parent corporation and to INTELSAT that the hydrogen-nickel oxide battery be considered for INTELSAT V, then in the manufacturing stage. The battery, which was designed to be interchangeable with nickel-cadmium batteries impressed scientists at Ford Aerospace, the prime contractor on INTELSAT V. Ford decided to use it in eight of the 15 satellites in the series. The battery was uniquely prepared to respond to the power demands of satellites well into the 1990s, when the stored-energy requirements on a new generation of satellites would increase by a factor of four to eight.

Along with the power sources, another important, life-limiting element was the on-board propulsion system, which was used to position the satellite properly and maintain that position. The propulsion system included thrusters and valves which had to perform properly for the projected life of the satellite and a supply of fuel which itself limited the satellite's lifespan.

"You have to appreciate that once the thing is up there no one ever touches it again," Fred Esch emphasized. "We still don't have a sufficiently long screwdriver that can reach up that high."

The problem was the hydrogen peroxide system that powered the thrusters was unreliable and unpredictable. The hydrogen peroxide apogee motor had malfunctioned dramatically on the first launch of INTELSAT II, placing the satellite into an exaggerated elliptical orbit. The scientists in the Spacecraft Lab felt they needed something more reliable. The system they decided upon worked with hydrazine.

"It had some of the characteristics of hydrogen peroxide," Esch explained. "It was catalytically decomposed, but you could also electrically heat it and increase the thrust and thereby increase the efficiency of the system."

While the hydrazine system was proving its effectiveness, Dunlop and his team were improving the hydrogen-nickel oxide battery to the point where it could be considered a complete electric power and propulsion system.

"Battery-powered electric propulsion is the next step," he explained. "Hydrazine fuel provides the propellant to maintain satellites in their proper orbits, but there's no reason why a battery-powered electric thruster can't perform this same function more efficiently. A satellite's lifetime could be extended from 10 or 15 years to 20 or 25 years with the same propellant mass."

Between periods of solar eclipse, the battery could provide power to an ion thruster for two hours each day in order to maintain a stable orbit. Over a 20-year-plus lifespan, this would require the battery to undergo some 7,000 deep discharge cycles. The hydrogen-nickel oxide battery could meet that requirement.

The battery's long-life potential and rechargeability have made it a prime candidate as the power source for the United States' first manned space station, according to Dunlop.

so that portion of the antenna was always pointed toward the earth, as opposed to Early Bird and INTELSAT II which radiated their signals in all directions. But, the electrically de-spun antenna could not be made to work."

In the middle of the satellite design phase, the electrically de-spun antenna was dropped in favor of one that was mechanically de-spun. (This is the familiar truncated conical antenna that can be seen in models of INTELSAT III.) In order to maintain the position of the antenna beam relative to the earth on a spinning satellite, the antenna is driven opposite to the spin of the satellite by a counter-rotating motor. Therefore, the satellite needs a series of bearings. These bearings, however, were being effected by the great swing in temperature they would experience in orbit. When they got too cold, the bearings seized; when they got too hot they seized.

"We were aware that there was a cold condition on the satellites, so a heater was put on the bearing system to keep it warm," Flieger explained. "But we found that the bearings still seized during tests."

The tests on the antenna were proving very frustrating.

"I spent a lot of time working with the engineers at TRW studying the problem," Flieger said. "I would pick up design information and test results in California and take the data back to the labs to conduct my analyses. I made so many trips back and forth that my wife threatened to leave me, but in those early days, many labs people traveled a lot."

It was the worst of all possible worlds for the thermal engineer, both too hot <u>and</u> too cold in space. The hot condition occurred when the sun was at its most northern extreme and the antenna exterior was in full sunlight. The cold condition occurred during the eclipse season around the Equinoxes. But the worst condition, too hot and too cold, was when the sun was the farthest south and the antenna was only partially illuminated. To accommodate this, a lot of changes were made to the antenna thermal design. Heaters were used to correct the cold situation, and special thermal control coatings were applied to the outside of the antenna in an attempt to limit the heating effects of the sun.

"Everyone thought we finally had a handle on the problem and a fix in hand," Flieger said, "but we were in for a shock when the satellite finally went into orbit. The same old problem of the sticking antenna came up."

Finally an operational solution was found: simply flipping the satellite upside-down every six months, which kept the antenna uniformly sunlit.

Paul Schrantz was another of those engineers who follow Fred Esch to COMSAT from the Applied Physics Lab at Johns Hopkins where he'd been working since earning his masters at Northwestern in the early 1960s. At APL, he'd had a lot of hands-on experience launching 33 low-orbit satellites, including the United States' first double-decker satellite -- a wedding of two satellites that are separated in space via an explosive clamp and sent to separate orbits. Schrantz was an expert in vibration dynamics; Esch had been impressed with him at APL and he needed a man of his particular skills for his new Spacecraft Laboratory.

Schrantz remembered those early days as a period when you did your own structural testing and vibration analysis, using strip charts, checking peak levels and and relying on a lot of gut engineering.

"During the early 1960s at APL, we'd go from concept to a launch in 90 days with a satellite, which was important for some research that the Navy wanted done," he said. "I worked under Fred Esch in the mechanical design, structural analysis, testing and balancing of satellites, worrying about weights and how they go together and what the launch does to them -- everything."

The decision to leave APL was a tough one for Schrantz who liked what he was doing there.

"But I also knew Fred to be one of the finest engineers I'd ever met -- in terms of total commitment and understanding and an ability to work with people," Schrantz recalled as the deciding factor in tipping the scales for COMSAT. "He was just a total, people-type guy and totally competent. We launched 33 satellites together at APL and never had a flaw that was traced to poor engineering. He set a good example."

Schrantz came to COMSAT at the end of the INTELSAT III program, heading into INTELSAT IV. He had had only low-orbit experience, but he felt he knew his stuff when it came to launch dynamics and related areas. But once again his first experience was a matter of being thrown into the water to prove he could swim.

"I'd been at COMSAT about two weeks," he said, "and we had had a launch failure on INTELSAT III. Marty Votaw heard that I was on board and he said, 'We're going to have a meeting with TRW and the Air Force and NASA and I need a dynamics guy out there.' So I was invited to go out and join the meeting. The day before the meeting, Marty walked in with this stack of test reports on the satellite and he said, 'Tell me if we should have had any problems with this launch.'"

Schrantz knew Votaw to be a demanding, can-do, gung-ho kind of person. He decided he'd better burn the midnight oil to see what he could determine about the failure.

"I found that TRW had had a pump failure in the quality test," he explained. "They'd had to discontinue the test. But, in tracking further through their documentation I couldn't find that they had ever re-run the test to the full level. So then I went through the stress report and looked at the margins."

He went to Votaw with his analysis.

"I'm confident that the thing was properly designed and tested," he told his superior, "but I don't think you have a test report here that you want to wave in front of the Air Force tomorrow, we need more time."

Schrantz recalled walking into the meeting and Votaw telling the gathering, "look, we've had a launch failure here. We all know something happened to our launch vehicle. I wish you'd tell us what you think. We're very confident about our satellite."

The Air Force did a thorough analysis and found the problem, but the handling of the situation made Schrantz feel good about the confidence that had been expressed in his ability and the credibility Votaw had placed in his recommendation. He felt COMSAT was going to be a place where if you had the skills they were going to put you in the hot seat and let you do something.

Schrantz went immediately to work on INTELSAT IV, coordinating with the contractor, Hughes Aircraft. He was working on structural design, the loads, the weight problems, balancing, and similar areas that he was responsible for as one of COMSAT's one-man gangs, coordinating the manufacturer of the satellite in California.

"I was walking from office to office meeting people, and I'd say, 'hey this says COMSAT,'" he said. "COMSAT was in a position to make the contractor aware that we had competence in these areas and were going to hold them accountable. COMSAT was the manager, so we had direct responsibility. But I found the exciting part was not only were we getting to create the new satellites, but also COMSAT at that time, in late 60's early 70's, had a commitment to launch advanced satellite technology."

The evolution of the antennas on the satellites was a study in refinements. Advances in antenna design followed a smooth progression from one satellite to the other.

"The first satellites [Early Bird and INTELSAT II] had a beam that was shaped like a doughnut," said Robert Gruner, who spent a career at COMSAT making better antennas, "The satellite was spun for stabilization and the energy from this doughnut-shaped beam would hit the earth. But this really wasn't very efficient because while you're sending some energy to the earth, you're also wasting energy by sending it into outer space. The INTELSAT III antenna directed the energy just towards the earth. This resulted in an improvement in the power that came down to the earth by a large factor."

The INTELSAT IV antenna took the next logical step. It had global beams which covered the earth, but it also had two spot beams that would concentrate energy on certain high-traffic areas.

"For example," Gruner continued, "you'd have a beam that would cover the eastern part of the U.S., and Europe which are high density traffic areas. Thus even more power was being sent to discreet areas."

On the next satellite series, the INTELSAT IV-A, the beams were shaped to fit the continents.

"The beams were formed so that they actually covered the land masses, because there were no earth stations out in the middle of the ocean," Gruner said. "You now concentrated the power into beams that were shaped roughly like the continents. It was a major step."

This was done with multi-element feeds and offset reflectors. If you took an antenna's reflector and its feed and you put the feed in a certain region of the reflector, it sent a beam to a point. Then you could add another feed and activate it to send a beam to another point. Now, if you fed these two feeds in phase, the two beams would form an ellipse instead of a circle. You then kept adding feeds until you defined the shape you were seeking.

"It was almost like following the dots," Gruner said. "For example, you might have 15 beams which are placed at specific spots in the U.S. So when you add the individual beams they form a rough contour of the map of the U.S. You're juggling a lot of factors around when you do this, including the size of the main reflector, which sizes the constituent beams, and the number of feeds used. The bigger the main reflector, the narrower the elemental beams, and the narrower the beams the more closely you can approximate the shape of the continents. So there is a lot of interesting design work there."

On the next satellite series, INTELSAT V, dual polarization was used to further increase capacity. It was a method of sending and receiving signals at 90-degree (orthogonal) angles to each other.

