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Future Commercial Communications Satellites for Shuttle Launch

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FUTURE COMMERCIAL COMMUNICATIONS SATELLITES FOR SHUTTLE LAUNCH

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ABSTRACT

Commercial communications satellites have grown from infancy seventeen years ago to a major element of the spaceflight program. The paper describes the major commercial communications satellites and their development with emphasis on INTELSAT, United States and foreign domestic and MARISAT/INMARSAT. Future direct broadcast satellites and the possibilities for geostationary platforms are also discussed. These commercial communications satellites and their offsprings will constitute a stable, growing payload base for shuttle launches throughout this decade. It will be necessary that the costs of Shuttle launches remain economic so this payload base is not eroded by other launch vehicles.

INTRODUCTION

Today, 22 separate civil and military satellite communications systems are operational, with some 30 additional systems planned. The existing systems serve 144 countries, providing national and international networks to fixed stations, to ships at sea, and in some cases, to aircraft and mobile land vehicles. Combined commercial revenues for satellite communications are approaching \$2 billion per year for telephone, television, and data services. Over the seventeen years since the launch of the first commercial communications satellite, satellite communications has proved to be the most practical and profitable application of space technology. International, domestic, and maritime services introduced during this period have been effective operationally and commercially and have had profound international impact.

INTELSAT

The INTELSAT system has progressed through five generations of satellites over the last 17 years. Membership has increased from 11 to 106 countries. The present system uses 14 opera-

tional and standby satellites to provide a global communications network with an in-orbit capacity of 85,000 telephone circuits. INTELSAT handles about two-thirds of the world's transoceanic telecommunications traffic. (1)

One hundred and forty-four user countries and territories on six continents now operate 300 earth stations over 800 pathways in the INTELSAT network. The present traffic load exceeds 20,000 full-time telephone circuits, plus TV and data. In addition to international communications, the INTELSAT system also provides leased capacity to 16 countries for their domestic communications requirements.

Through INTELSAT, the world has observed such momentous events as man's first step on the moon, Olympic Games, World Cup Soccer Matches, and the royal wedding. Because of this system several events of world-wide interest have had estimated audiences of over 500 million viewers.

One of INTELSAT's most significant achievements has been cost reduction. INTELSAT's 1981 charge for a telephone circuit (\$4,680 per half circuit) is only one-sixth of its original charge in 1965. Moreover, INTELSAT is profitable for network participants, and system users also benefit as communications carriers. From its revenues of \$213 million last year, it will return about 14 percent on investment to its members.

DOMESTIC SYSTEMS

The electronics and space technology that made international satellite communications possible also provides domestic, maritime, and other services. In the early 1970's, several of these systems were developed. The Soviet Union was the first nation to inaugurate its own domestic system; Canada was second; and

the U. S. third. Now, the United States has four domestic systems in operation -- WESTAR, SATCOM, COMSTAR, and SBS; several others are being developed. Indonesia and Japan also have separate systems in operation. The Arab countries, the Nordic countries, Australia, Colombia, France, India, Italy, Mexico, and others are planning, and in some cases building, domestic and regional systems. The geostationary orbit and the allocated frequency spectrum for satellite communications are becoming crowded.

Of the four United States domestic satellite systems, the largest is COMSTAR (Figure 1) which is owned and operated by the COMSAT General Corporation. Four COMSTAR satellites are in orbit; each has 24 transponders,* the capacity of which is leased to the American Telephone & Telegraph Company and used by AT&T, GSAT, and others. Through the major AT&T earth stations, 18,000 telephone circuits per satellite can be achieved. The circuits are used primarily in the public-switched telephone network.

The RCA SATCOM satellites also have 24 transponders. Three satellites are operational; the launch of another failed last year due to malfunction of the apogee solid rocket motor. These satellites are used primarily to provide CATV distribution, private line, and inter/intra Alaskan services. The WESTAR (Western Union) satellites have 12 transponders. Three in-orbit satellites provide a wide variety of private line service.

