**Communications Satellites Facts**

**by David J. Whalen**

In 500 years, when humankind looks back at the dawn of space travel, Apollo's landing on the Moon in 1969 may be the only event remembered. At the same time, however, Lyndon B. Johnson, himself an avid promoter of the space program, felt that reconnaissance satellites alone justified every penny spent on space. Weather forecasting has undergone a revolution because of the availability of pictures from geostationary meteorological satellites--pictures we see every day on television. All of these are important aspects of the space age, but satellite communications has probably had more effect than any of the rest on the average person. Satellite communications is also the only truly commercial space technology- -generating billions of dollars annually in sales of products and services.

**The Billion Dollar Technology**

In fall of 1945 an RAF electronics officer and member of the British Interplanetary Society, Arthur C. Clarke, wrote a short article in *Wireless World* that described the use of manned satellites in 24-hour orbits high above the world's land masses to distribute television programs. His article apparently had little lasting effect in spite of Clarke's repeating the story in his 1951/52 *The Exploration of Space* . Perhaps the first person to carefully evaluate the various technical options in satellite communications *and* evaluate the financial prospects was John R. Pierce of AT&T's Bell Telephone Laboratories who, in a 1954 speech and 1955 article, elaborated the utility of a communications "mirror" in space, a medium-orbit "repeater" and a 24-hour-orbit "repeater." In comparing the communications capacity of a satellite, which he estimated at 1,000 simultaneous telephone calls, and the communications capacity of the first trans-Atlantic telephone cable (TAT-1), which could carry 36 simultaneous telephone calls at a cost of 30-50 million dollars, Pierce wondered if a satellite would be worth a billion dollars.

After the 1957 launch of Sputnik I, many considered the benefits, profits, and prestige associated with satellite communications. Because of Congressional fears of "duplication," NASA confined itself to experiments with "mirrors" or "passive" communications satellites (ECHO), while the Department of Defense was responsible for "repeater" or "active" satellites which amplify the received signal at the satellite--providing much higher quality communications. In 1960 AT&T filed with the Federal Communications Commission (FCC) for permission to launch an experimental communications satellite with a view to rapidly implementing an operational system. The U.S. government reacted with surprise-- there was no policy in place to help execute the many decisions related to the AT&T proposal. By the middle of 1961, NASA had awarded a competitive contract to RCA to build a medium-orbit (4,000 miles high) active communication satellite (RELAY); AT&T was building its own medium-orbit satellite (TELSTAR) which NASA would launch on a cost-reimbursable basis; and NASA had awarded a sole- source contract to Hughes Aircraft Company to build a 24-hour (20,000 mile high) satellite (SYNCOM). The military program, ADVENT, was cancelled a year later due to complexity of the spacecraft, delay in launcher availability, and cost over-runs.

By 1964, two TELSTARs, two RELAYs, and two SYNCOMs had operated successfully in space. This timing was fortunate because the Communications Satellite Corporation (COMSAT), formed as a result of the Communications Satellite Act of 1962, was in the process of contracting for their first satellite. COMSAT's initial capitalization of 200 million dollars was considered sufficient to build a system of dozens of medium-orbit satellites. For a variety of reasons, including costs, COMSAT ultimately chose to reject the joint AT&T/RCA offer of a medium-orbit satellite incorporating the best of TELSTAR and RELAY. They chose the 24-hour-orbit (geosynchronous) satellite offered by Hughes Aircraft Company for their first two systems and a TRW geosynchronous satellite for their third system. On April 6, 1965 COMSAT's first satellite, EARLY BIRD, was launched from Cape Canaveral. Global satellite communications had begun.

**The Global Village: International Communications**

Some glimpses of the Global Village had already been provided during experiments with TELSTAR, RELAY, and SYNCOM. These had included televising parts of the 1964 Tokyo Olympics. Although COMSAT and the initial launch vehicles and satellites were American, other countries had been involved from the beginning. AT&T had initially negotiated with its European telephone cable "partners" to build earth stations for TELSTAR experimentation. NASA had expanded these negotiations to include RELAY and SYNCOM experimentation. By the time EARLY BIRD was launched, communications earth stations already existed in the United Kingdom, France, Germany, Italy, Brazil, and Japan. Further negotiations in 1963 and 1964 resulted in a new international organization, which would ultimately assume ownership of the satellites and responsibility for management of the global system. On August 20, 1964, agreements were signed which created the International Telecommunications Satellite Organization (INTELSAT).

