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8.0 Satellite Systems

Objectives

This section will:

- Examine direct broadcast satellites
- Discuss PCSS
- Introduce GPS

The world wide space industry employs abut 1.2 million people. In 1998 it generated 98B$US. This is expected to grow to 137.8B$US by 2002.[1]

The deployment of satellites has not yet become routine. It is always fraught with danger.

Galaxy 10.

There are a phenomenal number of satellites and debris in orbit. For more information about debris, refer to:

For Advanced Students

http://nmsp.gsfc.nasa.gov/tdrss/tdrsshome.html

http://sn-callisto.jsc.nasa.gov/newsletter/news_index.html.

http://www.eurobird.org/

EUTELSAT (European Telecommunications Satellite Organization), is the leading satellite operator in Europe, managing 18 geostationary telecommunications satellites. http://www.eutelsat.com/

Minimum Reading

http://www.space.com/spacenews/

8.1 Satellite Applications

Satellites support a number of applications including:

- Communications systems
- Broadcasting systems

1 Alcatel Telecommunications Review 4th Quarter 1999.

- Remote sensing
- Global positioning and navigation
- Search and rescue
- Weather and pollution monitoring
- Surveillance

Approximate Number of Satellites[2]

Country	Satellites
Canada	16
China	15
France	24
Germany	15
India	11
Japan	55
United Kingdom	18
United States	658
Europe	27
International	51
Other	10

For Advanced Students

Satellite Communications by Hart

Satellites in Geostationary Orbit by Johnson

http://www.lyngsat.com/index.html

http://www.sbca.com/

http://www.esatcom.net/

http://www.msua.org/mobile.htm

http://www.estec.esa.nl/mercure/homepage.htm

http://www.satellitetoday.com/

http://www.ses-americom.com/

http://www.astronautix.com/

http://www.isr.umd.edu/CSHCN/

http://www.cs.ucl.ac.uk/staff/S.Bhatti/D51-notes/node24.html

8.1.1 DBS

Europe is the largest DBS market in the world. In 1999 there were more than 250 TV channels being broadcast in 24 languages.

2 http:/www.atek.com/satellite/table

The first TV satellites operated in the C-band, and broadcast between 5 to 24 watts. C-band receivers require large parabolic antennas.

New direct broadcast satellites transmit television signals use the Ku band and broadcast signal levels up to 200 watts. This reduces the receive antenna size to approximately one meter in. A disadvantage of the Ku band is its high atmospheric losses due to rain.

Ku band satellites often carry 32 x 24 MHz channels. Left and right hand circular polarization is used to allow frequency reuse.

8.1.2 VSAT

☞ **Minimum Reading**

http://www.spacenet.com/tools/satellite_basics/

VSAT[†] networks carry voice, data, and video services via a small dish satellite link. Two principle applications for this type of service are ALOHA packet networks, and cellular radio facilities.

US VSAT Market Share[3]

HNS	59%
AT&T Tridom	14%
GTE Spacenet	13%
Scientific Atlantic	9%
Others	4%

Current domestic satellites have a few broad beams, however this makes for a very limited user environment. Multiple narrow or spot beams are required to cope with the growing number of customers. Frequencies can be reused in each of the spots, thus increasing capacity.

VSAT networks are deployed in a star configuration with all traffic being switched through a master control center which does both inter and intra-beam switching. An inter beam communications link therefor requires two hops. Newer designs support switching at the satellite.

A&P VSAT Network[4]

A&P[†] was the first national supermarket chain to replace its dial-up data network with VSAT terminals. Currently, there are about 750 stores in the network. At present, there are more than 20 different food chains operating 5000 terminals.

† Very Small Aperture Terminals

3 Telecommunications, March 1993

4 *Communications News*, November 1994

The A&P central hub uses a 6-meter dish and is located at Columbia Maryland. Remote terminals use 1.8-meter dishes, and communicate via X.25 packets on 56 Kbps channels. Each terminal can interface with PC workstations, cash registers, credit card readers, and bar code scanners.

Food chains use these systems for:

- Electronic funds transfer: debit card transactions, credit card verification
- Inventory and accounting from the POS† terminals
- Pricing updates
- Audio and video in store advertising
- In store sales training

A database on shopper activity allows the company to offer such programs as frequent shopper incentives, electronic coupons and direct-mail promotions.

United States Postal Service

The USPS is the largest retailer in the U.S. with 27,000 small and 7,000 large offices.

The VSAT network is used for point-of-sale data polling, credit authorization, delivery confirmation, software distribution, streaming video, interactive distance learning, and multicast content delivery.