The SBS network is the newest and most advanced U. S. domestic satellite system. Figure 2 shows the SBS satellite. The system is unique in its use of the 14/12-GHz frequencies, all-digital modulation, and the demand-assigned, time-division multiple-access method. The system will initially provide a full range of business communications for large corporate organizations, including voice, high- and low-speed data transmission, teleconferencing, and computer interconnections. Later, it will offer services to smaller organizations and the public.

MARITIME SYSTEM

In 1976, the first of a series of three MARISAT satellites (Figure 3) was launched to provide global satellite communications service to ships at sea. The MARISAT system is operated by the COMSAT General Corporation with the participation of several other U. S. carriers; it provides high-quality telephone and

* A transponder is a satellite-borne radio repeater which accepts radio transmissions from earth stations, amplifies them, shifts them in frequency, and retransmits them to receiving earth stations.

telex service to ships at sea around the world. Presently, some 1,000 ships flying the flags of more than a dozen nations are equipped with MARISAT satellite communications terminals.

The introduction of maritime satellite services by the United States has stimulated interest by many other nations, and led to the formation of INMARSAT -- an organization currently of 34 countries, formed to provide international maritime satellite services. INMARSAT will start service in February 1982, using leased capacity from MARISAT satellites; later, two European Space Agency MARECS satellites and INTELSAT V satellites will be used to provide global ocean coverage.

TECHNOLOGICAL PROGRESS

Tremendous technological progress has been made in satellite, earth station, and transmission system technologies over the past decade and appears to be continuing at a very rapid pace (2), (3). The trends in technological development and the degree of improvement from one generation to the next are clearly evident in the INTELSAT system, which has recently introduced its fifth generation of satellites. As the satellites have increased in capacity and performance, concurrent improvements have been made in earth stations and transmission techniques, and most importantly, in service applications.

SATELLITES

Several generations of INTELSAT satellites are shown in Table 1, and remarkable improvement can be seen. For example, Early Bird (INTELSAT I) weighed only 38 kg. With limited power and bandwidth, its communications capacity could sustain about 240 two-way telephone circuits. The INTELSAT V satellite, the first of which was launched in December 1980, weighs 967 kg and can simultaneously carry 12,000 telephone circuits plus two television channels.

Great improvements were made in each succeeding satellite generation, so that the INTELSAT V series being entered into service represents an order-of-magnitude improvement in most operating parameters (e.g., prime power and bandwidth) and in operating capacity. As shown in Table 1, the per circuit-year cost decreased by a factor of 40 in a decade.

INTELSAT V (Figure 4) is the first body-stabilized spacecraft in the INTELSAT series. Its capacity is greatly increased over that of previous generations, partly because of the increased primary power available and to

a larger extent because of the increased communications bandwidth utilized. The INTELSAT V satellite uses not only the 6/4-GHz frequency band (6 GHz is the receive band, and 4 GHz is the transmit band) employed in earlier INTELSAT satellites, but also inaugurates use of an additional 500 MHz of bandwidth available in the 14/11-GHz band.

Figure 4 shows the distinguishing features of the INTELSAT V satellite. The body, which is stabilized along three axes in space, is used as a platform on which to mount the large sun-oriented solar array and the complex of earth-oriented antennas. The INTELSAT V satellite, with several planned step improvements, is expected to carry projected global traffic through the mid 1980's.

INTELSAT recently completed the system definition and started the procurement process for the INTELSAT VI series needed for operational use in 1986. This spacecraft will be designed to provide up to 40,000 telephone circuits plus two TV channels. It will require 2,000 W of power and have a mass of about 1,800 kg, to be launched on either the Space Shuttle, Ariane IV, or possibly an up-rated Centaur vehicle. INTELSAT VI will have a total equivalent bandwidth of 2400 MHz using both the 6/4- and 14/11-GHz frequency ranges, which will be achieved by multiple frequency reuse. Its large communications capability will be achieved by high satellite transmitter power and multiple frequency reuse, but also importantly from transmission techniques that incorporate switching in the satellite (i.e., SS/TDMA satellite-switched time-division multiple access).