By the end of 1965, EARLY BIRD had provided 150 telephone "half- circuits" and 80 hours of television service. The INTELSAT II series was a slightly more capable and longer-lived version of EARLY BIRD. Much of the early use of the COMSAT/INTELSAT system was to provide circuits for the NASA Communications Network (NASCOM). The INTELSAT III series was the first to provide Indian Ocean coverage to complete the global network. This coverage was completed just days before one half billion people watched APOLLO 11 land on the moon on July 20, 1969.

From a few hundred telephone circuits and a handful of members in 1965, INTELSAT has grown to a present-day system with more members than the United Nations and the capability of providing hundreds of thousands of telephone circuits. Cost to carriers per circuit has gone from almost $100,000 to a few thousand dollars. Cost to consumers has gone from over $10 per minute to less than $1 per minute. If the effects of inflation are included, this is a tremendous decrease! INTELSAT provides services to the entire globe, not just the industrialized nations.

**Hello Guam: Domestic Communications**

In 1965, ABC proposed a domestic satellite system to distribute television signals. The proposal sank into temporary oblivion, but in 1972 TELESAT CANADA launched the first domestic communications satellite, ANIK, to serve the vast Canadian continental area. RCA promptly leased circuits on the Canadian satellite until they could launch their own satellite. The first U.S. domestic communications satellite was Western Union's WESTAR I, launched on April 13, 1974. In December of the following year RCA launched their RCA SATCOM F- 1. In early 1976 AT&T and COMSAT launched the first of the COMSTAR series. These satellites were used for voice and data, but very quickly television became a major user. By the end of 1976 there were 120 transponders available over the U.S., each capable of providing 1500 telephone channels or one TV channel. Very quickly the "movie channels" and "super stations" were available to most Americans. The dramatic growth in cable TV would not have been possible without an inexpensive method of distributing video.

The ensuing two decades have seen some changes: Western Union is no more; Hughes is now a satellite operator as well as a manufacturer; AT&T is still a satellite operator, but no longer in partnership with COMSAT; GTE, originally teaming with Hughes in the early 1960s to build and operate a global system is now a major domestic satellite operator. Television still dominates domestic satellite communications, but data has grown tremendously with the advent of very small aperture terminals (VSATs). Small antennas, whether TV-Receive Only (TVRO) or VSAT are a commonplace sight all over the country.

**New Technology**

The first major geosynchronous satellite project was the Defense Department's ADVENT communications satellite. It was three-axis stabilized rather than spinning. It had an antenna that directed its radio energy at the earth. It was rather sophisticated and heavy. At 500-1000 pounds it could only be launched by the ATLAS- CENTAUR launch vehicle. ADVENT never flew, primarily because the CENTAUR stage was not fully reliable until 1968, but also because of problems with the satellite. When the program was canceled in 1962 it was seen as the death knell for geosynchronous satellites, three-axis stabilization, the ATLAS-CENTAUR, and complex communications satellites generally. Geosynchronous satellites became a reality in 1963, and became the only choice in 1965. The other ADVENT characteristics also became commonplace in the years to follow.

In the early 1960s, converted intercontinental ballistic missiles (ICBMs) and intermediate range ballistic missiles (IRBMs) were used as launch vehicles. These all had a common problem: they were designed to deliver an object to the earth's surface, not to place an object in orbit. Upper stages had to be designed to provide a delta-Vee (velocity change) at apogee to circularize the orbit. The DELTA launch vehicles, which placed all of the early communications satellites in orbit, were THOR IRBMs that used the VANGUARD upper stage to provide this delta-Vee. It was recognized that the DELTA was relatively small and a project to develop CENTAUR, a high-energy upper stage for the ATLAS ICBM, was begun. ATLAS-CENTAUR became reliable in 1968 and the fourth generation of INTELSAT satellites used this launch vehicle. The fifth generation used ATLAS-CENTAUR and a new launch-vehicle, the European ARIANE. Since that time other entries, including the Russian PROTON launch vehicle and the Chinese LONG MARCH have entered the market. All are capable of launching satellites almost thirty times the weight of EARLY BIRD.