8.2 Satellite Orbits

Minimum Reading

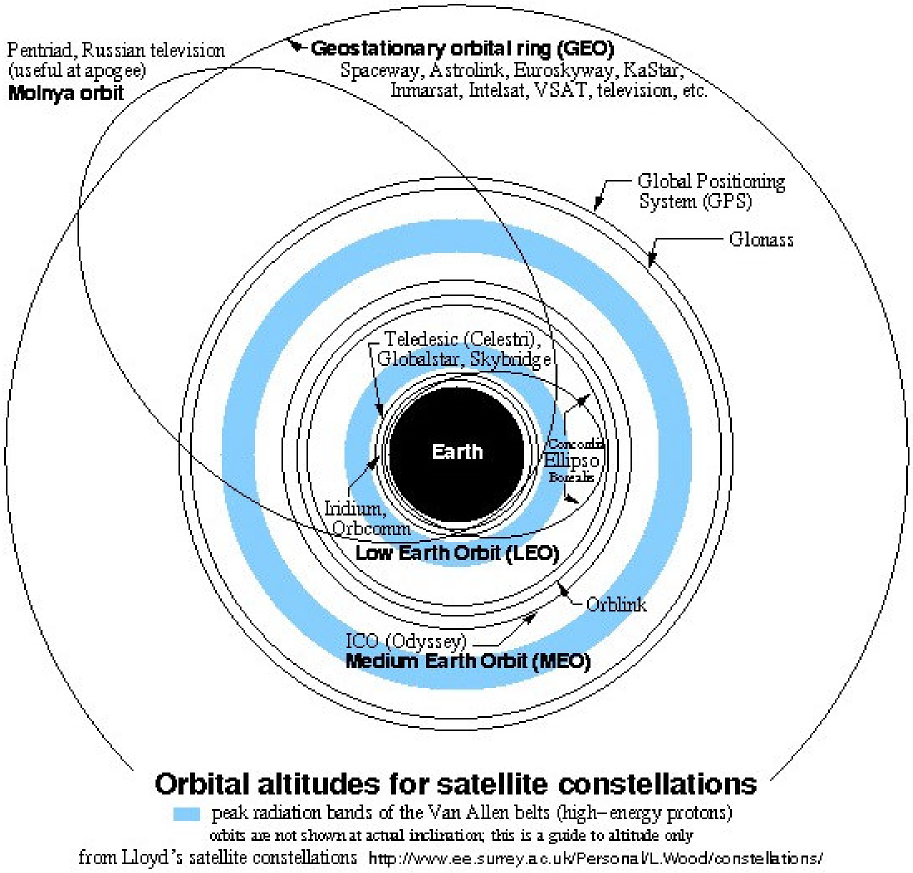
http://satellite.about.com/msub104.htm

Satellite networks are often categorized by their orbits:

System	Altitude [Km]	Comments
GEOS	35,786	Geostationary satellites
MEOS	10,000	Medium earth orbit
LEOS	1,000	Low earth orbit
HEOS		Highly elliptical orbit

† Great Atlantic and Pacific Tea Company

† Point of Sale



Ground stations communicate with satellites orbit over a high-powered, microwave link. The area that can receive the satellite downlink is called a footprint.

8.2.1 GEO Satellites

The majority of communications satellites today are in GEO orbit. This orbital plane is located at an altitude of 36,000 Km above the equator. The signal return trip takes about 0.25 seconds.

International regulatory bodies such as the ITU and national government organizations like the FCC assign communications satellite positions. The geostationary spacing is typically 2^o however, increasing demands may lower this to 1^o.

A satellite that orbits around the earth at the same rate that the earth turns is known as a synchronous orbit. Synchronous orbits can be of any inclination. If they are polar orbiting, the satellite will appear to be over the same spot at the same time every day.

Remote sensing satellites can be place in orbits that are synchronous with the earth's rotation over a longer period than a day, and thus will be able to view the entire ground surface over a number of orbits.

If a geosynchronous orbit is placed over the equator, the satellite will appear to stop moving in the sky. This is referred to as a geostationary orbit.