"Think about dual-polarization in terms of your car radio," Gruner explained. "You have a vertical whip antenna out there receiving the ball game at some frequency. But you could also receive the opera in the other sense of polarization at the same frequency. So by using both a vertical and horizontal antenna, you could use the same frequency twice and receive both transmissions. You could look at the available frequency spectrum and the orbital arc as natural resources. There's only so much to go around and when you use orthogonal polarization, you actually double the use of the available frequency spectrum."

The development of spacecraft antennas has been an evolutionary process with a logical, step-by-step progression: INTELSAT I and II used broad toroidal beams; INTELSAT III used global beams; INTELSAT IV had global beams plus two transmit spot beams that could be steered around the earth; INTELSAT IV-A had regional beams that were shaped to the continents; INTELSAT V used the shaped beams with dual-polarization. The major change in INTELSAT VI would be regional beams that would illuminate continents in the Southern Hemisphere, as well as the northern.

The life-limits on the satellites had come a long way since Early Bird and the spacecraft had become more complex, but more dependable. Those working on the earth stations were laboring hard to keep up and making dramatic progress in their own arena. The system had expanded far beyond the dreams of the early prognosticators.

CHAPTER ELEVEN: WITH FEET FIRMLY PLANTED IN THE GROUND

OCTOBER 20, 1964 -- The Communications Satellite Corporation today asked 15 companies to submit proposals to provide research data and consultant services for definition of design and performance requirements of ground terminal stations for the global communications satellite system. The solicitation has these purposes: to take advantage of research already done . . . to augment the Corporation's technical in-house effort . . . to insure an effective ground station design will be achieved . . . to establish performance and requirements for each subsystem . . .

-- News Release,
Communications Satellite Corporation

While the novelty of an orbiting communications satellite remained the focus of attention, and Early Bird gained a notoriety that elevated it to celebrity status, reality in the world of satellite communications was, for all terrestrial participants, the earth station. At the time that Early Bird became a functioning satellite in 1965, there were only five countries who maintained legitimate earth stations: the United States, United Kingdom, France, Germany and Italy. The new satellite's limited capabilities did not permit multiple access, so the four earth stations in Europe could communicate with the earth station in the U.S. only on a rotating basis. The prospect of satellites over the Pacific and Indian Oceans joining the Atlantic satellite and thereby completing a global network by 1969, meant there was a lot of work to be done on the terrestrial side. Sometimes the work seemed a bit way out even to the engineers involved.

When Bob Gruner, a young engineer from the Boston area, first came to COMSAT, he was told he would be sent to the field to measure some antennas. Then his boss, Bill Kreutel, added, "you're going to measure earth station antennas using the signals from radio stars."

"C'mon," Gruner said, "don't kid with me. That's not very nice. I'm new here."

Kreutel explained that stars discovered by means of radio astronomy radiate energy in the communications spectrum and one way to measure an earth station antenna was to receive that power. You pointed the antenna at the known position of the source and if you knew how much power per unit area (flux) it was sending toward you, then measured what you received out of the antenna terminals, that allowed you to determine the effective collection area of the antenna. It had been a technique developed by radio astronomers and picked up by people in the satellite industry. Kreutel had written a definitive paper on the subject, used for years by antenna test engineers.

The star sends you something called power density, at so many watts per square meter. The antenna receives it at say one watt per square meter. If you've got a square meter of antenna, out the other end should come one watt -- if yours were a perfect antenna. In practice only about 60 percent of the power is captured and fed to the receiver. Thus the effective collecting area might be 0.6 square meters.

Except that the amount of a star's energy reaching the earth is generally quite small.

"The power density on the earth from the star is infinitesimally small," Gruner explained. "On the other hand, you've got a large earth station antenna which has a lot of capture area so you still could get some measurable amount of power -- but you're talking millionths of millionths of a watt."

After learning the process, Gruner took the cases of measuring equipment and headed out into the field bound for Andover, Maine.

Gruner's next big surprise was the cassegrain horn antenna, itself. Although he had seen pictures of the big antenna at Andover, built by Bell Labs for the TELSTAR program and modified for Early Bird, Gruner was still not quite prepared for what he found. The antenna was housed in a bubble structure which was kept up by air pressure similar to the bubbles used at swimming pools and tennis courts. There was a two-door entry system to maintain the pressure. Gruner opened the first door, walked into the interlock chamber, then closed the door behind him. After the pressure equalized, he opened the door into the room that held the antenna.

"I just gasped," he recalled. "It was just unbelievable to me that man could build something like that. It was really the seventh wonder of the world, an enormous antenna built on a railroad track within the big bubble. The ceiling must have been 250 feet high, and the railroad track, 200 feet in diameter, running around the room with this enormous horn mounted on the tracks, allowing the whole horn to pivot. The horn looked like a giant cornucopia with a 65-foot opening. It blew my mind."

Measurements were done at night, because you didn't have any sun interference, and at that time, the earth station could be taken off the air during the night. Gruner prepared to take measurements from a star that would be at a prescribed position in the sky at four o'clock in the morning. He set up his equipment, clambered up into the feed room, pointed the giant antenna toward the proper azimuth and elevation angles and waited. He was positioned in the bowels of the giant cassegrain antenna, listening to the groaning and creaking, waiting for something to happen.

"I was sitting there watching the meter when all of a sudden at four o'clock in the morning it began moving," he said. "I can remember saying, 'god, it works!'

Gruner spent the rest of the night accumulating data, following the star to its zenith, then losing it over the horizon. The measurements allowed him to determine the gain and gain-to-thermal noise temperature.

The calibration and testing of earth station antennas has been critical throughout the years that the global satellite system has been in operation and during that time the antennas have remained cantankerous. For years, teams from COMSAT Labs have packed up and gone off to sites, tested for a week, or two at a time, and have come home with new discoveries, new challenges. A good deal of testing was done from the Paumalu antenna in

Hawaii. Like Andover, Paumalu was a cassegrain horn antenna, a big snow shovel,

"One time," microwave expert Chris Mahle said, "I was taking data up there and the operator in the trailer, put the antenna in auto-track on the spacecraft, and just punched the button."

Instead of tracking on the spacecraft, the antenna began to swing up, with a surprising acceleration. It did this very fast. Mahle was standing there wide-eyed as half a ton of equipment began to slide toward him.

"The guy was not paying close attention," Mahle said. "When I called to him to put it in auto-track, he just looked over, punched the button, and went back to what he'd been doing. When I started screaming, he finally pushed the emergency stop."

To make matters worse, the testing platform was a makeshift Rube Goldberg affair of two-by-fours at a 45-degree angle, which created optical illusions like the old Ernie Kovacs TV trick in which the set and the TV camera were on the same angle, so it looked like he was pouring milk at a 45-degree angle. The COMSAT equipment sat on a platform which hung by two chains so pieces could be moved back and forth.

"We have a photograph that shows people standing up and there is this wrench hanging on a piece of string that came across the picture, at an angle," Mahle said.

Paumalu was also very leaky and it rained a great deal in the mountains of Oahu.

"One day, we were up there and it was raining outside, and there was water dripping in," Mahle recalled. "We made measurements and wrote the data down on a piece of paper. Sy Bennett was sitting in the trailer keeping track of things and talking to the control center, because we needed things switched in the satellite, and so on."

"I need one more point, one more point," Bennett said.

"Simon it's raining," Mahle replied.

"Just take one more point," Bennett demanded.

Mahle took the measurement, climbed down the antenna and went into the trailer, then handed Bennett the sheet of paper, crumpled and very wet.

"Well, where is the data?" Bennett said.

"There!" Mahle pointed.

The rain had washed it off the page.

There was always some friction between the "space cadets" as the teams from the labs were called, and the station personnel.

"The station personnel did not like us to screw around with their antennas," Mahle explained. I mean we came in sort of heavy-handed from Washington and the station personnel didn't like the fact that we had a free run of things and could do pretty much what we wanted."

Sometimes they found ways to get even.

A recurring problem with the cass-horn antenna at Paumalu involved its tracking system. The antenna included a built-in tracking system that was designed to keep it pointed at the satellite at all times.

"For us to do measurements, it's vital that the system works," Mahle said. "One day we were working and the antenna had a particular problem at one frequency where we had to take data. There was something wrong and we didn't know quite what. So Sy Bennett left a note for the station personnel to fix the problem by the following day and our team left."

It was a problem with the power amplifier which had lost a crucial vacuum. In the process of fixing it, however, the station personnel moved the antenna too far down and the broke a hydraulic line.

"There was hydraulic fluid all over creation," Mahle remembered, "and there was that 45-degree angle to the platform we were working on, plus a big hole in the safety net. We thought, 'they're trying to tell us something.'"

This form of testing, that was for the most part non-computerized, continued through INTELSAT satellites I to IV. With INTELSAT IV-A, computerization took over.

"IV-A had a more-complicated antenna pattern," Chris Mahle explained. "We needed to do antenna pattern cuts in a short period of time and that called for computer assisting. We had six months to install the first permanent satellite test setup at Paumalu. We had to learn a lot about how the computer interfaced with the instruments, how you got your data out and so on, but the process slowly but surely grew into a very-sophisticated measurement machinery. Today, the measurement experience of the last 20 years is reflected in the software. A technician just needs to push a couple of buttons and the machine will get the right answer for him. If it can't, it will tell him why. It's very comfortable these days. You could actually do it by remote control from Washington."

One of the most significant developments in antenna design at COMSAT Labs was the Multi-Beam Earth Station Antenna, called the Torus, described by COMSAT CEO Joseph Charyk as "the shape of things to come," when it debuted in 1981. "Shape" was the active word here. The Torus is named for the shape of its surface, which is toroidal. A toroidal-shaped surface is formed by swinging a second-degree figure -- a circle, a parabola, an ellipse -- around an axis. The relationship between the axis and the figure describes a conic section which gives the Torus its peculiar property. It does not scan in a flat plane but on the surface of a cone, and that approximates the geostationary arc of the satellite, an ideal configuration for earth stations of the global satellite communications system.

In the case of satellite communications, the birds in the sky were improving at a rate faster than the stations on the ground could keep up, in several significant areas. For one thing, a one-satellite-per earth station relationship was not an efficient system, considering the size and cost of an earth station vs the satellite and the commitment in hardware and real estate necessary to build an earth station. An antenna that could interface with multiple satellites would result in significant cost efficiencies not to mention productivity improvements. Solutions, however, come only with thinking and a good deal of hard work.

