AC 2008-819: THE IMPACT OF SATELLITE ON TELECOMMUNICATIONS INDUSTRY AROUND THE WORLD

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The Impact of Satellite on Telecommunications Industry around the World

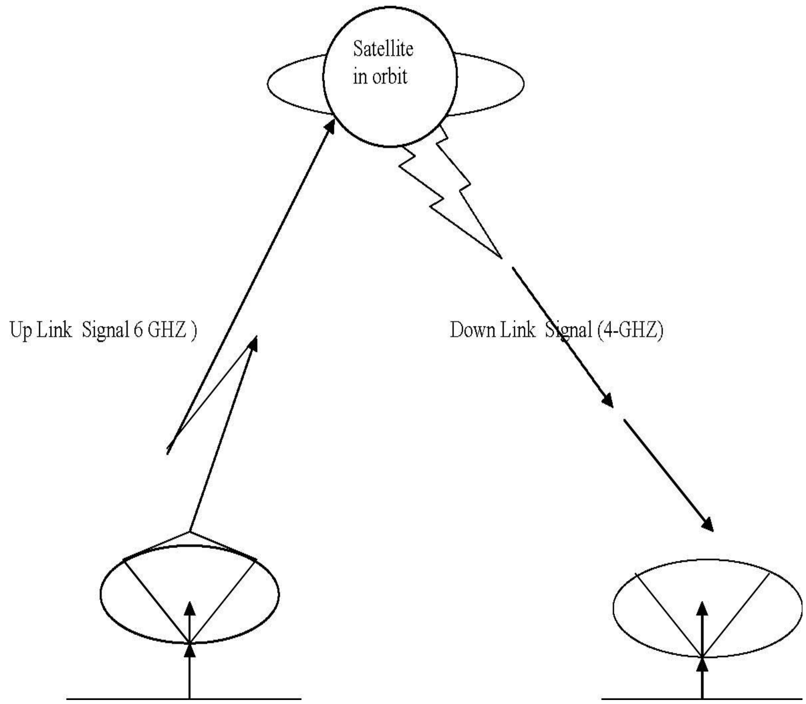
Satellite communications is now indispensable part of most major telecommunications systems. Today, the world has become a very small place because of satellite communications allowing people with no access to physical connectivity to join roundtable discussions from thousands of miles away. This paper will focus on advantages and disadvantages of satellite communications, reliability, coast, satellite services, frequency allocations, band designations, satellite launching, licensing of satellite systems, economic of satellite systems, properties of satellite communications, whale studies/satellite, and different orbits/satellites (GEO, MEO, and LEO).

This paper will also look into satellite and television networks in United States, satellite industry in Asia, the satellite market survey, the United States and Russian early warning satellites, worldwide successful space launches, effects on culture in developing countries, and comparative assessment of different types of satellite systems.

Satellite:

Satellite communications are radio-based systems, where information is transmitted from one point on the earth to another point on the earth, via moving equipment located 22,300 miles above the equator, the geostationary orbit. At this distance, the satellite rotates at the same speed with the rotation of the earth. Consequently, it appears to earth stations that the satellite is stationary, thus making communications more reliable and predictable.

In 1965, the first commercial satellite used for telecommunications was launched into space from Cape Kennedy. The Intelsat, known as Early Bird, was designed to handle an average of 240 voice channels. Since then, various countries have deployed communications satellites. As a result, satellite communications has become a major facet of the telecommunications industry.
The basic principles of the satellite operations is that information in the form of electromagnetic waves or microwave signal is transmitted (up-linked) from one earth station to a device called a transponder on board the satellite. The transponder receives the weak microwave signal at a higher frequency, amplifies and transforms it into a frequency less than the one received, and then retransmits (down-links) to a distant receiving earth station.[7]



The above setup shows how information can be transmitted via satellite in orbit at about 23,000 miles from earth.
Satellite located about 23,000 miles cannot be seen from this ground satellite station. For the satellite to stay in orbit, the speed of rotation has to be about 6800miles per hour, for 24 hours to complete the cycle around the earth. The interesting part of it is that, the earth also rotates about the same period. As such, if one is able to see the satellite at 23,000miles from any location on earth, it will appear to be a standstill object.

