1.2 A BRIEF HISTORY OF SATELLITE COMMUNICATIONS

Satellite communications began in October 1957 with the launch by the USSR of a small satellite called *Sputnik I*. This was the first artificial earth satellite, and it sparked the space race between the United States and the USSR. *Sputnik I* carried only a beacon transmitter and did not have communications capability, but demonstrated that satellites could be placed in orbit by powerful rockets. The first satellite successfully launched by the United States was *Explorer I*, lofted from Cape Canaveral on January 31, 1958 on a Juno I rocket. The first voice heard from space was that of President Eisenhower, who recorded a brief Christmas message that was transmitted back to earth from the Project Score satellite in December 1958. The *Score* satellite was essentially the core of the Atlas ICBM (intercontinental ballistic missile) booster with a small payload in the nose. A tape recorder on *Score* had a storage capacity that allowed a 4 min message received from an earth station to be retransmitted. The batteries on *Score* failed after 35 days in orbit.

After some early attempts to use large balloons (*Echo I* and *II*) as passive reflectors for communication signals, and some small experimental satellite launches, the first true communications satellites, *Telstar I* and *II*, were launched in July 1962 and May 1963. The Telstar satellites were built by Bell Telephone Laboratories and used C-band transponders adapted from terrestrial microwave link equipment. The uplink was at 6389 MHz and the downlink was at 4169 MHz, with 50-MHz bandwidth. The satellites carried solar cells and batteries that allowed continuous use of the single transponder, and demonstrations of live television links and multiplexed telephone circuits were made across the Atlantic Ocean, emphatically demonstrating the feasibility of satellite communications.

The Telstar satellites were launched into what is now called a medium earth orbit, with periods of 158 and 225 min. This allowed transatlantic links to operate for about 20 min while the satellite was mutually visible. The orbits chosen for the Telstar satellites took them through several bands of high energy radiation which caused early failure of the electronics on board. However, the value of communication satellites had been demonstrated and work was begun to develop launch vehicles that could deliver a payload to geostationary orbit, and to develop satellites that could provide useful communication capacity.

On July 24, 1961, U.S. President John F. Kennedy defined the general guidelines of U.S. policy in regard to satellite communications and made the first unambiguous references to a single worldwide system. On December 20, 1961, the U.S. Congress recommended that the International Telecommunications Union (ITU) should examine the aspects of space communications for which international cooperation would be necessary. The most critical step was in August 1962, when the U.S. Congress passed the *Communications Satellite Act*. This set the stage for commercial investment in an international satellite organization and, on July 19, 1964, representatives of the first 12 countries to invest in what became Intelsat (the International Telecommunications Satellite Organization) signed an initial agreement. The company that represented the United States at this initial signing ceremony was Comsat, an entity specifically created to act for the United States within Intelsat. It should be remembered that, at this point, the Bell System had a complete monopoly of all long-distance telephone communications within the United

States. When Congress passed the *Communications Satellite Act*, the Bell System was specifically barred from directly participating in satellite communications, although it was permitted to invest in Comsat.

Comsat essentially managed Intelsat in the formative years and should be credited with the remarkable success of the international venture. The first five Intelsat series of satellites (INTELSAT I through V) were selected, and their procurement managed, by teams put in place under Comsat leadership. Over this same phase, though, large portions of the Comsat engineering and operations groups transferred over to Intelsat so that, when the Permanent Management Arrangements came into force in 1979, many former Comsat groups were now part of Intelsat.

In mid-1963, 99% of all satellites had been launched into LEO. LEO, and the slightly higher medium earth orbit (MEO), were much easier to reach than GEO with the small launchers available at that time. The intense debate was eventually settled on launcher reliability issues rather than on payload capabilities. The first 6 years of the so-called space age was a period of both payload and launcher development. The new frontier was very risky, with about one launch in four being fully successful. The system architecture of the first proposed commercial communications satellite system employed 12 satellites in an equatorial MEO constellation. Thus, with the launch failure rate at the time, 48 launches were envisioned to guarantee 12 operational satellites in orbit. Without 12 satellites in orbit, continuous 24-h coverage could not be offered. Twenty-four hours a day, seven days a week—referred to as 24/7 operation—is a requirement for any successful communications service. A GEO systems architecture requires only one satellite to provide 24/7 operation over essentially one-third of the inhabited world. On this basis, four launches would be required to achieve coverage of one third of the earth; 12 for the entire inhabited world. Despite its unproven technological approach, the geostationary orbit was selected by the entities that became Intelsat.

The first Intelsat satellite, INTELSAT I (formerly *Early Bird*) was launched on April 16, 1965. The satellite weighed a mere 36 kg (80 lb) and incorporated two 6/4 GHz transponders, each with 25-MHz bandwidth. Commercial operations commenced between Europe and the United States on June 28, 1965. Thus, about 2 decades after Clarke's landmark article in *Wireless World*, GEO satellite communications began. Intelsat was highly successful and grew rapidly as many countries saw the value of improved telecommunications, not just internationally but for national systems that provided high quality satellite communications within the borders of large countries.