How does a Torus antenna come into being?

"You start with an objective," explained Dr. Geoffrey Hyde, who was one of the principal scientists on the Torus project in the late 1960s and early 1970s. "You consider the various configurations which have symmetries that you can take advantage of: a sphere, for example. No matter what way you look at a sphere, it looks the same, spherical symmetry. So I looked at a sphere for a while."

But a sphere has some very severe aberrations. Hyde had done his doctoral dissertation on a radio telescope in Puerto Rico, which uses a spherical surface. He wanted something better. He kept asking himself is there anything of higher efficiency than the sphere, with less aberration? He knew of one such shape, the Torus antenna used by the BMEWS radar installations in his native Canada. But that antenna only scanned in a plane.

"When I scanned in a plane, I could only look at a little part of the geostationary arc," he explained. He experimented with cuts a little below and to one side of the toroidal shape, but it only approximated a small portion of the geostationary arc. He experimented with twisting the Torus into a smile and a frown and that started to look right. He discussed it with a colleague, Bill Kreutel.

"We thought about it," he said, "Bill and I both analyzed the problem and we came to the same conclusion: if you moved the axis of rotation, it approximated the geostationary arc."

Hyde designed and built scale models and did mathematical calculations and experiments with the shape of the scan cone. Then Kreutel showed that an optimum was reached for a 95-degree tilt of the axis, rather than the 90-degree tilt that was normal for the Torus. They completed the initial design in 1973. The design was a great improvement over existing antennas.

"You can put several feeds in the feed area, and their beams overlap on the reflector," Hyde explained. "As a consequence of that, if you were to look at three satellites at once, you would need an amount of surface area of metal significantly smaller than three separate antennas. Not only that, but we got some subsidiary benefits in very easy beam steering along the arc or even across the arc that were not obvious when we started, but were very obvious when we were done, so that even if the satellite moves a little you can follow it. It is a very well-behaved design, it does what you predict it will do."

But Hyde wasn't finished. The first Torus design was point-fed from the front. It had limitations due to aberration. That meant you could not change frequency arbitrarily because the amount of aberration was related to the number of wave-lengths across the aperture illuminated with the feed horn. Hyde kept working on refinements.

"It turned out that restraint could be eliminated," he said. "I showed how that could be done, and indeed proved it with a scale model. If you were willing to accept some aberration, and chose your parameters correctly, you could raise the efficiency to very significantly higher levels. That meant you could cut down even further on the amount of metal that you needed. This aberration-corrected Torus was the final step."

The Torus made a celebrated public debut in August of 1981 at the annual Satellite Users Conference in Denver, Colorado.

"We stole the show," said Richard E. Thomas, Chairman of Radiation Systems, Inc. the COMSAT-licensed manufacturer. The Torus received simultaneous television signals in the 4 gigahertz range from three different satellites and in the 12 gigahertz range from a fourth one. And that was less than one-quarter of its capability, which was up to 17 independent beams, each of which could be directed at a satellite in geostationary orbit.

The Torus had important implications for cable TV operators, national TV networks, and independent TV broadcast stations. Because it could access multiple satellite transmissions at the same time, the dimensions of earth station locations could be greatly reduced, easing the burden of heavy real estate costs. Torus antenna installations could now make the transition from the drawing boards to the tops buildings. The Torus also had the potential to reduce the number of antennas in the expansive "antenna farms" of parabolic dishes that had sprung up across the United States.

The new developments in earth station design sent some of the early players back down to the farm. With the development of the INTELSAT V satellite in the early 1980s, all earth stations communicating with the new satellites had to be retrofitted for dual polarization.

Bob Gruner was project manager of these modifications. The mission created a strange sense of deja vu.

"When I worked on the COMSAT stations on the west coast, it was really quite a kick for me because I was one of the original designers of the antennas at Brewster, Washington and Paumalu, Hawaii, back in the 1966," he said. "I went out to antennas that I had helped design 15 years before and took out the things that I had installed when I was in my mid-20's. I actually pulled out the hardware that I'd built in 1966, then put in something that I had designed in 1980. It felt like lost youth. But it was a good feeling knowing that something you'd designed as a kid was still there, working when you took it out with your own hands when you were 40."

The developments in earth stations continued the race to keep pace with the developments in satellites, with the objective of getting more benefits out of antennas of smaller sizes and lower costs. The improving technology allowed for such developments as earth stations in mobile vans that permitted broadcasters to do

"Live from the Scene" telecasts. Maritime earth stations were shrunk to the point where they became viable accessories for pleasure yachts, as small as 50 feet. There was even the "Earth Station in a Suitcase," a transportable earth station that fit into two cast-metal cases weighing a total of 100 pounds.

However, the large, parabolic dishes were still the most used antennas and their proliferation, particularly during the 1980s began to create problems of another sort. Town fathers viewed them as unsightly, and planning or zoning boards passed ordinances prohibiting or severely restricting the installation of the dishes. In 1983, the people at COMSAT Labs loosed their energies to finding a solution, an antenna everyone could live with. They concentrated their efforts on a "flat plate" design, which could be mounted easily to the siding or on the roof of a house, even erected inside near a window. To function at the level of a dish antenna, the engineers would have to get the efficiency ratings of the antenna up and the cost of producing it down.

COMSAT began talking with the Matsushita company of

Japan, which had been designing a flat plate antenna of its own, and a collaboration of efforts was struck. The Matsushita antenna had an aperture efficiency of only 20 percent, as opposed to a 55- to 65-percent efficiency for parabolic dish antennas.

COMSAT Labs managed steady increases in the bandwidth of the antenna, reduced the size to less than two feet square, designed around commercially available materials, in a matter that would lend itself to easy manufacture.

While the traditional parabolic dish antenna collected signals in its dish and focused them into a feeder horn, the flat plate antenna collected them across its surface. It could receive channels over the full band of satellite transmissions.

The new antenna would be the shape of things to come, with applications in the developing direct broadcast market, i.e. from satellite to end-user and in business conferencing networks.

So earth stations had gone from the gigantic cassegrain horns of the mid-1960s, through the giant parabolic dishes that followed. These have since been shrunk to about half their original size. For some applications still smaller earth stations can be used and in one case even fitted into a suitcase. Then the shapes were changed to improve efficiency, cost, even aesthetics, leading to the development of the Torus and the flat plate antenna. While the earth station may have begun its life as the unglamorous step-brother of the high-flying satellite, it certainly grew in stature over the years. It was, after all, the link to the invisible bird in the sky.

CHAPTER TWELVE: A VITAL LINK TO THE SHIPS AT SEA

At the end of his retirement party in 1983, Kim Kaiser slipped into a room off the main corridor on the ground floor of COMSAT Laboratories, pulled on a pair of roller skates and, as his final act, skated the length of the building and out the front door.

Why?

"I'd promised to do it on a skateboard," he said, "but my wife felt that was too dangerous."

Kaiser had spent his career at the labs living on the edge. A hands-on kind of person, he was one part scrounger, one part tinkerer, one part theoretician and 100 percent can-do. Kaiser was the man who took the laboratories' solutions and demonstrated them in that often inhospitable environment know euphemistically as "the field." His work took him to the tops of mountains, up the sides of buildings, to overgrown jungle landing strips and, more often than not, to the pitching decks of ships, in sometimes unfriendly waters.

While not a part of every day life for the vast majority of us, maritime communications have made a quantum leap since the potential of satellites has been harnessed for the benefit of ships at sea and oil rigs off the coast. Unfortunately, while the technology had existed for more than a decade, it had not been applied on a broad scale until the 1980s. A witness before a House committee put the need for applying the technology into perspective in 1981 when he described the state of radio communications on the high seas as being where Marconi had left it 70 years before. The necessity for improving maritime communications was brought into focus during investigations into the disappearance of an American merchant vessel, the S.S. Poet in the North Atlantic in the late autumn of 1980. Bound for Port Said, Egypt, with a cargo of corn and a crew of 34, the Poet disappeared without a trace and without anyone receiving a distress signal.

"It was the first time in 18 years that a U.S.-flag ship had disappeared without anyone receiving a distress call or without someone subsequently finding some trace of the vessel," said Congressman Walter B. Jones, chairman of the House Merchant Marine & Fisheries Committee. "The S.S. Poet tragedy poignantly brought to our attention the need for global satellite communications."

As a witness before Congressman Jones's committee put it, "unreliable radio communications are a fact of life." And the consequences were sometimes fatal.

While the early development of satellite technology concentrated on providing communications between fixed points, those involved in the process knew that one of satellites' unique capabilities would be its ability to provide communications between mobile points -- obviously impossible with cables.

In the early 1960s, Dr. Burton Edelson, who later became the second director of COMSAT Labs, was a lieutenant commander in the Navy involved in the Navy's Navigation Satellite Program. The idea of navigating ships via satellites had obvious appeal to the Navy.

"We put a large terminal on the USNS Kingsport, a converted World War II victory ship," Dr. Edelson explained. "It was a 30-foot terminal under a big plastic radome. We sailed the ship off to sea. It went to Lagos, Nigeria, and when the SYNCOM satellite was launched that ship was the first satellite communication connection between the U.S. and Africa."

The Kingsport had served as the distant communication terminal for SYNCOM, the progenitor of geostationary communications satellites, and, since it was aboard ship, was the first mobile terminal.

But it was not until 11 years after Early Bird's launch in 1965 that MARISAT became a reality in 1976, as the first mobile satellite system to go operational on a grand scale. But before such a system was put in place, COMSAT had to prove some of the critical systems could work in the field.

In the early 1970s, the career path of Kim Kaiser was about to intersect the need to help put a maritime system into place. Kaiser had received a liberal arts education at a small college in Parkville, Missouri. In his spare time, he played with radios, taking them apart and trying to put them back together again, with varying degrees of success. In the process, he had caught the electronics disease. Called into the service, he learned radio and radar technology in U.S. Army Signal Corps schools at Fort Monmouth, N.J., then went overseas and was involved in message-sending activities.

"In a way I grew up with the practicalities of communications," he explained. "At Fort Monmouth, we had one of the first pulse-position-modulated, gigahertz transmission systems. This basically consisted of two small antennas -- one for receiving, one for transmission -- to provide communications for an Army corps area."