Types of Satellites:

There are three basic types of satellites:

1 Geostationary Earth Orbit (GEO) Satellite
2 Medium Earth Orbit (MEO) Satellite
3 Low Earth Orbit (LEO) Satellite

The GEO satellite is the furthest from Earth, located at 35,786 km or 22,300
miles in orbit. A GEO satellite is geostationary in that it rotates at the same speed as the Earth. At that elevation, only a few GEOs are needed to scan the entire globe. Because of their high altitudes, there is a resulting significant propagation delay of about 250 milliseconds. As such, GEOs are best suited in non-interactive transmissions such as TV broadcasting,

Video on Demand, and asymmetric data services. For interactive applications such as voice communications, video conferencing or multimedia services, the service performance over GEO is a significant detriment. NASA launched a GEO satellite called Advanced Communication Technology Satellite (ACTS) in 1993, with the capability to transmit hundreds of megabits per second of information.
Because of the growing need in data communication, several companies are working on satellite projects that will meet the demands of people around the world in this industry. Internet via GEO may not be as easy as claimed due to several issues that need to be addressed. GEO is not very efficient when it comes to small transactions, due to the long time delays. For example, when using GEO, the number of messages involved in even a simple update of customer records could add as much as 10 seconds to the time required to perform the transaction.

Medium Earth Orbit (MEO) satellites orbit in the region 6250 to 13,000 miles away from Earth. Information transmission using the MEO satellite is suitable for voice communications; time delay here is about one-forth to one-sixth that of GEO. Since the Medium Earth Orbit satellites are not geostationary, multiple satellites are required to cover a given point continuously. However, the number of satellites required to cover the Earth using MEO region is less than that of Low Earth Orbit (LEO), but more than GEO. Nonetheless, MEO is not as popular as LEO that provides even better latency and higher capacity.
The Low Earth Orbit (LEO) satellites are located in the region 500 to 1500 miles from Earth. The time delay for transmission using the LEO satellites is about 0.03 seconds, which makes it more effective for the delivery of time critical applications such as multimedia interactive services.

High-speed connectivity over the LEO satellite becomes very practical and effective.
Some of the applications using the LEO satellites include database access, audio, video conferencing, e-mail, new data broadcasting multi-media information services, telemedicine, direct-to-home video, electronic transaction processing, distance learning, and news gathering.
Low Earth Orbit satellites do have problems. Due to their close distance to earth, many more satellites are needed to be able to provide the necessary coverage. Consequently, setting up a LEO network is very expensive. However, launching can be incremental to allow initial targeting of profitable market segments.[1]

Satellite Services:

There are eighteen satellite services as defined by the International Telecommunications Union (ITU)[11]

These services are as follows:

1 Fixed Satellite Services (FSS)
2 Broadcast Satellite Service (BSS) (also known as Direct Broadcast Satellite Service (DBS) or small dish television)
3 Broadcast Satellite Service for Radio (BSSR)
4 Radio Determination Satellite Service (RDSS)
5 Radio Navigation Satellite Service (RNSS)
6 Inter-Satellite Service (ISS) (also known as Inter-
7 Satellite Links (ISL))
8 Mobile Satellite Service (MSS)
9 Aeronautical Mobile Satellite Service (AMSS)
10 Aeronautical Radio Navigation Satellite Service (ARSS)
11 Maritime Mobile Satellite Service (MMSS)
12 Maritime Radio Navigation Satellite Service (MRSS)
13 Land Mobile Satellite Service (LMSS)
14 Amateur Satellite Service (ASS)
15 Meteorological Satellite Service (MSS)
16 Space Operation Service (SOS)
17 Space Research Service (SRS)
18 Earth Exploration Satellite Service (EESS)

Frequency Allocations for Satellite Services:

Allocating frequencies to satellite services is a complicated process, which requires international coordination and planning. This is carried out under the auspices of the International Telecommunications Union. To facilitate frequency planning, the world is divided into three regions: Region 1: Europe, Africa, the former Soviet Union, and Mongolia. Region 2: North and South America and Greenland. Region 3: Asia (excluding Region 1 areas), Australia, and the southwest Pacific. [15]