DIRECT BROADCAST SATELLITES

Plans have been made to implement satellites which can provide broadcast services (e.g., television, radio, etc.) directly to the home. The home receivers would have antennas with diameters of approximately a meter, requiring satellites which transmit very high radiated powers towards the service areas on the earth. Seven companies have applied to the FCC for permission to launch such satellites to provide direct broadcast services in the United States. These satellite designs generally require a launch mass of either 1270 kg or 2000 kg. The COMSAT proposal envisions several of the lower mass satellites in order to provide three television channels throughout the United States. The European and the Japanese are also proposing similar satellite systems. The Japanese, in fact, have already demonstrated a direct broadcast satellite and have plans for operational ones. The most advanced plans in Europe appear to be those of a Swiss company; however, firms in several other countries are actively developing proposals.

FOREIGN DOMESTIC SYSTEMS

The USSR, Canada and Indonesia have extensive domestic communications satellite systems. All have in place, or in implementation, second generation satellites. Australia has contracted for a system and Brazil, Colombia and Japan have advanced implementation plans. India will obtain a domestic capability through the INSAT satellite and other countries through regional or shared usages (e.g., INTELSAT, Telecom, ECS, L-Sat, etc.). It is believed that the technical trends of these foreign domestic satellite systems will be somewhat similar to that of the U.S. domestic communications satellite systems and, consequently, will generate similar launch mass requirements.

GEOSTATIONARY PLATFORMS

The Shuttle, used with high-energy upper stages, will have the capability of placing extremely heavy and complex spacecraft into orbit. This mass could easily accommodate several large communications payloads on one large satellite platform.

Large geostationary platforms may be used to carry quite a number of different payloads and perform multiple missions, thus replacing many separate small satellites that perform individual missions. The missions, incidentally, may include others besides communications, such as certain earth resource observation and meteorological services which operate from geostationary orbit. Combining many of these missions on a single platform should result in significant economies of scale. Other advantages of geostationary platforms include the ability to interconnect missions (e.g., international and maritime services) and conservation of orbital arc and radio-frequency spectrum through the efficient use and reuse of several frequency bands.

Artists' concepts and drawings of geostationary platforms have shown them bristling with many antennas of different types and sizes; thus, the platforms have sometimes been termed "orbital antenna farms" (OAFs). Such spacecraft will evolve for operational service in the 1980's.

The eventual realization of these large platforms will necessitate the solution of a number of problems that will be encountered in growing from present-day communications satellites (under 2,000 kg) to the large platforms predicted for the 1990's (perhaps 10,000 kg or more).

First, a number of technical problems are involved in the interconnection, mutual support, and prevention of interference between and

among payloads. Solutions to many of these problems have been found (e.g., ATS-6, INTELSAT V, and TDRSS). Second, technical problems have been experienced in erecting and assembling large structures in space, and combining the payloads of several orbiters. NASA has instituted several development programs in this area.

Third, and there are institutional concerns such as who should own and operate geostationary platforms and how to get the potential users of platforms to work together and to share resources and risks. Although such problems are not amenable to engineering solutions, it seems that if the promised performance advantage economies are sufficiently great, institutional problems will be solved.

Although some very large geostationary platforms have been suggested (4), the first attempt at developing the concept should involve an experimental platform based upon only a single Shuttle launch. Such a platform could be large enough (e.g., 5,000 kg) to provide a good test of the concept, but would eliminate the need for the rendezvous of two or more orbiters and for extensive structural joining and assembly in space. It would also keep costs and institutional problems at a minimum.

NASA is now defining an experimental flight system for launch in the late 1980's to demonstrate in space, on a single Shuttle-launched platform, the necessary technologies, systems, and operational capabilities. This experiment or demonstration system will serve as a model for operational geostationary platforms which would follow. It will also serve as a development step or forerunner to test the platform structure, deployment mechanisms and other subsystems.

Although the system definition is not complete, initial studies show a 5,000 kg experimental geostationary platform could accommodate several advanced communications payloads, such as an experimental 30/20-GHz frequency system, a large aperture (12-m) diameter multi-beam antenna 6/4-GHz frequency system, an SS/TDMA 14/11-GHz frequency system, and a 12-GHz frequency direct broadcast satellite system -- all interconnected.