With his interest piqued, he went back to the school this time at the University of Michigan, where he took courses in mathematics. After completing his studies, he went to work for Bendix Corporation in the late '40s, then was asked to come to Washington to work for the Institute of Defense Analysis in the Pentagon. While he was there he met Siegfried Reiger, and they became good friends. From that point on he was involved in satellite communications.

"We ran -- out of the Institute for Defense Analysis -- a summer study on the hard-limiting repeater," he said, "which is basically used in every satellite. It was done in Maine, in 1961, and a whole lot of communications experts were there. It ended up to be a very fruitful exercise. The report that came out of that formed the basis for an awful lot of the techniques that were developed later for satellite communications."

One of the satellites he worked on for the military was called ADVENT, a geostationary satellite, which kept him in a close working relationship with Sig Reiger. So when COMSAT was formed, Reiger asked Kaiser to join. It took five years for Kaiser and COMSAT to reach a meeting of the minds. He joined the team at the labs in 1968.

"I worked in Systems Analysis with George Welti and Sigmund Honnel, and we did a number of studies to see how you could get more communications out of satellites. Honnel issued a technical report on Maritime Satellite Communications, without much coming of it. In those days people were interested in large antennas. The INTELSAT business was just starting and everybody was convinced that the 80-foot or 100-foot diameter antenna was it."

Earth stations of that size would have little relevance for maritime communications, but as the work progressed, the equipment got smaller, satellite capabilities expanded. The work in mobile communications taking place at COMSAT Labs during the early 1970s initially was directed at solutions for aeronautical communications.

"We were trying to work in digital" explained Dr. Joseph Campanella, "but as it turned out, the digital technique at that time wasn't sufficiently good, so we chose FM as the method of transmission. In the same period of time there were a number of experiments in the interest of demonstrating mobility of communications via satellites, the most significant being an agreement with Cunard Lines to mount an antenna on the QE2. That particular event was one of the major turning points in alerting the world to the potential significance of satellites for maritime communications."

The impetus was a visit by a certain Colonel J.D. Parker.

"He was with CIRM," Kaiser said, "Committee Internationale Radio Maritime. He came to visit John Puente and they went to see a thing called DI-COM, which Dick McClure, Chet Wolejsza and Eugene Katchamani were working on in Joe Campanella's laboratory. DI-COM was a rack of digital communications equipment designed to replace the analog system. Colonel Parker got to see this, then he and Puente went to lunch and had one too many Guiness stouts. In the process, Parker asked could this be put on a ship? Evidently Puente said yes."

Two weeks later, they got a letter from Colonel Parker indicating that he had arranged to put DI-COM on the Queen Elizabeth 2.

"The letter came to John Puente," Kaiser said. "John didn't know what to do with me anyway, so he handed it to me and said, 'Kim you take care of this.'"

Much easier said than done. While the DI-COM system did exist, not much else did -- an appropriate antenna, for example. Activate Kaiser the scrounger.

"I called my friends at Bendix Communication Systems in nearby Towson, MD," he said, "and asked casually if by any chance they happened to have an antenna . . . about eight feet in diameter . . . C-Band . . . that could be moved around. The chap there said 'well, wait a minute, I'll call you back.' He called back 10 minutes later and said, 'yep, we have an eight-foot dish sitting on a pedestal. It's been there for a long time. It's got several drives on it and the feed you have to worry about, but it's C-band.' So, I said 'well, can I have it?' He said, 'well, I'll call you back.' He called me back 10 minutes later and said, 'bring a truck.'"

Kaiser located a "low-boy," went to Maryland, dismantled the antenna, put it on the truck and made his way back to the laboratories. It was a start.

"As luck would have it," he said, "I poked around in the upper reaches of the labs, where there weren't even any walls yet and found an old telemetry transmitter that COMSAT had inherited from the Andover earth station. It had a nice panel in front that said, 'Azimuth' and

'Elevation' and a big dial, and there were all kinds of instruments behind it."

The problem now became one of how do you turn the hardware into a working version of what you need? When you're stuck, read the book. Kaiser took a tour through the technical library at COMSAT which, among other things contained a full set of "Rad-Lab" series books which were the electronics bibles of radar and communications personnel during World War II. He found a set of equations for stabilizing an antenna on board ship, wrote them down, then stared at them for quite a while. They were complicated, and had Kaiser scratching his head. How, he wondered am I going to build such a device?

"Then I remembered back at Bendix when I was doing guided missile work that we had worked with a horizontal gyro that was used to do the first over-the-pole airplane travel. So, I made another call to Bendix, this time to Teterboro, NJ, and asked my friends there by any chance did they have one of those gyros?"

Deja vu.

"One of the guys was about to retire and he had one," Kaiser said. "Not only did he have a gyro, but he had a motor-generator set, which was important because the gyro worked on 400-cycles AC, three-phase, rarely used except in airplanes."

Kaiser was off to Teterboro, whence he loaded the heavy equipment and trucked it back to COMSAT Labs. He had engineers from the Spacecraft Laboratory look over his equations, then put all the parts together, including an analog computer they built that actually transformed the ship coordinates to earth coordinates.

Then came the critical logistical questions. Where do they put it on the ship, and how do they get it all on board?

The commodore who was in charge of the ship had some suggestions. He wanted them to put it on top of the children's playroom, which happened to have some skylights in it and was on the very top of the ship. But they decided the best thing to do was to literally glue it to one of the top decks. They'd had a platform built of unseasoned oak and it was affixed to the deck with epoxy glue. Then in February of 1971, Kaiser and a colleague, John McClanahan, made their way to Norfolk, VA, with the antenna et al in tow. They'd hired a helicopter to put the earth station in place on board the ship and met with the pilot the night before, but there was a snag.

"Somebody asked the president of your company what would happen if the helicopter crashed on the QE2," the pilot explained, "and they got worried about it and said we aren't going to take a chance on it." Then, he added, . . . But you didn't hear me say that, right?"

"Nope." Kaiser replied.

He'd been assured by the pilot that there'd be no problem; the pilot said he was used to tough assignments. He said he'd been a helicopter pilot in Vietnam, had crashed once, hurt his back and was told never to fly a helicopter again, but he quickly added, "you know I'm not going to crack up this time. If anything goes wrong I'll be in drink before you know it."

Kaiser was a bit confused about the job assignments. "There were only two of them," he said, "the helicopter pilot and his signal man. McClanahan and

I looked at each other and asked, 'who's going to unhook the cables?' 'You are,'" they said.

So, the COMSAT duo ended up beneath an enormous Sikorski helicopter, hovering 20 feet above. But the pilot set the equipment right on the four bolts, they unhooked the cable and off he went.

"We had those idiotic plastic helmets on that wouldn't have done anything," Kaiser said.

The ocean liner made four trips to the Caribbean with the team from COMSAT on board. Each time they got within the general vicinity of Cape Hatteras, NC, it stormed.

"They had stabilizers on the ship," Kaiser said. "But when the waves and storm got too bad, they didn't risk them, they pulled them in so they wouldn't break up. So, things were pretty grim. But we got our equipment going and it worked fine."

What they'd installed was one FM channel. They demonstrated its use with voice, a teletype machine and a facsimile machine, transmitting all sorts of interesting things back to the small four-and-a-half meter antenna at

COMSAT Laboratories, which was plugged into the telephone network, so they were able to make calls from the QE2 to just about anywhere in the world. They even called the Cunard commodore back at his residence at two o'clock in the morning to tell him they were still working. Then they conducted demonstrations for the ship's crew and passengers. They asked for volunteers to make calls back home, then selected first a couple who wanted to wish their 16-year-old daughter a happy birthday.

"The call went through," Kaiser said. "There were a couple of thousand people listening in via a loudspeaker. Her boyfriend answers the telephone. It took several minutes before they found the grandmother, who'd been locked in a closet. It was a very embarrassing few minutes."

It got worse. A second couple called to talk to their children whom they'd left with a grandmother. The 10-year-old answered the phone and told her parents their apartment had burned down. Since no one was staying in the apartment, no one got hurt, but the news ruined the cruise for that couple as well. Fortunately, the remainder of the calls were more mundane.

After the short runs to the Caribbean, the team was off to Europe on the QE2. Kaiser's luck with the weather did not improve, however.

"We got into the worst storm in the North Atlantic in 40 years," he said. "The ship spent two days hovering in the middle of the Atlantic, exactly 60 years to the day after the sinking of the Titanic in the same place."

As part of their experiment they'd gotten charts of principal locations for ice, because they were going to send some weather information from the ship. Kaiser had the charts showing where the ice usually was. He gave them to the captain. They compounded the navigational problems. To ride out the storm, the only way to go was north, into the wind, but that was where the ice was.

"So one evening in the middle of the dinner he turned the ship around, for reasons best known only to him," Kaiser said. "This caused a real calamity because when he went broadside with the waves, the ship took an enormous roll, just when John and I went into the dining room. It rolled six times, about 45 degrees each time, and when you're on a ship that's 150 feet tall, it is an awful experience."

On the first roll, the one the captain anticipated when he turned the ship around, a computer which controlled the engine room, got conflicting information -- simultaneous high- and low-water indications in the boilers from this enormous roll. Confused, the computer shut down everything.

"So here we were, dead in the water," Kaiser said. "The engineering officer, who had been eating his dinner, went down seven decks, by steps because the elevators had stopped, hit every button he could find and got the thing going again. John and I went into the dining room singing hymns, and the maitre d' kept saying, 'don't do that!'"

The wind gauge had registered 80 knots. Kaiser remembered the radar officer praying for his equipment; while he was hoping against hope that the earth station had stayed put. It had.

Their experiments proved you could send voice, teletype and facsimile material via satellite, all of which had important ramifications for maritime communications, especially emergencies at sea, including problems requiring medical assistance and advice. Conducted over existing INTELSAT satellites, the QE2 experiments used one of the 64 kilobit per second SCPC channels which were established as part of the INTELSAT transponder allocation to SPADE (Single Channel per Carrier Demand Assigned Multiple Access Communications).

"We had connected a fairly small antenna through an INTELSAT satellite, INTELSAT IV-F2, and it all worked," Kaiser said.