Other satellite applications include service provision directly to customers using small low cost earth stations; mobile communication to ships, aircraft and land vehicles, and public television/sound broadcasts, and data distribution from widely distributed terminals. In many applications, such as video distribution, service-providers are combining the benefits of satellite communications with optical fiber systems to produce the best solution to users' needs. [13]

TABLE 1:

Frequency Range (GHz) Band Designation

0.1-0.3 VHF
0.3-1.0 UHF

1.0-2.0 L
2.0-4.0 S
4.0-8.0 C
8.0-12.0 X
12.0-18.0 ku
18.0-24.0 k
24.0-40.0 ka
40.0-100.0 mm

Table 1 show the frequency band designations in common use for satellite services. The C band, for example, is used for fixed satellite services, and no direct broadcast services are allowed in this band. The VHF band is used for certain mobile and navigational services and for data transfer from weather satellites. The L band is used for mobile satellite services and navigation systems. The 6/4 GHz frequencies (i.e. the 6-8 GHz slot and the 4-6 GHz frequency slot) are used for C band transmissions. The higher frequency 6-8 GHz slot is for uplink signals to the satellite, and the lower frequency 4-6 GHz slot is used for downlink signals to earth receivers. For the direct broadcast service in the Ku band, the frequency used is 14/12 GHz. However, since the frequency for each band is a range, the above stated frequencies may be within the acceptable approximation. The limitation of available frequencies has driven the technology in several ways. Many communications satellites use C-band and Ku-band. As a result, there is frequency congestion in this spectrum, which has necessitated frequency reuse, frequency compression by multiple satellites, multiple beams, and polarization. However, there is a room at higher frequency spectrum where bandwidth is greater.[14]

Satellite Launching:

Normally, satellite communications service users are not directly concerned about the process by which the satellites are launched. However, it is good for the satellite users to have some basic knowledge about the launching process. Placing the satellite at 22,300 miles above the earth, which is referred to as geosynchronous orbit, needs a lot of energy from a rocket.
The process of launching the satellite can be divided into two levels: The launch level, and the orbit injection level. During the launch level, the Launch vehicle places the satellite in a transfer orbit, which is an elliptical orbit that, during its highest point (apogee), is at the geosynchronous elevation of 22,300 miles, and which during its lowest point (perigee) is at an elevation around 100 miles. [9]

Once a satellite is launched from earth, it enters an orbit whose plane has an inclination that is equal to the latitude of the launch site. Satellites launched from Kennedy Space Center in Florida, for example, will have an Orbital inclination of 28-degrees. However, to obtain inclination of 0-degrees at the equatorial orbit, there has to be some adjustment during the process of moving from the transfer orbit to the final orbit, which requires additional energy.

The inclination energy requirement can be adjusted by using a supersynchronous transfer orbit, where the perigee elevation is much greater than the geosynchronous elevation. The thruster on the satellite supplies the energy needed to raise the satellite from the elliptical transfer orbit to the circular geosynchronous orbit. In the past, an apogee kick motor (AKM), which is a single-use solid-fuel rocket, has been used to place the satellite into its final geosynchronous orbit. Some satellites have been lost in this process, when the one time fire from the solid-fuel rocket failed.

Today, another method referred to as liquid apogee engine (LAE), whereby a liquid-fueled engine is used that can fire repeatedly, controlled from a ground station. There are two types of launch vehicles: Expendable Rocket and Space Shuttle. Expendable Rockets: The expendable rocket vehicles for communication satellites have multiple stages that allow the rocket to drop off the weight in stages as they are used up. A typical expendable rocket will have three stages. The first stage contains several thousand pounds of kerosene and liquid oxygen mixture, plus a number of solid fuel rocket boosters that produce a tremendous display of flame as the satellite lifts off from the pad. The first stage of the rocket will move the satellite to an elevation of about 50 miles, the second will take it to about 100 miles, and the third stage of the rocket will place it in the region called transfer orbit.