LAUNCH VEHICLES

Figure 5 indicates the derivation of an approximate formula relating the cost/kilogram of a satellite to its mass. Figure 6 indicates the approximate cost/kilogram to launch such satellite based on current cost estimates. It is evident from these Figures

that the launch costs represent a very large portion of the total space system cost. Besides the desirability of reducing launch costs, increased flexibility in scheduling and rescheduling launches is important since the satellite communications systems just described carry large amounts of important traffic.

SUMMARY

Commercial communications satellite systems are expanding rapidly as described in this paper. Mature systems are implementing later generations (e.g., INTELSAT, INMARSAT and Canadian, United States, USSR and Indonesian domestic) and new systems are being built such as the Australian domestic system. Additional systems are in advanced planning, most notably various European communications satellites and direct broadcast satellites. Beyond this in time are the creation of geostationary platforms. All these future satellites desire launch vehicle capability which is economic and which allows reasonable scheduling and rescheduling flexibility.

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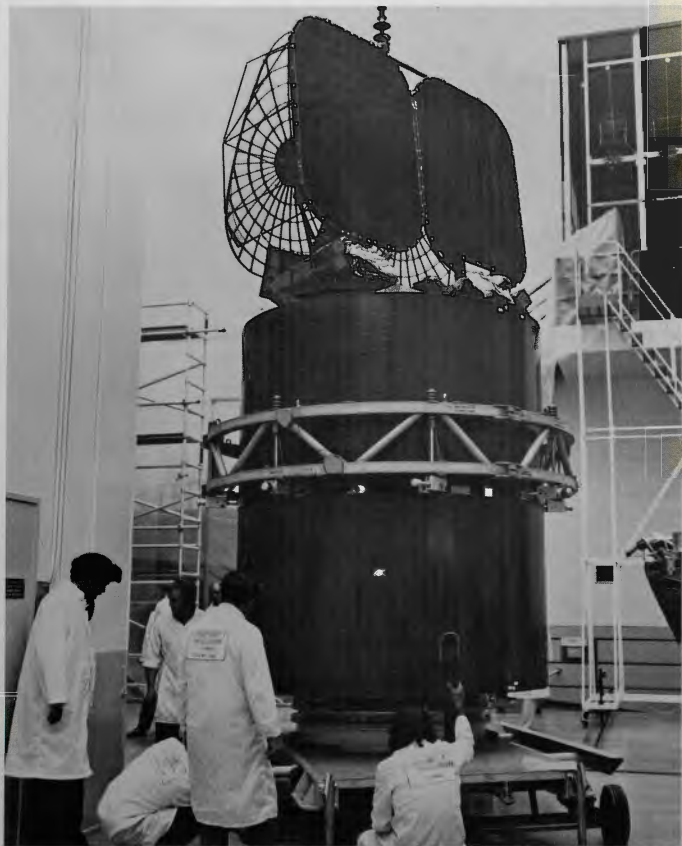