The gravitational acceleration of an object as a function of altitude is:

$$a_c = \left(\frac{r_e}{r_s}\right)^2 g$$

where
$$\begin{aligned} r_e &= \text{equatorial radius of the earth} \\ &= 6378.388 \text{ Km} \\ r_s &= \text{radius of satellite position} \\ g &= \text{earth's gravitational acceleration constant} \\ &= 9.80665 \text{ m/Sec}^2 \end{aligned}$$

The centrifugal acceleration on a satellite is given by:

$$a_c = r_s\omega^2 = r_s\left(\frac{2\pi}{T_s}\right)^2$$

where
$$\begin{aligned} \omega &= \text{angular velocity in radians/sec} \\ T_s &= \text{time for 1 orbit} \\ &= 86400 \text{ seconds (24 hrs) for geostationary orbit} \end{aligned}$$

For a stable orbit, the two forces associated with these accelerations must be equal:

$$\left(\frac{r_e}{r_s}\right)^2 g = r_s\left(\frac{2\pi}{T_s}\right)^2$$

Solving for r_S we obtain:

$$r_e{}^2 g = r_s{}^3\left(\frac{2\pi}{T_s}\right)^2 \quad \Rightarrow \quad r_s{}^3 = \left(\frac{r_e T_s}{2\pi}\right)^2 g$$

$$r_s = \sqrt[3]{\left(\frac{r_e T_s}{2\pi}\right)^2 g} = \sqrt[3]{\left(\frac{6378\ Km \times 86400 \sec}{2\pi}\right)^2 9.8\ m/\sec^2}$$
$$= 42,254.22\ Km$$

Therefore the height above the earth is 42,254 Km - 6378 Km = 35,876 Km or 22,292 miles.

The velocity of a satellite in a circular orbit is given by:

$$v = r_e\sqrt{\frac{g}{r_s}}$$

This works out to 3.073 Km/Sec for a satellite in a geostationary orbit.

These satellites will appear directly overhead at the equator. As one moves northward, the orbital plane appears to move south. Since a satellite must appear about 5^o above the horizon in order to be seen by a ground station, it is not possible to receive signals within about 1000 km of the poles. Consequently, countries with significant population at extreme northern (or southern) latitudes must rely upon a different obit for communications satellites.

8.2.2 Molniya Orbit

The former USSR is not able to make great use of geostationary satellites, because of the northern latitude of the country. Consequently, communications satellites have required a slightly different approach.

Orbital inclination	63.4^o
Orbital period	719.19 minutes
Perigee	1000 Km
Apogee	39,375 Km

The size of the ellipse was chosen to make the orbital period equal to half a sidereal day, and therefore in synchronism with the earth. Because the earth is an oblate spheroid, most elliptical orbits of this type would slowly precess around the earth. However, this apsidal rotation does not take place for an orbit with an inclination of 63.4^o.

The satellite remains visible for 11 of its 12-hour orbit. Several satellites are required to provide continuous coverage. The earth stations are quite complex since they must track the satellite.

8.2.3 MEO Satellites

MEO satellite orbit at an altitude of about 8000 miles. Communications signals travel a shorter distance and have less signal loss, thus allowing the use of smaller, lightweight-receiving terminals. The return trip time for a MEO satellite is less than 0.1 seconds. These satellites are often in inclined orbits.

8.2.4 LEO Satellites

Several LEO systems have been proposed at an altitude of about 500- 1000 miles. The return trip time for these systems is about 0.05 seconds. These satellites are often placed in polar orbits.

Some of the frequency bands for these systems are: 800 MHz, 2 GHz, and 20-30 GHz range.

8.2.5 High Altitude Long Endurance Platforms

HALE platforms are airplanes carrying a communications repeater at an altitude of about 70,000 feet. They can be powered by high efficiency turbine engines or a combination of battery and solar power. Transmission delays are less than 1 mSec.

8.3 PCSS

WARC† -92 allocated part of the L-band [1.5 to 1.7 GHz] for universal personal communications. This includes both terrestrial and satellite components.[5]

PCSS† depends upon the deployment of cheap and reliable LEO satellites. Although a considerable amount of money has been spent on developing and promoting these systems, here is still considerable debate as to whether these systems are cost effective.[6]

Some of the technologies, needed to support these systems include[7]:

- Small communications satellites
- Phased array antennas
- Radiation tolerant semiconductors
- Advanced baseband processing architectures
- Distributed network architectures

There are a number of proposals for worldwide satellite communications. Initially it was thought that these systems might compete with local telcos and cellular radio systems. It is now thought that one of the main users of the system might be the telcos themselves. This is because without telco cooperation, the satellite service customer base might never come into existence. The Globestar system is to be sold exclusively to telcos to supplement the existing cellular system, and will be transparent to the end-users.

It may be that these systems will be useful in providing connection to existing PSTN facilities where cellular service is not available. If this is the case, the largest customers will be in developing countries.