At that stage, the rocket has completed its mission. The final lift of the satellite to geosynchronous orbit is done by apogee kick motor (AKM), which is on board the satellite, and controlled from the ground station. The Space Shuttle: The Space Shuttle, or Space Transportation System (STS) as it is sometimes called, performs the critical functions of the first two stages of the expendable launch vehicle. A satellite with an Integrated Upper Stage, or what is sometimes referred to as Payload Assist Module, is mounted in the cargo bay of the shuttle. When the shuttle reaches its orbital elevation of about 150 to 200 miles, the satellite and the payload assist module are ejected from the cargo compartment. The payload assist module is then fired, and this places the satellite in the transfer orbit. The apogee kick motor (AKM) on board the satellite then fires to transport the satellite to its final destination, which is geosynchronous orbit, and shuttle returns to earth for reused.[8]

Licensing of Satellite Systems:

The process to obtain a license for a satellite system in the United States can take a very long period of time. The domestic authorizations process of filing for a construction permit and operating license for satellite systems can take years before it is forwarded to the International Telecommunications Union (ITU) for further processing. The procedure is different from one country to another. In the U.S. process, there are certain threshold (Regulatory) issues that dictate the requirements, such as whether the proposed system is national or international, or whether the satellite's capacity is to be offered as a common carrier or a private network.

Additional issues include the type of satellite service that will be offered under the ITU definition of the offering, and the associated frequency allocations. As a matter of improving the process, FCC now allows filings for satellite systems pursuant to Title III of the Communications Act of 1934 {amended) to be carried-out in a single one-step process. As a result, applicants can seek in a single step authority for construction, radio licensing, and launch. It still covers all the technical, legal, and financial information, as well as earth station construction and licensing.

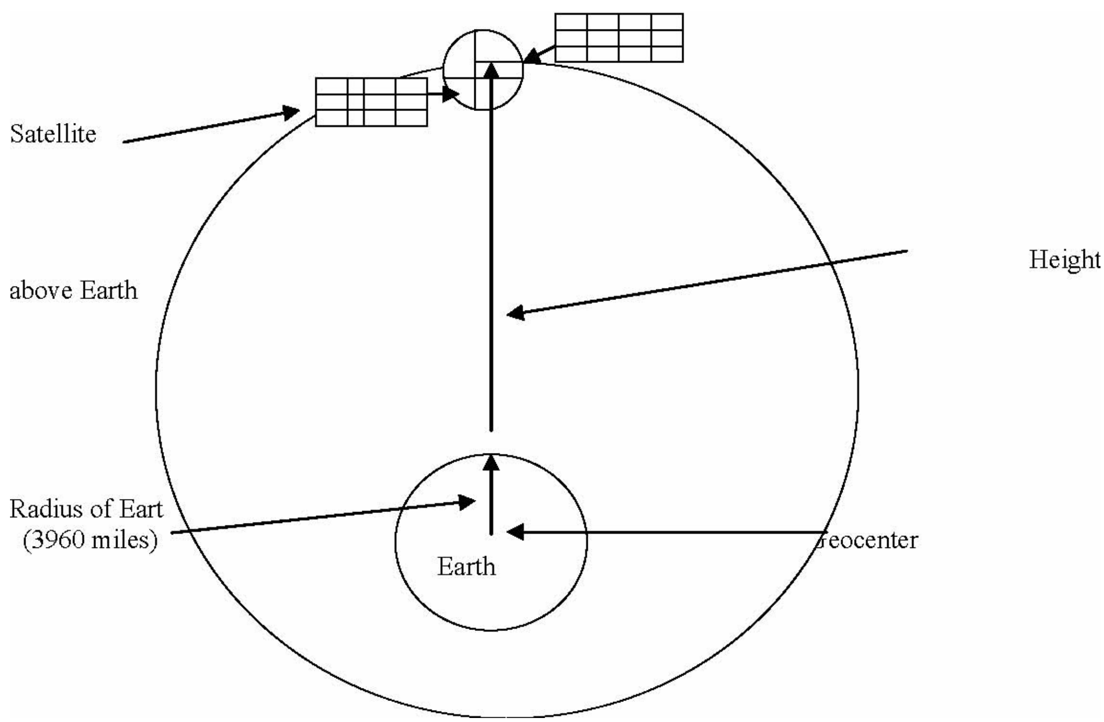
The application must justify why the public interest would be served by such technology, in terms of the requested frequencies and orbital locations. The detailed requirements for such application are specified in Rule 25 of the FCC Rules and Procedures. Because of the complexity and volume of the requirements (500 to 2000 pages), an experienced law firm familiar with the FCC procedures to prepare and submit the application is needed.