People in the Navy Department began to take notice.

"The after-effect of the matter was that the SPADE channel wasn't the ideal bandwidth for going into a small antenna," Dr. Campanella explained. "Making that happen took a little bit of stress to power that channel down to the QE2 with more power than we would normally put into a SPADE channel for a big 30-meter, Standard A earth stations."

They would make adjustments for future tests. With the QE2 experiment completed successfully, interest shifted to the SS Hope, the hospital ship that seemed a natural for satellite communications. Roaming the seas on its on-going mission of mercy, the Hope would benefit mightily from the type of link-up that COMSAT could provide. COMSAT's President, Dr. Charyk knew the director of the Hope project and they agreed to do an experiment with the ship. So, off went Kaiser again, this time with a colleague, Dave Rieser, to a place called Maceio, a tiny town north of Rio de Janeiro in Brazil.

"It's right on the equator," Kaiser said, "a grim place. We stayed their five months."

They got there just in time for carnival. Now the carnival in Rio is famous throughout the world, but in Maceio, the carnival couldn't be that big a deal, right? Wrong.

"Carnival is taken so seriously that no one does anything for two weeks," Kaiser explained.

He and Rieser spent the down time hooking up the equipment and demonstrating how it could be used for administrative communications. Then things got going in earnest. The ship was re-supplied once a week by airplane from the States. COMSAT instituted a teletype schedule and satellite communications replaced spotty ham radio service for supplies.

"After that, we did a number of very interesting experiments," Kaiser said. "We had an electrocardiogram and freeze-frame equipment from RCA. It was brand new equipment that theoretically could be used to send a video picture using a telephone channel. You just froze the thing and scanned it at a very slow rate, then reproduced it."

To showcase the link with the Hope, a demonstration was arranged for the medical community which would link-up the new auditorium in COMSAT headquarters at L'Enfant Plaza, in Washington with the ship moored at Maceio. Dr. Charyk would chair the Washington end of the conference. It was nail-biting time. Kaiser was having trouble with the transmitter on the Hope. About half an hour before this event was to begin, he had arcing on the housing. He borrowed some cleaning tools from the dentist on board the Hope and scrubbed down the high-voltage electrodes.

They were arcing from the salt that had collected on them.

Minutes before the appointed time, the equipment began working beautifully. They sent signals using a slow facsimile transmission of X-rays and photos showing wounds and sores. The system demonstrated that you could take a picture of an X-ray and transmit it to a specialist back in the U.S., then he or she could give the medical people down on the Hope the recommended treatment. They could send up anything that could be photographed.

Doctors on the Hope gave presentations on different tropical diseases, including malnutrition problems and stomach diseases that occurred in that part of the world which many of the doctors back in Washington had never seen before.

"The circuit held up very well over the entire span of the event," Dr. Campanella said, "then about fifteen minutes after it was over with, the circuit arced again and I don't think that Kim ever got it back up."

Kaiser and Rieser spent a good deal of time wrestling with the system, but the technology was young and they were making headway.

"We sent back pictures of patients,"Kaiser said. "We sent back dental work that they had done. We transmitted these pictures to the laboratories, then to the headquarters of the Hope in Washington."

They had problems that were peculiar to the tropics.

"The 'look' angle to the satellite was 81 degrees," Kaiser explained, "which meant the antenna was virtually pointing straight up. That was a problem because in the tropics it rains every afternoon. The first afternoon the dish filled with water. We drilled a hole which kept the water draining."

A side benefit was that the Brazilian telecommunications people were becoming more impressed with what they saw. They wanted a demonstration in conjunction with their communications system.

"In our usual fashion, things didn't go easy," Kaiser said. "The access to the roof of the building in Brazilia was too small for the dish, so the local fire department had to hoist it up 10 stories with ropes."

They linked the demonstration circuit via Tangua, the Brazilian Standard A earth station, then demonstrated the quality of the satellite service versus the microwave service the Brazilians had been using between Braziiia and Rio.

"They realized that their microwave system was terrible," Kaiser said. "As a matter of fact, I noticed in Brazil that everyone using the telephone had a handkerchief. When they were through, they wiped off the telephone because they had to speak so loud, they spit into it. When they talked over our satellite system, we had to keep them from shouting because they were over-deviating and wrecking our system."

The Brazilians wanted to see more to be convinced about the benefits of satellites, but they had one more condition.

"There was a general who had the say-so in these matters," Kaiser explained. "He said, 'I will believe this works if you can put it into the jungles of the Amazon.' So, we said, 'well, if you can get us there, we can put it there.'"

The trip inland would have been a challenge for Indiana Jones.

"It was a fascinating journey over the jungles of the Amazon in an old C-119, Flying Box Car," Kaiser recalled. "We flew commercial to Belem, then on to Manaus, where they picked us up in the C-119."

It wasn't exactly American Airlines.

"Dave Rieser was a heavy smoker and I noticed he wasn't smoking in the back of the plane, "Kaiser said. "I mentioned it to Dave and he pointed to six barrels, 55 gallon drums of high-test aviation fuel for the return trip. But that wasn't stopping the crew from cooking over a hotplate."

When the COMSAT duo asked why they did not have parachutes in a military aircraft they were told parachutes were irrelevant. If they had to bail out over that dense jungle, they would not survive anyway. They were assured that if the plane should go down, it would create an inferno that marked the spot, but two weeks later the jungle would move back in and you wouldn't know anything had happened. It was not the kind of reassurance they were looking for.

Kaiser found out later that the Brazilians referred to the C-119 as "the widow-maker." During the flight, however, he was too concerned about finding the airstrip they were supposed to use to worry about the larger issue of landing in one piece.

"I was in the cockpit watching," he said. "They were really searching, but there was nothing except green beneath us -- water and trees . . . and nothing else, nothing. The crew members were getting a little concerned when finally I saw a big grin spread over each of their faces. It was beneath us. Nobody knew how long the runway was so the sergeant who was cooking soup asked somebody to hold the lid on while we were landing. But his cooking was all for naught. We had been at 12,000 feet, in an unpressurized cabin and it wouldn't cook."

The pilot had brought the aircraft to an abrupt halt. Smack in front of them was the River Amazon. They were at the very end of the runway.

The military guest of honor arrived later, in his own airplane, which had had a near disaster of its own running low on fuel and almost not finding the only refueling stop.

"He was a pompous individual," Kaiser recalled. "We had to eat in the mess hall and we had to eat when he wanted to, not when anybody else wanted. When we couldn't tolerate his arrogance any longer, Dave and I deliberately did not show up for dinner one night, which upset him very much. Then, Dave let it be known that at one time I had held the rank of brigadier general and this changed things considerably, even if it wasn't quite true. I'd had the rank bestowed on me for an exercise we did at the Institute for Defense Analysis. At that point he felt that I had equal rank, so we tamed him down a good bit."

There was a small army detachment on the base and they had never been able to talk back to their families and friends at home. The communications link-up, if it worked would be a godsend. After tackling problems of the rains, a sun outage -- in which the sun shines directly into the satellite beam -- and assorted other problems, the link was made and the Brazilian general convinced.

Two weeks later, they left the base in a short-take-off-and-landing aircraft, along with a load of bananas, a parrot, a group of Amazon Indians and two Brazilian soldiers. Just another of what had become ordinary assignments for Kim Kaiser.

The Navy had become impressed with all that was going on at COMSAT Labs and in the field trials. As fortune would have it in the early 1970s, the Navy was looking for a way to fill a gap until the launch of its FLEETSATCOM satellites later in the decade. As a "Gapfiller," the Navy decided to lease UHF capacity from COMSAT on a commercial basis during the interim period. COMSAT responded with a proposal of its own. It would design a hybrid satellite capable of providing the Navy with its UHF service requirements for a period of at least two years, while including aboard the satellite transponders operating at frequencies in the maritime services L-band. The Navy services would run at a peak as soon as the satellite was successfully in orbit, while the maritime services segment would begin with a low level of usage, which would increase as the Navy decreased its requirements. The Navy said yes and with the award of the contract in 1973, it represented the first time military and commercial capabilities would share the same satellite. It also marked the first time L-band capabilities would be offered via satellite communications. The transmitter could be operated at three different power levels, permitting the limited power of the satellite to be shared between the UHF and L-band users and regulating the power as demand for one increased and the other decreased.

In 1976, maritime communications took a giant step forward with the orbiting of three MARISAT satellites over the Atlantic, Pacific and Indian Oceans. Shore stations were operational at Southbury, Connecticut; Santa Paula, California; and Yamaguchi, Japan; while additional telemetry, tracking and control was provided via the Fucino station in Italy.

The first commercial telephone call utilizing the system occurred on July 9 of that year, when the seismic ship Deep Sea Explorer, at sea off the coast of Madagascar in the western Indian Ocean, called home, its head office in Bartlesville, Oklahoma. "The most fantastic communications I've ever seen," exclaimed ship's quality control officer Ronald Payne, at the time.

The MARISAT system put into every day use some of the most innovative concepts and designs developed at COMSAT Labs. Voice grade channels were frequency modulated on a single channel per carrier basis. Telegraphy channels utilized time division multiplexing in the shore-to-ship direction, time division multiple access in the ship-to-shore direction. Twenty-two telegraph channels shared the same frequency.

There were standard 66 words-per-minute telex services, fully interconnected with worldwide teleprinter networks. Automatic and semi-automatic telephone connections were possible. Medium- and high-speed data transmission at rates up to 2.4 kilobits per second and 56 kb/s were provided plus both analog and digital facsimile transmissions, utilizing telephone channels.

In 1978, the Communications Satellite Act of 1962 was amended to provide for COMSAT's mandate as the U.S. representative to the newly formed INMARSAT organization (which replaced MARISAT), and a Maritime Services Division was created at COMSAT to provide this on-going representation.

By that point maritime communications services were being provided to: freighters and container ships, tankers and liquid natural gas carriers, fishing ships, construction barges, government ships, passenger liners, seismic ships, ice breakers, tugs, cable ships, even pleasure yachts and stationary drilling platforms -- a total of 5,000 ships and platforms.