Since these systems operate on a global scale, some rather important global issues must be addressed. Some of these include:

- Frequency allocations
- Signaling protocols
- Connection to PTTs†
- Regulatory issues
- Licensing and tariffs

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† World Administrative Radio Conference, held in Malaga-Torremolinas, Spain in 1992

5 *Satellite-based Personal Communication Services*, Telecommunications, December 1993

† Personal Communications Satellite Services

6 TE&M, Oct 1, 1993

7 *Iridium: Key to Worldwide Cellular Communications,* Telecommunications, October 1991

† Public Telegraph and Telephone

Some analysts give PCSS approximately 10% chance for success as envisioned.[8]

Some Satellite System Facts (subject to change)

System	# Sat	Comments
ACeS	2	Asia Cellular Satellite, GEO, Voice, data, paging, e-mail
Aries	48	Australian Resource Information and Environment Satellite
Astra	13	Provides European TV, internet & multimedia communications. Part of SES Global
Celsat	3	GEO, Voice, data, fax, paging
ECCO	12	LEO, South America, Voice, data, fax, paging
Ellipso	14+3	LEO/MEO, Voice, data, paging, e-mail, CDMA
E-Sat	6	Data Services
FAISAT	26	Data, paging, voice
GEMnet	38	Data
GE Starsys	24	Data messaging
Globalstar	48	B-LEO, Voice, data, fax, paging, GPS, CDMA
ICO	10+2	MEO, Voice, data, fax, paging, TDMA
Iridium	66	B-LEO, Voice, data, fax, paging
Inmarsat P	10 + 2	
Koskon	32	B-LEO, Voice, data, fax, paging
LEO One	48	Data
M-Star	72	Broadband services
~~Odyssey~~	~~12~~	~~B-LEO, CDMA~~
Orbcomm	48	Data service
SkyBridge	80	Broadband LEO
Spaceway	12	GEO, Voice, data, video, broadband
Teledesic	840	LEO, Broadband services, ATDMA+, CDMA
Thuyara	2	GEO, Voice, data, paging, e-mail
VITAsat	2	Data services for volunteer disaster relief.

For Advanced Students

8.3.1 AceS

http://web.acesy.com/menu.htm

Coverage Map

ACeS (Asia Cellular Satellite System) is a combined cellular and satellite wireless system from Ericsson that provides GSM services in the Asia Pacific Region. It was expected to be available in 1999 to serve a combined population of three billion. ACeS has signed over 19 roaming agreements with GSM operators.

The system uses a Garuda geo-stationary satellite. A second satellite will expand the ACeS footprint into the West and Central Asia, Europe, and Northern Africa.

8 TE&M, Feb 15, 1993

The satellite will have two 12-meter antennas that will create 140 spot beams and support 11,000 simultaneous telephone channels.

8.3.2 AMSC (Skycell)

www.skycell.com appears inactive.

Status	Unknown
Cost	
Orbit	There are two HS601 GEO satellites. The MSAT satellite can act as a backup.
Uplink	Transmit frequency: 1.6265 to 1.6605 GHz
Downlink	Receive frequency: 1.525 to 1.559 GHz
Data rate	Data rate up to 4800 bit/s
Owners	Hughes Communications Corp., RonaldBaron, Singapore Telecom, AT&T.
Services	Mobile and fixed voice, messaging, GPS
Coverage	USA, Mexico and the Caribbean.
Market	AMSC is targeting businesses that require remote communications to thrive. AMSC-2 may provide handheld mobile services. Airtime rate ranges from US$0.85 to US$1.99 per minute, depending on applications.

8.3.3 Aries

The ATM Research and Industrial Enterprise Study (ARIES) is an experiment in high-speed terrestrial and satellite communications in the petroleum industry and for other applications. Using the NASA ACTS satellite, and technologies from various project partners, the ARIES Project has demonstrated world-class achievements in fixed and mobile telecommunications, in support of real-world industry goals and objectives.

Astra

http://www.astra.lu/ or http://www.ses-astra.com/

This 16-satellite system is built by GE Astro Space and provides radio and TV broadcasting, high speed internet, webcasting, Business TV, and interactive shopping channels, in Europe.

They have 16 transponders with an EIRP of 52 dBw and a bandwidth f 26 MHz. They operate in the 11.2 – 11.45 GHz region.

8.3.4 Astrolink

www.astrolink.com

This system consists of:

Four Regional Network Control Centers (RNCCs) - assign network resources, validate users, and monitor thesystem.

One Master Network Control Center (MNCC) - overall network resource management and collect usage statistics.

Two Satellite Operation Control Centers (SOCCs) - perform satellite housekeeping functions.

Three Telemetry, Tracking and Control (TT&C) facilities - enable the SOCCs to communicate with the system.

30 to 50 Gateway Earth Stations - allow customers to connect at data rates up to 110 Mbps. The gateways provide protocol conversions for T1/E1, TCP/IP, frame relay and X.25, and other protocols.