In some special circumstances, an application may be submitted for what is called "pioneer preference," depending on whether such application has some special and unique feature based upon the technology. If the preference is granted, it means the FCC accepts the application, and six months head start for licensing and seeking ITU registration is granted. However, this preferential status is not easily obtained.

It is even more difficult when filing for mobile satellite systems in low and medium earth orbit. This in most part is due to the limited spectrum in frequencies below 2 GHz. There are not enough frequencies to accommodate large numbers of applicants. Therefore, the FCC tends to use the lengthy comparative hearing process.

In some countries, there is normally only a single satellite system at a time that is under consideration for deployment. It may also be a project supported by the government. As such, there is no difficult local process and no competition. In the United States, there is considerable local and international satellite licensing competition. In most cases, the proposals are of good quality and competitive, which does not make Federal Communications Commission's work any easier to decide on such proposals.

After the applicant has received a permit for satellite construction and a license for the satellite system, the regulatory oversight does not end there. There are requirements for reports on satellite construction on any tests that show substandard performance, satellite launches and performance in orbit.
Also, there are reporting requirements for how much of the satellite is utilized and for what purpose. In addition, semiannual reports are required on specific test measurements that indicate the technical and operational conditions of all satellite systems, including frequencies and carrier plans.[10]



The above sketch shows the height of the satellite from the center of the earth. For example: If a satellite is 7500 miles above the earth in circular orbit it simply means that, the distance from earth to the satellite location is (3960 + 7500) miles since the radius of earth is 3960 miles.

Satellites offer many advantages including:

1 Distance insensitivity
2 Single-hop transmission
3 Solutions for remote areas and maritime applications
4 Good error performance for data
5 Broadcast technology
6 Disaster recovery
7 Large amounts of bandwidth
8 Ballistic missiles early warning systems
9 Aviation industry
10 Weather forecasting
11 No location restrictions

Disadvantages of satellite communications include the following:

1 One-way propagation delay (about 270 milliseconds to 540 milliseconds)
2 Multi-hops increase delay and detrimentally impacting voice,
3 High path loss in transmission to satellite,
4 Rain absorption affects path loss,
5 Congestion buildup, and
6 Risk during launching.

Satellite to Aid Whale Studies:

GPS will soon be used to follow whales around the world, according to Asahi Shimbun. A satellite will collect data from small electronic tags attached to the whales and will downlink such information to a control center at Chiba Institute of Technology Japan. The satellite will collect such information as how deep the whales swim and their migrating patterns. A similar United States project managed to follow the whales for only two months because of the short life span of the electronic device that was attached to the whales, but to be able to observe whales globally is groundbreaking.[18]

TABLE 3: Satellite Market Survey 1994 to 2000

Amount in US-Dollars

Satellite Market	Market Size as of 1994	Market Size of 2000
Fixed Satellite	$14 Billion	$23 Billion
Mobile Satellite	$2.5 Billion	$10 Billion
Direct Broadcast Satellite	$1.5 Billion	$6 Billion

Military Mobile Communications Satellite	$7 Billion	$12 Billion

Table 3 shows a tremendous increase in satellite market within a period of six years. This is because technology has to be extended to the most remote part of the World, and in most cases, physical connectivity is not possible.
In addition, the cost for satellite technology is coming down, as various new technologies are used in the process. [10]

Table 5: Reliability of a Communications Satellite [3]

Subsystem	Reliability (%)
Communications	90
Attitude determination and Control	93
Electrical Power	96
Propulsion	99.7
Telemetry, command, and ranging	95

Note: Usually, spacecraft's reliability figure does not include the launch reliability.