Once the important requirements of maritime communications were satisfied, the engineers and scientists at COMSAT Labs turned their attention to a little entertainment. They developed a revolutionary compressed video technique that permitted the viable transmission of TV signals to ships at sea. In January of 1986, they conducted an experiment with a gracious old friend, the QE2, relaying the Super Bowl game to the ship 100 miles off the coast of Peru. The experiment brought raves from the passengers and crew. Compressed video promised to turn the experiment into an on-going process. Prior to its invention, live television transmissions to ships at sea had not been possible via maritime satellites. Compressed video allowed for the relay with adequate signal strength.

Once again, the transformation of an entire segment of the communications universe had occurred to the point where its use became a matter of course, almost taken for granted -- almost. When a crewman on a container ship 900 miles off the coast of Bermuda was injured so seriously that the captain contacted a hospital in Staten Island, New York for help, the transmission was so clear that the incredulous hospital operator kept having the captain repeat his "address." "Nine hundred miles off the coast of Bermuda," the exasperated captain kept repeating. Finally the operator cried, "I've heard all that. Just tell me where to send the ambulance."

CHAPTER THIRTEEN: THE PATH TO THE 1990S

In a statement marking the 20th anniversary of COMSAT in 1983, Massachusetts Senator Edward M. Kennedy said, in part:

> . . . Through COMSAT, we have learned anew the fundamental truth of the interdependence of the modern world. Information and technology transcend national borders and provide important building blocks for peace . . .
>
> The example of COMSAT . . . reminds us of the power of technology and the fundamental choice that humanity must make. Do we, as John Kennedy hoped, "advance the peaceful and productive use of space to accelerate the march of civilization?" Or, do

> we make space an arena for the arms race and accelerate the march of destruction?
>
> . . . Satellites . . . are circling the earth providing the kind of instant communications once mentioned only in science fiction. We know now that when we reach boldly into the future, we can accomplish important things. All those who have been a part of this magnificent endeavor can take pride in their participation. "Together," President Kennedy said, "let us explore the stars and invoke the wonders of science instead of its terrors." COMSAT has met the challenge of that last great frontier.

When John Evans came to COMSAT Labs in April of 1983, he was about to take on one of the great challenges of his distinguished career. It was a difficult period for the labs. Twenty years after the founding of COMSAT, the great frontiers in space had long since been conquered. The new challenges involved perfecting the art, while at the same time trying to make sure the money was available to continue what was to be very sophisticated R&D for the next generation of satellite systems.

A native of the United Kingdom, Evans came to the U.S. in 1960 to work at MIT's Lincoln Laboratory. There he met Jack Harrington who was director of the Radio Physics Division.

"They had built a very high powered radar which was capable of getting echoes from Venus and had in the planning process a still more powerful one that could get echoes from Venus, Mars and Mercury," Dr. Evans explained. "I was in Radar Astronomy, having worked in that field in Britain, studying reflection properties of the moon, so I went to work for Jack."

Dr. Harrington left three years later to become head of MIT's Center for Space Research, set up in conjunction with NASA to serve as a bridge between different departments -- physics, chemistry, etc. During this period Dr. Harrington served as a consultant to COMSAT which had been trying to woo him away from MIT, almost since the company's inception. Harrington, in fact, had been a strong supporter of the need for a research facility. "Engineers don't last long as paper-pushers," he said, arguing if COMSAT were to be an "intelligent buyer" of technology, it needed people who knew what they were buying. As chairman of a committee to evaluate the need for a labs -- along with Sig Reiger, Jack Morton of Bell Labs and fellow MIT department head Bill Davenport -- he helped write the charter for the labs, which Reiger then presented successfully to the board of directors. While at MIT, Harrington had consulted on a number of technical projects for COMSAT, including the challenging problem of maintaining stability in the INTELSAT IV satellite with its new despun antenna. The symbiotic relationship turned into a formal one when Harrington became Vice President of Research and Engineering in the mid-1970s. He took over as director of the labs when Dr. Edelson left.

At about that time, Harrington and Evans bumped into each other at an airport one afternoon. The fortuitous meeting had long-range consequences.

"He told me that COMSAT was looking for people to fit various positions and was I interested. One thing led to another and I ended up coming here."

Evans joined as director of research, reporting directly to Harrington. He was also heir-apparent to the lab director's job. However, he was not aware that he would make the step to the top spot so rapidly. Harrington opted for early retirement and Evans therefore became the fourth director of the labs in October of 1983, just six months after coming to COMSAT.

It was a difficult time at the labs which was laboring through a period of transition that was taking its toll on morale, resulting in an escalating turn-over.

"The corporation had been engaged in a battle since 1979 with the FCC over the process of funding research at the labs and charging U.S. rate-payers for it," Evans explained. "This battle came to a close in 1984 when the FCC basically enjoined us from doing that to the degree we had. It essentially said that for any basic research that was funded with any jurisdictional funding component, there had to be a matching component from the corporate shareholders. They set a formula for doing that which put it about four-to-one, four times as many dollars from the shareholders had to go into this pool as you could charge rate-payers. We appealed and it ended up being two-to-one."

The consequence was that while COMSAT Labs was being called upon to develop some very complex, very sophisticated systems, the research budget was shrinking.

"My research budget the first year I was here was $18 million," Evans said. By 1986, it was $8 million."

The shrinking budget and the shifting emphasis at the labs created a sense of uncertainty. The size of the staff fell from more than 600 to under 400. The situation required a new sense of purpose. Evans felt the answer lay in taking on a difficult new challenge -- the serious competition from fiber-optic cables -- the biggest threat to satellites' domination of international communications since the launch of Early Bird.

"I think that this must have been a very exciting place in 1967 when the lab was first formed and 1969 when the people moved out here," Evans said. "It must have been akin in some respects to the early people in NASA who had the job of getting to the moon in 10 years time. In some ways we're victims of our own success. The INTELSAT system has worked, created a global satellite system, that carries two-thirds of the world's communications."

In view of what had been accomplished via INTELSAT, Evans said he felt the only reason the undersea cables continued to be used after the dawn of the satellite age was because AT&T and the European PTTs kept traffic on the cables even while more and more customers moved to satellites. That move paid off for them with the development of the fiber-optic cable.

"With the advent of fiber-optic cables, the tables have been turned on the satellites," Evans said. "You now have a technology which probably has greater capacity than the satellites or at least as much potentially. So the problem we have is trying to remain competitive with this technical threat. The approach we've been taking, and the research we've largely been doing to address it, is to say the cable only delivers the traffic to the shore and it then has to fan out through a network of either cables or microwave links to get to the ultimate customers. If satellites could be designed to deliver traffic much more closely to the ultimate customer, and bypass a lot of the internal toll charges, we could probably be as cheap or cheaper than the Trans-Atlantic cable when its 'tail' costs are added."

So that was the direction in which Evans pointed the labs. Such a dramatic new satellite system would be built very differently from previous ones. Up until that point, satellites illuminated large portions of the earth's surface, all of Africa, Europe, etc. -- the so-called hemispheric beams. As such, the intensity of the signals falling in the areas illuminated were relatively weak because they spread out over a big surface. If you could focus the beam on the satellite to just aim the signals where you wanted them -- in effect create a very thin, or "pencil" beam -- you could receive those signals with very much smaller antennas than were currently used, while keeping the transmitter power on the satellite constant. The existing INTELSAT system was designed basically with very simple satellites and large, expensive earth stations -- the big INTELSAT Standard A earth stations. Therefore, a principal objective was to reduce the cost of the earth stations so users could afford many more of them, and they could be placed around the countryside where they were needed. COMSAT Labs' objective was to invert the cost structure, i.e. shift any increase in cost to the satellites -- since they were much fewer in number -- and make the earth stations correspondingly cheaper, because there were a lot more of them. The scientists and engineers began working on technologies to create the pencil beam antennas for the satellites. Of course, the challenge involved solving complex problems, but that was the stock in trade of COMSAT Labs.

At the same time this was occurring, an old player was brought back into the commercial communications satellite game, NASA. NASA had all but bowed out of the arena with the establishment of COMSAT in 1963. But Presidential directive PD-42, issued in 1978, changed all that. It directed NASA back into the communications satellite arena to help build the satellite system of the

1990s and beyond. To do that would take resources far beyond those available to the private sector, for which the risks were deemed too great and the potential rewards too far over the horizon. Not to mention the fact that foreign competitors, the Japanese in particular, were marking the trails to the new satellite technologies, so there was pressure for the U.S. to stay in the game.

NASA'S reentry into communications satellite R&D was dubbed Advanced Communications Technology Satellite (ACTS). The objectives were to develop areas of advanced technology with NASA assuming the high level of risk involved, test the performance of systems and subsystems, bring the technology to flight readiness, then verify the technology in experimental use.

In a sentence, ACTS would be an advanced switching communications satellite -- a high-speed switchboard in the sky -- which utilized high-powered, narrow-scanning beams to achieve geographically targeted, point-to-point communication. A lot of the ACTS program objectives overlapped the direction in which Evans was taking the Labs.

RCA was awarded the principal contract. COMSAT Labs was selected to design and develop the ground elements of the system, including the earth stations and the master control station, one of the most complex pieces of hardware ever attempted for a communications satellite system.

So the teams at the labs went to work on the new technologies that would send and receive signals in far more well-defined routes, and to solve the myriad problems that would arise in trying to create the new pencil beam systems.

"Once you introduce these pencil beams you have a problem that signals which go up one beam have to be switched on board the satellite to go down the right beam and arrive at the proper destination," Evans explained. "So the satellite has to have on board some processing capability. It has to be able to recognize the destinations of the signals and possibly store them. The down-beam may not be directed exactly where you want it at the moment you want to send those signals. Or, you have a packet of arriving signals, a burst with traffic in it for different destinations, and you have to pull it apart. The simple way to handle that is to demodulate the arriving signals, recover the actual digital bits, and store them in a memory of some kind and then switch out of the memory the pieces you need to the appropriate destinations."

Basically it was the same idea that would dominate the design of ACTS experiment, with some important exceptions. The ACTS experiment involved frequencies in the Ka band, the highest frequencies assigned to the international satellite service. The most heavily used bands to that point were the C band, at 6 to 4 gigahertz or 5 and 7-1/2 cm wavelengths; and the Ku band, at 12 and 14 gigahertz or roughly 2-1/2 and 2 cm wavelength. The Ka band that ACTS was working with was 20 and 30 gigahertz, or 1-1/2 and 1 cm wavelength. At those high frequencies and correspondingly small wavelengths, the effects of rain-fading get to be very severe.