Status	Expected to be in operational service in 2000
Cost	US$4 billion.
Orbit	Nine A2100 GEO satellites in five orbital slots
Uplink	28.35 - 28.6 and 29.25 - 30 GHz
Downlink	19.7 - 20.2 GHz
Data rate	16 Kbps to 9.6 Mbps, total capacity of 6.5 Gbps per satellite
Owners	Lockheed Martin Telecommunications
Services	Principally data (over ATM)
Coverage	Worldwide
Market	Lockheed plans to market Astrolink to business and common carriers to provider worldwide high-speed, two-way data services.

8.3.5 Celestri

This system has now become part of Teledesic.

Status	This system has now become part of Teledesic
Cost	US$12.9 billion. (This includes the manufacture and launch cost of the first satellite of the Millennium project).
Orbit	63 LEO satellites in 7 planes are orbiting at an altitude of 1400km for the Celestri LEO constellation. Expected lifetime of eight years
Uplink	28.6-29.1 & 29.5-30.0 GHz
Downlink	18.8-19.3 & 19.7-20.2 GHz
Data rate	Sharing with Teledesic on a secondary basis. Data rates of up to 155.52 Mbps The Celestri LEO will be combined with up to four GEO satellites, possibly providing inter-satellite links, as well as complementary services.
Owners	Motorola Inc.
Services	Broadband data services, including interactive multimedia and point-to-point real-time user communications. It will also be suitable for fixed voice services.
Coverage	Up to 70 degrees north and south latitude
Market	Broadband Internet and intranet services from fixed terminals, particularly to large business users. Motorola intends to offer wholesale space segment capacity to carriers and service providers (not end-users). The Millennium and M-Star projects will be incorporated into Celestri.

8.3.6 Cyberstar

http://www.cyberstar.com/

Status	A dedicated constellation, which is intended to be ready in 1999, with full operational service expected in 2000.
Cost	US$1.6 billion.
Orbit	Three GEO satellites operating in Ka band.
Uplink	
Downlink	
Data rate	
Owners	Loral Space & Communications, Alcatel Espace
Services	Internet access, broadband interconnection, VOD and other data services.
Coverage	North America, Asia and Europe
Market	Broadband Internet and intranet access from low-cost fixed terminals. Loral has formed a strategic alliance with Alcatel to market the Cyberstar and Skybridge projects together.

8.3.7 EAST

Euro African Satellite Telecommunications

Status	EAST is expected to be in service around 2002
Cost	US$700 million (not including cost of gateways)
Orbit	A Eurostar 3000 GEO satellite
Uplink	
Downlink	
Data rate	
Owners	Matra Marconi Space
Services	Handheld mobile and rural/fixed telephony service. Main focus is on voice, but it will also offer data services.
Coverage	Africa and Middle East plus parts of Europe
Market	Provides low cost services that complement terrestrial fixed and mobile services.

8.3.8 ECCO

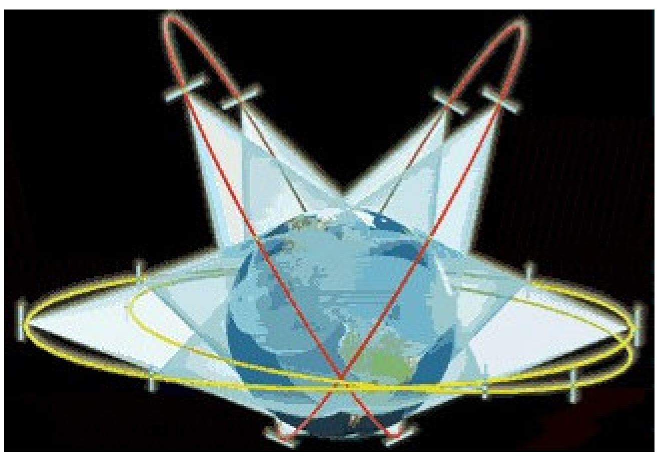
http://www.cciglobal.com/new2/index.html

The system will offer mobile services between 23^o north and south latitude. The system will consist of a single plane of 12 satellites in circular orbit around the equator, at an altitude of 2,000 km.

The downlink is 2483.5 - 2500 MHz and the uplink is 1610 - 1626.5 MHz. Each satellite will have 24 beams and can support up to 192,000 subscribers.

8.3.9 Ellipso

http://www.ellipso.com/



Status	Ellipso has recently been granted a US license and is expected to start operational service by 2000.
Cost	US$910 million.
Orbit	14 (with 3 in orbit spares), including elliptical LEO satellites orbiting at 520km and 7846km, and circular LEO satellites orbiting at 8040km.
Modulation	CDMA mobile users 5 MHz, fixed users 2.5 MHz
Uplink	1610.0 – 1621.5 MHz
Downlink	2483.5 – 2500.0 MHz
Data rate	Data rates of up to 9600bit/s.
Owners	Mobile Communications Holdings, Vulva Communications, Spectrum Networks Systems, Orbital Sciences Corp., Harris Corp., IAI, Spectrum Astro Inc., L-3 Com, Lockheed Martin.
Services	Mobile and fixed voice, data, fax, paging, GPS.
Coverage	Primarily the northern hemisphere but also as far south as 55 degrees latitude in the southern hemisphere.
Market	An extension of terrestrial mobile and fixed services to remote areas.