In the mid-1970s several satellites were built using three-axis stabilization. They were more complex than the spinners, but they provided more de-spun surface to mount antennas and they made it possible to deploy very large solar arrays. The greater the mass and power, the greater the advantage of three-axis stabilization appears to be. Perhaps the surest indication of the success of this form of stabilization was the switch of Hughes, closely identified with spinning satellites, to this form of stabilization in the early 1990s. The latest products from the manufacturers of SYNCOM look quite similar to the discredited ADVENT design of the late 1950s.

Much of the technology for communications satellites existed in 1960, but would be improved with time. The basic communications component of the satellite was the traveling-wave-tube (TWT). These had been invented in England by Rudoph Kompfner, but they had been perfected at Bell Labs by Kompfner and J. R. Pierce. All three early satellites used TWTs built by a Bell Labs alumnus. These early tubes had power outputs as low as 1 watt. Higher- power (50-300 watts) TWTs are available today for standard satellite services and for direct-broadcast applications. An even more important improvement was the use of high-gain antennas. Focusing the energy from a 1-watt transmitter on the surface of the earth is equivalent to having a 100-watt transmitter radiating in all directions. Focusing this energy on the Eastern U.S. is like having a 1000-watt transmitter radiating in all directions. The principal effect of this increase in actual and effective power is that earth stations are no longer 100-foot dish reflectors with cryogenically-cooled maser amplifiers costing as much as $10 million (1960 dollars) to build. Antennas for normal satellite services are typically 15-foot dish reflectors costing $30,000 (1990 dollars). Direct-broadcast antennas will be only a foot in diameter and cost a few hundred dollars.

**Mobile Services**

In February of 1976 COMSAT launched a new kind of satellite, MARISAT, to provide mobile services to the United States Navy and other maritime customers. In the early 1980s the Europeans launched the MARECS series to provide the same services. In 1979 the UN International Maritime Organization sponsored the establishment of the International Maritime Satellite Organization (INMARSAT) in a manner similar to INTELSAT. INMARSAT initially leased the MARISAT and MARECS satellite transponders, but in October of 1990 it launched the first of its own satellites, INMARSAT II F-1. The third generation, INMARSAT III, has already been launched.

An aeronautical satellite was proposed in the mid-1970s. A contract was awarded to General Electric to build the satellite, but it was canceled--INMARSAT now provides this service. Although INMARSAT was initially conceived as a method of providing telephone service and traffic-monitoring services on ships at sea, it has provided much more. The journalist with a briefcase phone has been ubiquitous for some time, but the Gulf War brought this technology to the public eye.

The United States and Canada discussed a North American Mobile Satellite for some time. In the next year the first MSAT satellite, in which AMSC (U.S.) and TMI (Canada) cooperate, will be launched providing mobile telephone service via satellite to all of North America.

**Competition**

In 1965, when EARLY BIRD was launched, the satellite provided almost 10 times the capacity of the submarine telephone cables for almost 1/10th the price. This price-differential was maintained until the laying of TAT-8 in the late 1980s. TAT-8 was the first fiber-optic cable laid across the Atlantic. Satellites are still competitive with cable for point-to-point communications, but the future advantage may lie with fiber-optic cable. Satellites still maintain two advantages over cable: they are more reliable and they can be used point-to-multi-point (broadcasting).

Cellular telephone systems have risen as challenges to all other types of telephony. It is possible to place a cellular system in a developing country at a very reasonable price. Long-distance calls require some other technology, but this can be either satellites or fiber-optic cable.