In Evans's view the Ku band frequencies were not yet so busy that they needed to go up to Ka band. His other key difference with the direction of the ACTS experiment involved antenna technology.

"What they were doing to move their beams around was simply turning horns on and off with ferite switches," Evans explained, "which is a way to go but is heavy and slow. We believed that the way to do it was the same way some radars are now made, to scan pencil beams around electronically with phased-array technology."

Then there was the matter of the on-board processor. Evans felt the one being used in the ACTS experiment was of limited capability and forced everybody to address the satellite with a TDMA system at a certain bit rate.

"We think that a commercial satellite will be successful only if users have a much greater freedom to choose what kind of bit rate they want, what kind of modulation scheme they want, and so on," he explained. "You don't force them all into the same mode. So, we addressed these other facets to make a truly successful commercial international satellite."

That involved work in four of the technical divisions at the Labs: Microwave Division, to design the antenna; Microelectronics Division, to design the electronic chips that would go in the antenna; Communication Techniques Division to design the on-board processing equipment; and Applied Technologies Division, to develop light-weight power supplies for the antenna array and remove the heat from it. It was the first time in a long time, that the labs had a focused program integrating as many as four of the six divisions into a common objective and a common theme. But there were monumental issues that had to be addressed.

Meanwhile, the INTELSAT VI series of satellites, being built by Hughes, was nearing deployment. The VIs would be the final generation utilizing essentially the existing technology, but carrying it to the nth degree -- i.e. using the satellite as simply a microwave repeater.

"Think of a microwave repeater on the ground," Evans explained. "Basically a tower is built with an antenna that looks at a distant tower. The signals are received and picked up by this antenna, then go down through a cable. They're amplified, their frequencies changed, further amplified, and then with the small power of a few watts go up another cable into another antenna that beams them on. Our satellite is a microwave repeater in space. It receives the signals from the ground on one frequency, amplifies them, changes the frequency, and re-transmits them in the new frequency, back to the ground. If you didn't change the frequencies, you'd have the danger of the transmitted signals being picked up by the receiving antenna and the whole thing would go into self-oscillation."

The INTELSAT VIs were not designed to do any processing on board. However, the major advance in the current technology that had been incorporated into the satellite was the re-use of the C-band frequencies several times over.

"In INTELSAT VI, the C-band frequencies are actually used six times," Evans said. "There's a hemispheric beam that illuminates South America and North America and uses the frequencies once; another hemispheric beam that illuminates the Atlantic Ocean, Africa and Europe and uses the frequencies a second time.

There are so-called regional beams which illuminate Europe and North America, with the opposite sense of circular polarization, so that you use the frequencies a third and fourth time. Then there is another regional beam on Africa and South America again with the same opposite sense of circular polarization, using it a fifth and sixth time. Finally, there are some transponders that have narrow spot beams at Ku band. But they're basically what we call 'bent-pipe' satellites -- they take the signals, amplify them and re-transmit them."

The work at COMSAT Labs contributed to how the antennas were built, and how you broke down the frequency band into narrow channels which could most effectively use available spectrum assigned through the FCC. That involved creating microwave filters which confine the operation of each of the repeater amplifiers into the appropriate range of frequencies without spilling over into adjacent ones. The INTELSAT VI was built with 48 transponders capable of carrying about 40,000 circuits without circuit multiplication. It was very large -- 40 feet tall -- and in the view of many of the people at

COMSAT Labs, the last of the big satellites.

Some of the differences in the development of the new technologies being work on at the Labs and the ACTS experiment involved mission. ACTS was being developed as a domestic system. The Labs envisioned a new satellite that would be used internationally and had all the right ingredients to be a commercial success. On the other hand, outside of the ACTS program, COMSAT Labs had to take the economic risks of developing new technologies onto its own shoulders, in expectation that at some time it would be developed to the point where they could make a convincing case to INTELSAT, and to the manufacturers, that this was the way to go, if they were to compete effectively against fiber optics.

"Formerly, when we were the technical manager for INTELSAT, we could take positions that this is what should be done and more or less carry it," Evans said. "We were now a lot weaker in that we were no longer the technical manager, so we could only argue as one of the owners that this is what should happen."

Even before they got that far, the Labs would have to convince its own corporate hierarchy at COMSAT itself, which was paying for the research, that they were not wasting the company's money, that they were building a case for a change in the technology that would give them a fighting chance to compete with the cables. If something were not done, the cables would increasingly eat into the two-thirds of the world's overseas traffic that satellites were carrying, bringing that share of traffic down to half or even less over the course of several years.

The new competition would be played out on a field that had lower cost as its principle objective, not increased capacity.

"In the early days capacity was the issue," Evans said. "Early Bird had 240 circuits and that was about equal to the capacity of the undersea cables at that time. I can remember phoning England in those days. You called AT&T and asked them to 'book you' to England. They called back a day or so later and said your call to England is now being put through. We've made enormous strides since then."

In the first several years of INTELSAT's operation, circuit capacity compounded at 20% per year. The real issue was to try and get more and more capacity out of the satellite. They made some technical mistakes, like trying to expand capacity by only broadening the bandwidth of the one or two transponders on the first satellites. They tried to make them cover a bigger and bigger band and that proved not to be the way to go because the amplifier on the transponder had, as its final stage a traveling wave tube, a microwave vacuum tube amplifier, with some unfortunate properties. It was a very non-linear device and in electrical circuits, if you put two signals into a non-linear device, they mix together and create unwanted new components which spill over and mix with other signals. Trying to put more and more signals into these broader and broader bandwidth transponders just created continual problems and the decision was made to go to narrow transponders, lots of them, which became operational with INTELSAT IV.

"That was a turning point in the ability to really create this capacity," Evans explained. "We killed the capacity problem and that was a factor in our research -- we have virtually stopped working on trying to create additional capacity. That problem is dead and buried."

The next great challenge was lowering the costs to the ultimate customer, the end-user. That, however, would have to be done within a dynamic environment, the rules of which seemed to change as they were being formulated. For example, in a communications world that had seen the break-up of AT&T a few years before and the spin-off of smaller companies, many of which were competing for the same long-distance traffic, should COMSAT deal directly with the regional operators, offering to install an antenna in each of their regions and taking their overseas traffic out for them as a way of trying to compete with AT&T? The Labs was now operating in a crazy world in which AT&T owned the customers -- an as such was COMSAT's largest customer. Yet because AT&T owned the undersea cables, it was also a competitor. Since AT&T also <u>manufactured</u> the undersea cables, it enjoyed a situation that COMSAT did not.

"When AT&T builds an undersea cable which is going to cost $400 million dollars, it gets to put its investment in that cable into its rate base," Dr. Evans explained. "It's allowed to earn say 10% on that rate base. So, there's no risk to AT&T laying all kinds of cables. If they're allowed to put them into the rate base, the customers, the American people, eventually pay for the cost of that facility. And they've never been turned down on a request to build a cable. They come in and argue with the FCC on the grounds of traffic -- they need it (the cable). If the FCC says, 'no, you've not made your case,' they argue on, 'it's new technology' or 'we need it for military reasons and the military would like not to depend on the satellites,' and they get approval. Once having laid the cable, they now have every incentive to load it with traffic while they lease circuits from COMSAT a circuit at a time. In an ideal world, the government would have created an entity like COMSAT -- say 'COMCABLE' -- which would be selling overseas cable circuits. The two could go head-to-head with their different technologies and neither would own the customers."

AT&T had been left owning the cables. It was merely prevented from getting into the satellite business, by the Communications Satellite Act of 1962. When AT&T built the first communications satellite, TELSTAR, the government became concerned that Ma Bell would extend its domestic monopoly into a global monopoly. So the Act had the effect of taking AT&T out of a potential monopoly situation in the satellite business.

"One of the ironies of that," Evans said, "is after the government took them out of the satellite business, they had every incentive to pour money into cable research, and they came up with the fiber-optic cable."

When asked to assess the communications satellite industry from the perspective of 25 years, Dr. Charyk said there had been a clouding of the more clearly defined objectives that existed when he'd become COMSAT's first president. He emphasized that early on they had seen the importance of establishing a well-recognized level of technical excellence and that the result had been to define COMSAT Labs as the repository of communications satellite technical expertise.

"If you go anywhere in the world and ask where does the most information on communication satellites exist," he said, "I think you'll find that COMSAT Labs is a household word. I think we can be proud of the kind of work that has been done. At the outset, there was never any question in anybody's mind, including the regulatory authorities and the Congress, that we had to spend a significant amount of money in doing research and development, otherwise you aren't going to be the leader very long. As long as the present legislation stays in effect, which says that COMSAT is the designated entity of the United States, then I think it is in the interest of the United States, if we are going to maintain the leadership role in communications satellite technology, to ensure that a proper level of R&D work is done, because once you have lost your leadership role, it is almost impossible to regain it."

He said there was a real challenge to the leadership role in the emergence of new pockets of technical excellence throughout the world.

"If the U.S. is going to maintain a leadership role," he said, "it is even more important than it was at the outset to make sure that we do the kind of work that is necessary, over a broad spectrum. Once you begin to cut way back, there is a serious danger that the sort of unique leadership role that the United States has enjoyed over all of these years will vanish. Whereas in 1962, although a lot of people didn't agree that this was the way to go, once the national policy was embodied in law, people said, 'if that's the law, okay, we'll follow it.' Unless there is someone saying this is the policy of this country, more and more questions are going to be raised by more and more people, and the end result will be the loss of U.S. leadership in this technology. We're getting perilously close to that now."

CHAPTER FOURTEEN: PUTTING IT ALL IN PERSPECTIVE

While an understanding of the complex solutions to complex problems solved by the people of COMSAT Laboratories over the years may elude all but the most technically minded among us, the applications of many of those technologies are readily apparent in many areas. The most obvious indication to the world that Early Bird was up there and functioning was not so much the news reports that heralded the accomplishment of the launch and the proper positioning of the satellite in geostationary orbit, but the television programs that began to appear from across the Atlantic and the new caption line, "live via satellite," or "live via Early Bird," that was appearing with greater frequency across the bottom of TV pictures.