8.3.10 Emsat

Coverage Map

Emsat is a part of the Eutelsat system. It provides voice, fax data communications, position reporting and monitoring services. It is used by trucking fleets and ships in the European theatre.

8.3.10 E-Sat

http://www.esatinc.com/

Status	The FCC has yet to grant E-Sat the operational license
Cost	US$50 million
Orbit	Six LEO satellites orbiting at 1260km.
Uplink	
Downlink	
Data rate	
Owners	Echostar Communications, DBSIndustries
Services	Store and forward messaging
Coverage	Focused mainly on North America
Market	Provide remote equipment monitoring for North America gas and electricity utility companies.

8.3.11 FAISAT

http://www.finalanalysis.com/

Status	Full operation is expected no later than 2002.
Cost	US$250 million.
Orbit	36 LEO satellites in 6 orbit planes inclined at 61^0 plus 2 satellites inclined at 81^0.
Uplink	
Downlink	
Data rate	300 bps to 300 Kbps
Owners	Final Analysis, Polyot Enterprises
Services	Two-way messaging, asset tracking, monitoring and control, file transfer. Services are offered in real-time, near real-time, and store & forward modes.
Coverage	Worldwide
Market	Multiple market applications in the US and international markets.

8.3.12 Gemnet

http://www.cta.com/

Status	Service was expected to begin in 1999.
Cost	US$160 million
Orbit	38 LEO satellites in 1000km circular orbits. Expected lifetime is 5 - 7 years
Uplink	
Downlink	
Data rate	
Owners	CTA Inc. Orbital Sciences announced in July 1997 that it would be buying CTA's space system unit.
Services	Tracking & monitoring, email, paging.
Coverage	Global coverage
Market	Monitoring and tracking markets with low data requirements.

8.3.13 GE*Star

http://www.geamericom.com/satellite/index.html

Europe*Star Brochure

Status	
Cost	$4 billion
Orbit	9 GEO satellites from Alcatel
Uplink	28.35 - 28.6 and 29.25 - 30 GHz
Downlink	
Data rate	384 Kbps to 40 Mps.
Owners	GE Americom
Services	
Coverage	
Market	

8.3.14 GE Starsys

http://www.geamericom.com/satellite/index.html

Status	Launches were expected to begin in July 1998 and service was expected to be operational in 1999. However, GE has returned its operator's license to the FCC as of Aug 4 1997.
Cost	US$170 million.
Orbit	24 satellites in 4 planes orbiting at 1067km.
Uplink	
Downlink	
Data rate	
Owners	GE American Communications, CLS North America.
Services	Messaging, asset tracking, paging.
Coverage	Worldwide, but North America and Europe would have been key areas for real-time services.
Market	GE Starsys would have provided near-real-time services as well as store-and-forward services in remote areas.

8.2.15 Globalstar

Minimum Reading

http://www.globalstar.com/

GlobalStar Brochure

Globalstar constellation.

Globalstar Coverage Map

Status	The first launch is expected in October 1997, with initial commercial operations starting in 1998. Full operational coverage is expected by 1999.
Cost	US$2.6 billion for satellites with US$2.35 billion already financed.
Orbit	48 LEO satellites in a circular orbit, comprising 8 planes, at an altitude of 1400km. Expected satellite lifetime: 7 .5 years
Uplink	User uplink frequency: 2.4835 - 2.5 GHz Feeder uplink frequency: 5.025-5.225 GHz
Downlink	User downlink frequency: 1.61-1.6265 GHz Feeder downlink frequency: 6.875-7.075 GHz
Data rate	Voice: Typically 2400bit/s Data: 9600 bit/s (maximum)
Owners	Loral, Qualcomm, AirTouch Communications, DACOM/Hyundai, France Telecom/Alcatel, Daimler Benz, Vodafone, Alenia Spazio, Elsag Bailey, Finmeccanica, Space System/Loral.
Services	Primarily mobile and fixed voice services, with paging, messaging, fax and GPS services as secondary applications.
Coverage	Can cover up to 74 latitudes provided that gateways coverage is available. Each gateway is expected to provide mobile coverage for an area almost as large as Western Europe.
Market	Low-cost, high-quality services to under-served areas particularly in developing countries.