Figure 1 - COMSTAR

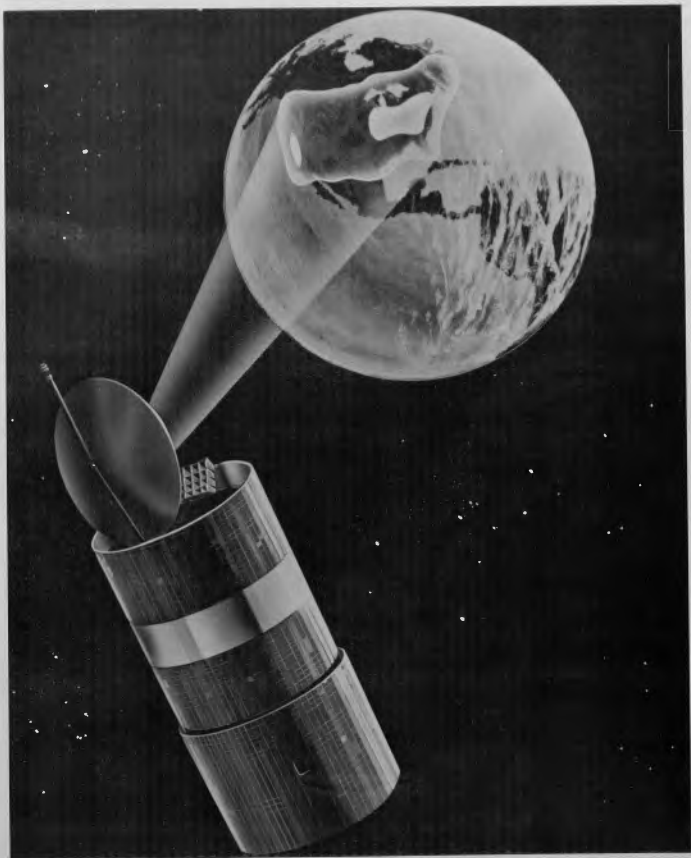


Figure 2 - SBS Satellite

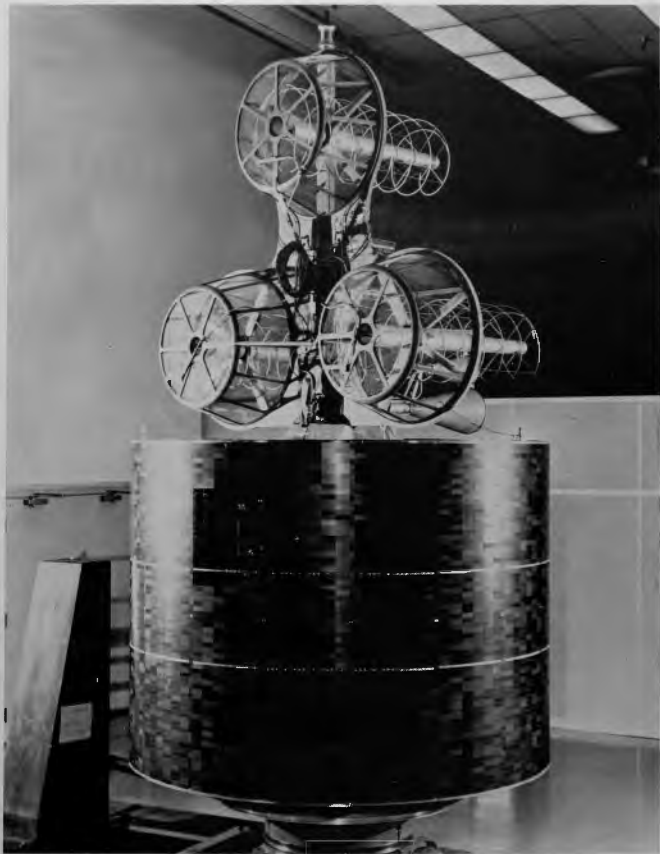


Figure 3 - MARISAT Satellites

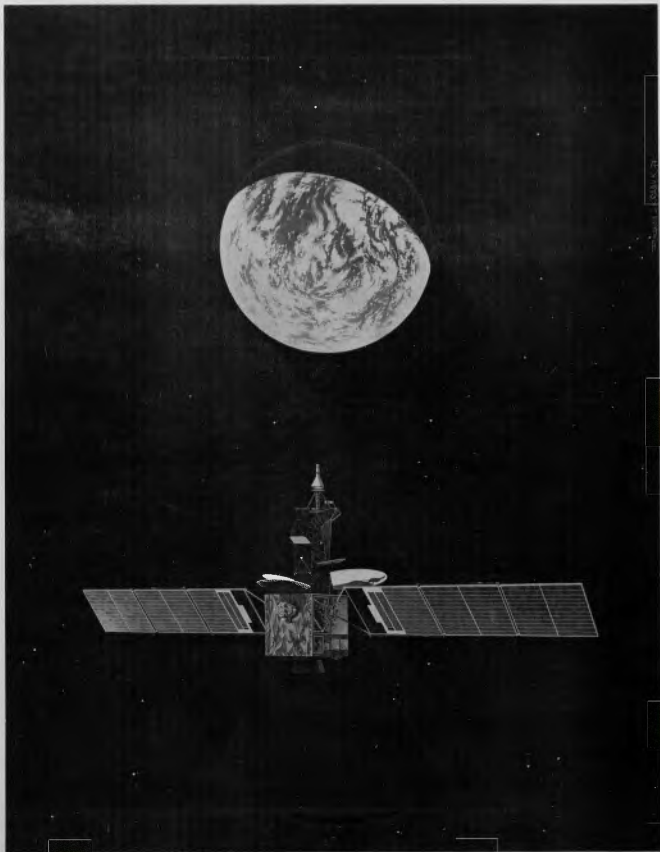
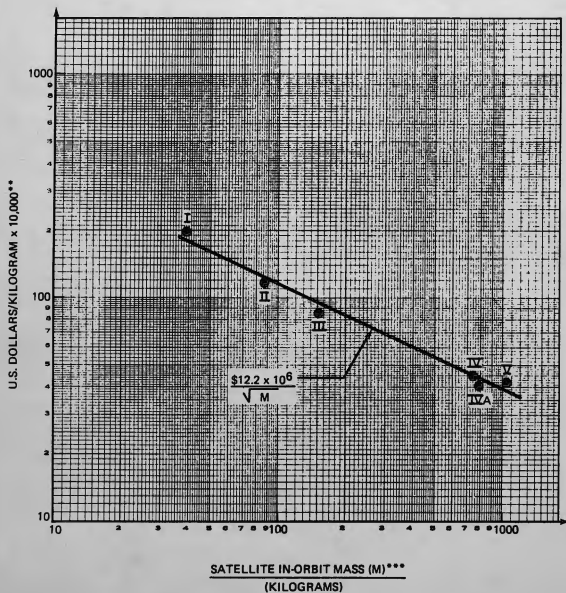


Figure 4 - INTELSAT V

Figure 5.

COST/KILOGRAM OF IN-ORBIT GEOSYNCHRONOUS SATELLITES*



- * INTELSAT SATELLITE SERIES
- ** 1967 DOLLARS (1981 DOLLARS ARE 0.36)
- *** BEGINNING OF LIFE AFTER APOGEE MOTOR FIRING

VEHICLE	SATELLITE MASS IN GEOSTATIONARY ORBIT (kg)	COST (\$M) FOR 1984 LAUNCH	COST (\$K/kg)
DELTA			
3910/PAM-D	580	33	57
3914	490	30	61
3920/PAM-D	670	38	57
ATLAS CENTAUR	1220	60	50
SPACE SHUTTLE			
PAM-D	670	16	24
PAM-A	1080	25	23
ARIANE III	1420	55	39
ARIANE IV	2060	UNKNOWN	UNKNOWN

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LAUNCH VEHICLE APPROXIMATE CAPABILITY AND COST

G-21571

Figure 6.

Table 1. INTELSAT Technological Progress

	INTELSAT I	INTELSAT III	INTELSAT IV	INTELSAT V
YEAR OF FIRST LAUNCH	1965	1968	1971	1980
PRIME CONTRACTOR	HUGHES	TRW	HUGHES	FORD AEROSPACE
DIMENSIONS DIAMETER (m)	0.72	1.42	2.38	2.0
HEIGHT (m)	0.60	1.04	5.28	15.7
IN-ORBIT MASS (kg)	38	152	700	967
LAUNCH VEHICLE	DELTA	DELTA	CENTAUR	CENTAUR, ARIANE OR SHUTTLE
PRIMARY POWER (WATTS)	40	120	400	1200
TOTAL BANDWIDTH (MHz)	50	500	500	2300
CAPACITY (TELEPHONE CIRCUITS)	240	1200	4000	12000
DESIGN LIFETIME (YRS)	1.5	5	7	7
COST/CIRCUIT YEAR (¢)	32500	2000	1200	800