Satellite and the Television Networks in USA:

During the time between 1965 and 1973, when Federal Communications Commission was in the process of determining how the satellite communications would be managed, the three television networks, American Broadcasting Corporations (ABC), Columbia Broadcasting System (CBS), and National Broadcasting Corporation (NBC), came together and formed the Joint Network Task Force (JNTF), to provide input to FCC and prospective satellite operators about their needs.

JNTF estimated in 1971 that the three networks would need 22 satellite transponders for their operations. Today, four networks, ABC, CBS, NBC and FOX, are using a total of 49 full-time transponders. As demands of more transponders are needed, compression technology is being used to compress three to seven channels into one transponder at 36 MHz. In addition, the 49 transponders do not satisfy all the needs for part-time occasional use backhauls of remotely produced content.

The use of fiber transmission to accommodate some of the point-to-point backhaul traffic is very helpful, but satellite continues to transport a larger percentage of the traffic. All the four major broadcast networks have ownership alliances with cable television program services, which together occupy another 32 full-time transponders. The estimated 22 transponders in 1971 have now grown to 81, not including the clusters of multi-channels that have been compressed.

ABC-Transponders: Walt Disney Company, the owner of ABC leases 10 satellite transponders. Seven C-band and two Ku-band for news gathering are in Loral Skynet's Telstar system, while the tenth transponder which is also Ku-band is on General Electric's GE-5. Walt Disney Company signed a major satellite contract with PanAmSat (PAS) in July 2001, for PAS to become the "aggregate satellite-capacity vender" to all of the television distribution needs of Disney's business. These include ABC, Cable Channel, Toon Disney, ESPN, and ESPN 2. The current agreement between ABC and Skynet extends until early 2006, at which time ABC will begin migrating its television traffic into the PAS system.

NBC-Transponders: General Electric owns NBC, and historically, its operation has depended primarily on Ku-band satellite transponders, as opposed to C-band, which has been dominated by the other three networks. NBC has 19 transponders at 36MHZ. Out of these 19 transponders, 18 are in the Ku-band (10 on GE's K2 and 8 on GE-1). The last transponder is the only one in the C-band, which is located on GE7. In the area of cable operations, CNBC and MSNBC make use of three C-band transponders for distribution.

FOX-Transponders: FOX television network leases eight C-band satellite transponders, located on Loral Skynet and PanAmSat satellites. FOX cable television service has 16 additional transponders, and most of them are on GE satellites. Sixteen transponders seem to be a large number for a cable operation. However, mostly it is because FOX provides numerous regional sports services.[16, 17]

Table 6: Comparative Satellite Launch Costs

Launch system	Cost (millions of dollars)
Delta 3910/PAM	36.0
Delta 3920/PAM	41.0
Delta 3924	37.8
STS/PAM	17.5
Ariane	31.0

Table 6 provides information regarding the cost to launch a satellite. This information shown above is an estimate because satellite launch cost depends on the result of competitive bidding, weight, and distance. However, it is clear that it costs many millions of dollars to put a satellite into orbit. [12]

Table 7: Worldwide Successful Space Launches

Year	USSR / CIS	US	Fran	Aust	China	Japan	U K	Euro / ESA	India	Israel	Sea Launch	Total
1957	2											2
1958	1	7										8
1959	3	11										14
1960	3	16										19
1961	6	29										35
1962	20	52										72
1963	17	38										55
1964	30	57										87
1965	48	63	1									112
1966	44	73	1									118
1967	66	58	2	1								127
1968	74	45										119
1969	70	40										110
1970	81	29	2		1	1						114
1971	83	32	1		1	2	1					120
1972	74	31				1						106
1973	86	23										109
1974	81	24										106
1975	89	28	3		3	2						125
1976	99	26			2	1						128
1977	98	24				2						124
1978	88	32			1	3						124
1979	87	16				2		1				106
1980	89	13				2			1			105
1981	98	18			1	3		2	1			123
1982	101	18			1	1						121
1983	98	22			1	3		2	1			127
1984	97	22			3	3		4				129
1985	98	17			1	2		3				121
1986	91	6			2	2		2				103
1987	95	8			2	3		2				110
1988	90	12			4	2		7		1		116
1989	74	18				2		7				101
1990	75	27			5	3		5		1		116
1991	59	18			1	2		8				88
1992	54	28			4	1		7	1			95
1993	47	23			1	1		7				79
1994	48	26			5	2		6	2			89
1995	32	27			2	1		11		1		74
1996	25	33			3	1		10	1			73