The Globalstar system has 48 LEO satellites in eight planes at an altitude of 1414 km. The constellation is designed for 100% single satellite coverage between $\pm 70^{o}$ latitude, and 100% dual or higher satellite coverage between 25^{o} to 50^{o} north or south latitude.

Globalstar will employ path diversity and three satellites may be used to complete the call. It uses CDMA for the mobile link.

It offers data rates of 1.2, 2.4, 4.8 and 9.6 Kbps. The vocoder rate drops to 1.2 Kbps when no voice activity is detected. This reduces interference and increases capacity, while maintaining synchronization and conveying background comfort noise.

The antennas create elliptical footprints along the satellite trajectory to increase the dwell time.

The system connects to the PSTN via 100 to 210 earth stations.

The system sells access to local service providers. They in turn only use the system when a terrestrial connection cannot be established.

8.2.16 ICO

Minimum Reading

http://www.ico.com/

http://www.i-co.co.uk/

Status	First launch is scheduled in 1998. Full operation is scheduled for the year 2000.
Cost	cost is expected to be $2.6 billion. To date, ICO has currently raised $1.5 billion
Orbit	10 operational medium earth orbiting (MEO) satellites (HS 601) circling at an altitude of 10 355km. Lifetime is expected to be 12 years.
Uplink	User uplink frequency: 1.98-2.02 GHz Feeder uplink frequency: 5 GHz
Downlink	User downlink frequency: 2.065-2.1 GHz Feeder downlink: 7 GHz
Data rate	Voice: 4800 bit/s Data: 38400 bits/s planned
Owners	45 telecommunications companies, Inmarsat, Hughes Electronic Corp.
Services	Mobile voice, data, fax, messaging.
Coverage	Global coverage.
Market	Domestic and international travelers, business and government organizations, commercial vehicles, maritime and aeronautical vessels, and residents of rural and remote areas.

Satellites in Orbit   Spot beams

ICO Global Communications Inc. was established in January 1995.

The major owners are NEC Corp, Hughes Network Systems and Ericsson. NEC will provide the access nodes, the network management systems and systems integration.

Hughes will provide the satellite and Ericsson the mobile switching centers. The Satellite Control Centre near London will manage the system.

The network will consist of 12 satellites in 2 inclined orbits at an altitude of 10,355 km. ICO satellites use the HS601 geostationary satellite bus and support 4,500 telephone channels.

Satellite diversity allows two or more satellites to access the same mobile terminal. The satellites relay the customer's channel to one of 12 earth stations linked to the PSTN.

The system uses dual mode terminals incorporating GSM and the local cellular standard.

A Zenit rocket carrying the first ICO Global Communications satellite exploded shortly after taking off from the Sea Launch platform in the South Pacific Sunday. (Mar 2000)

The satellite, built by Hughes Space and Communications, was the third launch for the Boeing-led venture. Sea Launch successfully launched a dummy satellite a year ago and a DirecTV satellite in October.

The lost satellite was valued at $100 million. Not only does the loss represent another setback for to ICO, which filed for bankruptcy protection last year, it' s another blow to the struggling mobile satellite services market.

In addition to Boeing, Energia of Russia, Kvaerner Maritime of Norway and KB Yuzhnoye/PO Yuzhmash of the Ukraine are partners in the Sea Launch venture.

8.3.17 Inmarsat-3

Minimum Reading

http://217.204.152.210/index.cfm

Status	Four satellites have been launched providing full global coverage, with one backup satellite to be launched near the end of 1997. A fourth generation, the Horizons project, is expected to be launched in 2001.
Cost	Approximately US$690 million.
Orbit	Five GEO satellites using spot beam technology. Satellite lifetime: at least 13 years
Uplink	
Downlink	
Data rate	Voice: 2400 bit/s Data: 2400 bit/s and above
Owners	Inmarsat signatories
Services	Mobile voice, data, fax, positioning
Coverage	The satellites will be over the four oceanic regions, providing coverage up to 70 degrees north and south latitudes. Spot beams are targeted at the main landmasses.
Market	Main new product is Inmarsat mini-M, a notebook-sized telephone which can be used virtually anywhere in the world. This is targeted mainly at high-end users with a need to communicate in remote areas.

8.3.18 Intelsat

Minimum Reading

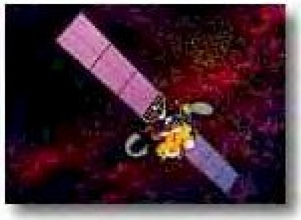
www.intelsat.com

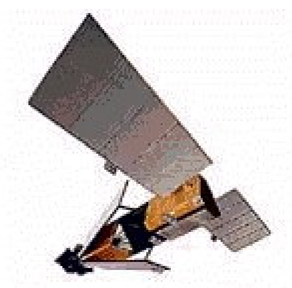
http://www.intelsat.int/

Intelsat developed the world's first international satellite communications system. It began with the Early Bird 1965, and by 1969 global coverage was acheived.