**The LEO Systems**

Cellular telephony has brought us a new technological "system"-- the personal communications system (PCS). In the fully developed PCS, the individual would carry his telephone with him. This telephone could be used for voice or data and would be usable anywhere. Several companies have committed themselves to providing a version of this system using satellites in low earth orbits (LEO). These orbits are significantly lower than the TELSTAR/RELAY orbits of the early 1960s. The early "low-orbit" satellites were in elliptical orbits that took them through the lower van Allen radiation belt. The new systems will be in orbits at about 500 miles, below the belt.

The most ambitious of these LEO systems is Iridium, sponsored by Motorola. Iridium plans to launch 66 satellite into polar orbit at altitudes of about 400 miles. Each of six orbital planes, separated by 30 degrees around the equator, will contain eleven satellites. Iridium originally planned to have 77 satellites-- hence its name. Element 66 has the less pleasant name Dysprosium. Iridium expects to be providing communications services to hand- held telephones in 1998. The total cost of the Iridium system is well in excess of three billion dollars.

In addition to the "Big LEOS" such as Iridium and Globalstar, there are several "little Leos." These companies plan to offer more limited services, typically data and radiodetermination. Typical of these is ORBCOM which has already launched an experimental satellite and expects to offer limited service in the very near future.

**Prospect and Retrospect**

Arthur C. Clarke's 1945 vision was of a system of three "manned" satellites located over the major land masses of the earth and providing direct-broadcast television. The inherent "broadcast" nature of satellite communications has made direct-broadcast a recurrent theme--yet one never brought to fruition. The problems are not technical--they are political, social, and artistic. What will people be willing to pay for? This is the question-- especially with the availability of 120-channel cable systems. Hughes is apparently about to enter this field and may encourage others to do the same. Only then will Clarke's prophetic vision be fulfilled.

There are currently six companies providing fixed satellite service to the U.S.: GE Americom, Alascom, AT&T, COMSAT, GTE, and Hughes Communications. They operate 36 satellites with a net worth of over four billion dollars. The ground stations which communicate with these satellites are innumerable and may have a similar net worth. INTELSAT has had competition in the international market from Pan American Satellite since 1986. Orion Satellite is expected to begin international service in 1994. Since Canada began domestic satellite service in 1972, that country has been joined by the United States (1974), Indonesia (1976), Japan (1978), India (1982), Australia (1985), Brazil (1985), Mexico (1985), and many others. Each year from 10-20 communications satellites are launched valued at about $75 million each. The launch vehicles placing them in orbit have similar values. Both satellites and launch vehicles are multi-billion dollar businesses. The earth station business is equally large. Finally the communications services themselves are multi-billion dollar businesses. John R. Pierce was right--it would be worth a billion dollars.

**A Selective Communications Satellite Chronology**

* 1945 Arthur C. Clarke Article: "Extra-Terrestrial Relays"
* 1955 John R. Pierce Article: "Orbital Radio Relays"
* 1956 First Trans-Atlantic Telephone Cable: TAT-1
* 1957 Sputnik: Russia launches the first earth satellite.
* 1960 1st Successful DELTA Launch Vehicle
* 1960 AT&T applies to FCC for experimental satellite communications license
* 1961 Formal start of TELSTAR, RELAY, and SYNCOM Programs
* 1962 TELSTAR and RELAY launched
* 1962 Communications Satellite Act (U.S.)
* 1963 SYNCOM launched
* 1964 INTELSAT formed
* 1965 COMSAT's EARLY BIRD: 1st commercial communications satellite
* 1969 INTELSAT-III series provides global coverage
* 1972 ANIK: 1st Domestic Communications Satellite (Canada)
* 1974 WESTAR: 1st U.S. Domestic Communications Satellite
* 1975 INTELSAT-IVA: 1st use of dual-polarization
* 1975 RCA SATCOM: 1st operational body-stabilized comm. satellite
* 1976 MARISAT: 1st mobile communications satellite
* 1976 PALAPA: 3rd country (Indonesia) to launch domestic comm. satellite
* 1979 INMARSAT formed.
* 1988 TAT-8: 1st Fiber-Optic Trans-Atlantic telephone cable