The escalation of the Vietnam War during the 1960s, was watched as it unfolded on the television sets of Americans back home, as they sat down to their evening meals and the stark differences between the comfort of their surroundings versus the rice paddies and gun emplacements of the men overseas were not lost on many. For the first time in American history, the folks back home got to observe the effects of the decisions being made in the meeting rooms of Congress, the offices of the White House or the halls of the Pentagon on the foot soldiers in the Mekong Delta, the pilots at Bien Hoa, the marines dug in at Khe Sanh.

Much of the material for those broadcasts was recorded on the battlefields then transmitted over the global satellite network. The effects of this kind of expansive, live or same-day news coverage, now possible from the most remote corners of the earth, were profound. The ultimate result was a smaller world, with fewer secrets.

"NBC-TV's Huntley-Brinkley Report on Feb. 2 presented via satellite one of the more stark realities of the war in a film sequence in which South Vietnamese Police Chief General Loan executed a Vietcong terrorist," read a caption in Broadcasting magazine, February 12, 1968. That photo shocked Americans, many of whom had images of America's allies as men involved in the necessary evils of war, not as perpetrators of those evils.

But all was not the dark side in the broadcasts that were splashed across TV screens. On the brighter side, the launch of the early communications satellites ushered in a series of TV audience "records" that were eclipsed almost as soon as they were set, with the Olympics outdoing the previous World Cup Soccer matches, which had outdone the previous Olympics, and so on.

Perhaps the most dramatic live coverage of all was the historic Apollo 11 landing on the moon in July of 1969. More television coverage of the epic mission, from lift-off to splash-down, was transmitted overseas via satellites to a worldwide audience that was larger than any previous event. Portions of the mission were seen by an estimated 500 million viewers in more than 40 countries on five continents. There were more than 230 hours of satellite time, involving about 200 individual programs, during the nine-day mission. Along with satellites over the Atlantic, Pacific and Indian Oceans, 20 earth stations interconnected with terrestrial networks carried the programming to the broad-based audience.

The live video of the moon walk by Neil Armstrong as he stepped down from the landing vehicle, Eagle, at 10:56 p.m. (EDT) on Sunday, July 20, 1969, was received by the big NASA parabolic dish antenna at Goldstone, California and at the Parkes Observatory in Australia, then the signals relayed via land lines and ultimately INTELSAT III satellites. The telecasts from "Tranquility Base" on the surface of the moon, 240,000 miles away, were made possible via the global satellite system and the skills of people around the world, who had become part of the expanding network during the five years since its inception. Even coverage of the splash-down in the Pacific went without a hitch via signals transmitted through a small earth station aboard the recovery carrier USS Hornet and relayed via the INTELSAT III satellite over the Pacific.

In the process of developing the technologies for the INMARSAT systems, smaller, more-efficient end products began to emerge. The development of the MCS-9100, a light-weight, extremely compact earth station that expanded the market for satellite communications to pleasure yachts as small as 50 feet in length, had applications far beyond its maritime uses. The core technology developed for the MCS-9100 was modified for land-based applications and the result was the TCS-9000, literally an "earth station in a suitcase" -- well, actually two suitcases, weighing less than 100 pounds.

The TCS-9000 brought portability to earth stations. Folding up into two weather-tight suitcases, the unit required only 385 watts of power, but its reach was incredible. The user could connect with the worldwide public switched telephone network, in effect plugging into a system that covered the globe. It could be transported as luggage aboard a commercial aircraft, or fit in the trunk of a car. And, remarkably, the system could be unpacked and set up in less than 15 minutes.

The user could pick up the telephone on the TCS-9000 and it was like picking up a telephone in the home or office. You could direct-dial to almost anywhere, while almost anyone who had a telephone could reach you. The connection was of long-distance telephone quality, i.e. no static attendant to HF radio systems. Furthermore the call enjoyed the privacy of a long-distance call, as opposed to radio calls that could be heard by anyone who happened to be tuned into your frequency. It was a powerful capability to have when the user was at an otherwise inaccessible location with a real need to receive and/or send information.

The Mexico City earthquake of September 1985 was a dramatic case in point. That quake, which resulted in almost 10,000 deaths and the loss of hundreds of buildings, wiped out Mexico City's terrestrial communications with the outside world. Immediately upon getting word of the disaster, engineers at COMSAT Labs began working to apply their particular talents, along with hardware they'd created, to re-establish a link to the devastated capital -- a city that had grown to almost 16 million people, the largest metropolis on earth. Concurrently, the broadcast media were in the midst of a frantic search to open communications lines for correspondents covering the tragedy. Within 36 hours of the quake, one COMSAT TCS-9000 was on the scene, with a second on the way, and a SkyBridge satellite broadcasting vehicle was being airfreighted in the cargo compartment of a C-130 aircraft.

The first TCS-9000 established a telephone link at Channel 13, Mexico City's only surviving television station, while the second was set up at the El Camino Real, a hotel popular with business people and tourists. A sign-up sheet procedure was established for the telephone, where a line of people soon materialized and continued 24 hours a day.

With the arrival of the SkyBridge, national news anchors Tom Brokaw and Peter Jennings were able to broadcast on-the-scene reports of the devastation and the search for survivors, including emotionally uplifting reports that people were in fact being found alive beneath the rubble.

The demonstration of this incredible shrinking technology began to raise expectations about just how portable such space age systems could eventually be made. Was a Dick Tracy wrist radio looming just over the horizon?

"A commercial wrist radio, usable for two-way communications with anyone anywhere in the world, is a lot closer than the average person suspects," a COMSAT executive remarked at the time.

Applications of technology designed and developed at COMSAT Labs was not limited to the broadcast image or sound, however. On September 23, 1974, COMSAT and Dow-Jones joined forces to transmit a production-quality page from the Dow-Jones regional composition plant in Chicopee, Massachusetts, to the publishing company's printing plant in South Brunswick, New Jersey. The result of the collaboration appeared as page 22 in the following day's edition of The Wall Street Journal.

To implement the procedure, COMSAT set up a small earth station at the Chicopee plant, which beamed its data off an INTELSAT IV satellite over the Atlantic, which in turn retransmitted the data down to a receive-only earth station at the South Brunswick plant. The photo film facsimile received in New Jersey was then used to create lithographic press plates for production pages. High-resolution scanners and recorders, data compression units and digital communication channel units made the process possible. It was the first time an entire process from composition to printing was conducted via satellite transmission.

"Of course that wasn't a very long distance from Chicopee to South Brunswick," Dr. Burton Edelson explained, "however what we showed was if you can transmit it from A to B, using the same facilities you can transmit it to point C, D, E, F and G as well. It really made a lot of difference. Now, not only Dow Jones is using it, but The New York Times, of course USA Today lives off it, the Christian Science Monitor is using it, Reuters and others. We created a whole new industry. With regard to the <u>Wall Street Journal</u>, they had printing plants in several places. After this demonstration, they decided to build a printing plant in Orlando, Florida. They put an earth station right on the lawn there. That printing plant has no writers, no editors, no journalists or proof-readers, etc. The only thing they've got is an electronic link that comes into the building and people there to develop the fax, put it on the plates, run the printing presses, load the newspapers and send them out of the plant. Then they started building these printing plants all around the country."

Perhaps the ultimate vote of confidence in the technology came when the U.S. and USSR announced in 1971 an agreement to shift the Hot Line link between the two countries to satellites. The agreement was designed to take advantage of the new communications satellite technologies developed independently in both countries and to improve upon the terrestrial Hot Line system, established in 1963. That Hot Line consisted of two teleprinters -- one in Washington and one in Moscow --

connected by a wire telegraph circuit routed under the Atlantic, then via London, Copenhagen, Stockholm and Helsinki. There was also a back-up radio telegraph circuit via Tangier.

Under the satellite agreement, there would be multiple terminals in each country, providing greater flexibility and reducing the risk of outages associated with the vulnerability of each capital during periods of "hostile environment."

The satellite Hot Lines were set up as duplex, telephone-bandwidth circuits, equipped for secondary telegraph multiplexing as well.

Both the INTELSAT system and the Russian MOLNIYA system were employed for the Hot Line to provide a level of redundancy.

The system which involves encoding, decoding and translations of alphabets is tested continually and has proved to be highly efficient since its inception.

These and scores of other widely used applications have translated the two decades of developments at COMSAT Labs into ingredients of every day life throughout the world. Their greatest achievement is perhaps the fact that they are now totally taken for granted by those who used them as a matter of course.

As commercial communications entered the latter part of the 1980s, the major battle lines were drawn between advanced technology communications satellites and the fiber optic cable. It could be looked upon as the good fight between two highly developed technologies. Unquestionably, there was room for both, each with its particular advantages. COMSAT Labs, however, was left with the task of demonstrating that this was indeed the case.

As for the communications satellites that had put the peoples of the world in easy touch with each other, Irving Goldstein, chairman and chief executive officer of COMSAT, offered this perspective on the first quarter century:

"When the final chapter is written a thousand years from now, I think I'd like it to say that what was accomplished here was accomplished through creative, innovative, healthy use of technology that benefitted the country, and benefitted the world. It was technology as well as good common business sense that made that happen and it really shows how clever, how far-sighted, the framers of the original Communication Satellite Act were. It's the only significant example of the commercialization of that kind of technology that's occurred yet in the world. It may prove to be the most significant ever. The people in that Kennedy era decided to take a major technology that had international and strategic implications for the United States and instead of holding it and hiding it, to give it to the rest of the world. By doing that, it would help us as well as everyone else. This had not been done from time immemorial, whether it was the crossbow or the long bow or whatever, anyone who had it kept it and tried not to let anyone else know about it. Instead, in the case of communications satellites, the idea was to broadcast it. I think that proved to be right."

The on-going role of communications satellites was perhaps best described by Arthur C. Clarke, when in the British magazine, Spaceflight, he likened them to the

Tower of Babel:

"Higher than the wildest dreams of its builders, 22,300 miles above the earth, we may regain what was once lost, when the Lord said, 'Behold they are one people, and they have all one language, and this is only the beginning of what they will do; and nothing that they propose to do will now be impossible to them.'"