Canada was the first country to build a national telecommunication system using GEO satellites. Anik 1A was launched in May 1974, just 2 months before the first U.S. domestic satellite, WESTAR 1. The honor of the first regional satellite system, however, goes to the USSR Molniya system of highly elliptic orbit (HEO) satellites, the first of which was launched in April 1965 (the same month as INTELSAT I). Countries that are geographically spread like the USSR, which covers 11 time zones, have used regional satellite systems very effectively. Another country that benefited greatly from a GEO regional system was Indonesia, which consists of more than 3000 islands spread out over more than a thousand miles. A terrestrially based telecommunication system was not economically feasible for these countries, while a single GEO satellite allowed instant communications region wide. Such ease of communications via GEO satellites proved to be very profitable. Within less than 10 years, Intelsat was self-supporting and, since it was not allowed to make a profit, it began returning substantial revenues to what were known as its Signatories. Within 25 years, Intelsat had more than 100 Signatories[4] and, in early 2000, there were 143 member countries and Signatories that formed part of the international Intelsat community.

The astonishing commercial success of Intelsat led many nations to invest in their satellite systems. This was particularly true in the United States. By the end of 1983, telephone traffic carried by the U.S. domestic satellite systems earned more revenue than the Intelsat system. Many of the original Intelsat Signatories had been privatized by the early 1990s and were, in effect, competing not only with each other in space communications, but with Intelsat. It was clear that some mechanism had to be found whereby Intelsat could be turned into a for-profit, private entity, which could then compete with other commercial organizations while still safeguarding the interests of the smaller nations that had come to depend on the remarkably low communications cost that Intelsat offered. The first step in the move to privatizing Intelsat was the establishment of a commercial company called New Skies and the transfer of a number of Intelsat satellites to New Skies.

In the 1970s and 1980s there was rapid development of GEO satellite systems for international, regional, and domestic telephone traffic and video distribution. In the United States, the expansion of fiber-optic links with very high capacity and low delay caused virtually all telephone traffic to move to terrestrial circuits by 1985. However, the demand for satellite systems grew steadily through this period, and the available spectrum in C band was quickly occupied, leading to expansion into Ku band. In the United States, most of the expansion after 1985 was in the areas of video distribution and VSAT (very small aperture terminal) networks. By 1995 it was clear that the GEO orbit capacity at Ku band would soon be filled, and Ka-band satellite systems would be needed to handle the expansion of digital traffic, especially wide band delivery of high-speed Internet data. SES, based in Luxemburg, began two-way multimedia and Internet access service in western and central Europe at Ka band using the *Astra 1H* satellite in 2001[6]. Several Ka-band satellite systems are expected to be operational in the United States by 2003[7,8].

The ability of satellite systems to provide communication with mobile users had long been recognized, and the International Maritime Satellite Organization (Inmarsat) has provided service to ships and aircraft for several decades, although at a high price. LEO satellites were seen as one way to create a satellite telephone system with worldwide coverage; numerous proposals were floated in the 1990s, with three LEO systems eventually reaching completion by 2000 (Iridium, Globalstar, and Orbcomm). The implementation of a LEO and MEO satellite system for mobile communication has proved much more costly than anticipated, and the capacity of the systems is relatively small compared to

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The first step in the move to privatizing Intelsat was the establishment of a commercial company called New Skies. New Skies is based in the Netherlands and, on 30 November 1998, six satellites were transferred from Intelsat ownership to New Skies. There was one INTELSAT V series satellite (*IS-513* at 183° E), one INTELSAT VII series satellite (*IS-703* at 57° E), two INTELSAT VIII series satellites (*IS-803* at 338.5° E and *IS-806* at 319.5° E), the INTELSAT-K satellite (in inclined orbit at 338.5° E), and a new satellite designed for direct broadcast services (*K-TV* at 95° E). New Skies has as their prime businesses plan the provisioning of TV services, both distribution and direct to home.

Intelsat is currently (2000) in the process of renewing its major assets through the purchase of up to seven INTELSAT IX satellites from SS-Loral to replace the current fleet of INTELSAT VI, and some of the INTELSAT VII, satellites. Each of these satellites carries the equivalent of 96 units of 36 MHz bandwidth. The satellites will be located at 62° E, 60° E, 335.5° E, 325.5° E, 332.5° E, 342° E, and 328.5° E. More details on the Intelsat fleet of satellites can be found at http://www.intelsat.int. Intelsat is moving forward with plans to privatize the remainder of the organization in the 2002/2003 time frame. Any reorganization will contain strong safeguards for smaller users to the system.

GEO satellite systems, leading to a higher cost per transmitted bit. Satellite telephone systems were unable to compete with cellular telephone systems because of the high cost and relatively low capacity of the space segment. The Iridium system, for example, cost over $5 B to implement, but provided a total capacity for the United States of less than 10,000 telephone circuits. Iridium Inc. declared bankruptcy in early 2000, having failed to establish a sufficiently large customer base to make the venture viable. The entire Iridium system was sold to Iridium Satellite LLC for a reported $25 M, approximately 0.5% of the system's construction cost. The future of the other LEO and MEO satellite telephone systems also seemed uncertain at the time this book was written.

Satellite navigation systems, notably the Global Positioning System, have revolutionized navigation and surveying. The Global Positioning System took almost 20 years to design and fully implement, at a cost of $12 B. By 2000, GPS receivers could be built in Original Equipment Manufacturer (OEM) form for less than $25, and the worldwide GPS industry was earning billions of dollars from equipment sales and services. In the United States, aircraft navigation will depend almost entirely on GPS by 2010, and blind landing systems using GPS will also be available. Accurate navigation of ships, especially in coastal waters and bad weather, is also heavily reliant on GPS. Europe is building a comparable satellite navigation system called Gallileo.