1997	28	37			6	2		12	1			86
1998	24	34			6	2		11	1			86
1999	26	30			4			10	1		2	73
2000	35	28			5			12			2	82
Total	**2,634**	**1,219**	**10**	**1**	**65**	**53**	**1**	**129**	**9**	**3**	**4**	**4,128**

Table 7 shows the number of satellites that have been launched into space by various countries between 1957 and 2000. [19]

As shown above, there was intense competition between the former Union of Soviet Socialist Republics (USSR) and the United States of America (USA). Between 1958 and 1971, the United States launched more satellites into space than USSR. However, between 1972 and 1990, there was a big change in these numbers. USSR launched about four times more than the USA per year. The USSR/CIS showed a major slow down in launch frequency during the 1990s. The slow down at both sides could have been from such factors as re-organization and internal struggle for power (USSR), economic, or strategy in competition on the side of the United States. China, Japan, and Europe are also seen in this satellite technology competition.

Summary:

This paper looked at the impact of satellite on communications around the world. Started with the history, relative advantages, disadvantages, the market survey, applications, space launches, launching cost, reliability, and how it compares with other medium of connectivity (copper and fiber).

Satellite technology started when a Russian school teacher, Konstantin E. Tsiolkovsky 1857, outlined the basic concept of liquid-propelled rockets which led to space technology, and ultimately the satellite communications systems which has become an indispensable part of most telecommunications networks of today.

Satellite communication is a radiated form of communications, which means that there is no physical connectivity. The advantages and disadvantages of satellite communications were discussed in this paper. Since physical connectivity is not needed, satellite networks provide solutions for remote areas and maritime applications. However, propagation delay and high risk of failure during launching constitute important disadvantages.
The two types of launching a satellite were also discussed in this paper. The various television networks in the United States that make use of satellite communications were discussed.

The limited frequency spectrum that is available has made the FCC Licensing process for satellites operations complex and highly competitive.
China and India have also launched satellites into orbit for various applications. The use of satellite communications by the U.S. military is very extensive, and cannot be replaced with fiber optic communications. The use of GPS by the United States military as well as the public sector is another area of satellite communications that is expanding.
The Indian multimission satellite and the presence of other satellites in Asia-Pacific region is an indication of the major role of satellite communications in the world today. A satellite market survey between 1994 and 2000 shows a tremendous increase in satellite market.

Conclusions:

Satellite communications is very attractive and powerful technology, since one geostationary satellite can cover about 42% of the Earth. This means that only three satellites are needed at geosynchronous orbit to communicate with people around the World. More satellites are needed at LEO and MEO as a result of the altitude. The lack of physical connectivity required in satellite communications means no matter where people live, they have a better chance of being able to do the kinds of things that people in the developed world are doing via satellite communications. Distance learning is another area that satellite communications had made a great impact.

There are some parts of the World today that are enjoying Internet connectivity that would not have been possible without the satellite technology.
Communications between Space station and the people on the Earth would not have been possible without satellite communications. Safety in the airline industry is better today because of satellite communications.

As technology continues to advance in satellite technology, total spacecraft reliability will improve, cost will be less, and the risk for investment in satellite communications will become less and profits will be high. In addition, satellites that are already in operation may have less risk in the sense that the launching risk is out of the question. Security problems with satellite communications are becoming better due to encryption technology of today.

As satellite technology dominates international telecommunications market, more people around the world despite barriers of distance, geographic isolation, or low income, will have access to the latest information via satellite communication. More people eventually will be able to receive medical treatment from some of the best doctors in the world, without having to travel thousands of miles because of satellite communications.

The mobility that satellite communications provides, coupled with the low expected charges, will bring about the pull factor in this industry, where many people will have less usage for the physical fiber/copper connectivity.

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