The present system supports voice, video, the internet, corporate and private networks in about 200 countries. It is presently consists of 17 satellites in geostationary orbit.

Intelsat Series	Image	Comments
V		Used both C and Ku bands. Spatial separation and polarization diversity, allowed some frequencies to be reuse four times. 15 of these satellites were built by Ford Aerospace.
VI		These are the largest commercial spacecraft ever built. Transponders static switch matrices or satellite-switched time division multiple access [SS/TDMA]. C-band frequencies are reused six times. Ku-band frequencies are reused twice. 5 of these satellites

		were built by Hughes.
VII		There are 4 of these satellites. They can reconfigure the coverage capability in-orbit
VIII		There are four of these satellites. They use six-fold C-band frequency reuse.
IX		Supports broadband applications such as trunking; telemedicine and remote learning; interactive video and multimedia.



8.2.19 Iridium

This system went bankrupt, but was restructured as Iridium Satellites.

Minimum Reading

http://www.iridium.com/
Iridium Constellation.
Iridium Product and Services Brochure

Iridium

Status	Partly operational
Cost	$4.4 billion +
Orbit	66 satellites orbiting at 780km (circular), using inter-satellite links. Expected satellite lifetime: 7 – 9 years
Uplink	User frequency: 1.616-1.6265 GHz Feeder uplink frequency: 2.91-29.3 GHz Feeder downlink frequency: 19.4-19.6 GHz Inter-satellite link frequency: 23.18-23.38 GHz
Downlink	
Data rate	Voice: 2.4 Kbps Data: 2.4 and 10 Kbps.
Owners	Motorola, Nippon Iridium Corp, Vebacom GmbH, Sprint, BCD Mobile Communications Inc, STET, DDI, UCOM, SK Telecom Corp., PT Bakrie Communications Corp., Raytheon.
Services	Voice, paging, data, fax.
Coverage	Global coverage, including mid-ocean and remote areas.
Market	Business professionals are expected to be the main customers. It is also expected to be an invaluable tool for aeronautical and marine uses.

The first proposed LEO system was Iridium[†], spearheaded by Motorola. This system initially proposed to use a combination of 77 low earth orbit satellites and the cellular telephone system. This ambitious scheme was eventually scaled down to 66 satellites many of which went into orbit. Unfortunately, the entire system went into bankruptcy early in 2000.

Some market forecasts estimated there would be 1.8M subscribers in the year 2001, growing to 2.8M in 2006, while others suggest it could be 3 times larger. Some have estimated the system cost at 2.5B$US while others place it as high as 3.4B$US[9] or even higher[10].

This system was intended to supplement ground based cellular systems, and provide government and business customers with advanced communications while traveling in less advanced countries.

Some of the system characteristics were:

- 7 to 9 year satellite life expectancy
- Six polar orbital planes inclined at 86.4^{o}
- Eleven active and one spare satellite per orbital plane
- Orbital period 100 minute 28 seconds
- Orbital elevation of 780 km
- Cell diameter: 372 nautical miles

† An element with 77 orbiting electrons

9 TE&M, Feb 15, 1993

10 Telecommunications International, March 1993

- 48 spot beams per satellite
- Telephone & messaging link: L-band (1.616 – 1.6265 GHz)
- Access: FDMA/TDMA
- Inter-satellite: link Ka-band (23.18 – 23.38 GHz)
- Ground segment: Downlink Ka-band (19.4 – 19.6 GHz) Uplink Ka-band (29.1 – 29.3 GHz)
- Ground based digital switches: Siemens GSM-D900
- Maximum number of simultaneous customers per cell: 110 [assuming 10.5 MHz total spectrum]

The services offered include:

- Terminals: hand held, portable, and vehicle-mounted .
- Position finding
- Facsimile service
- Dial-up data transmission: 2.4 Kbps, Data direct: 10 Kbps
- Worldwide paging

The satellites used 3-axis stabilization and a hydrazine propulsion system. The two solar panels had 1-axis articulation.

The Iridium system was based on the GSM architecture.

8.3.20 LEASAT

LEASAT, are US military geostationary satellites.

These enormous spin-stabilized satellites are 4.26 meters in diameter, 6.17 meters high with antennas deployed, and weigh about 7000 kg when launched from the space shuttle. The initial on station weight is 1388 kg.

8.3.21 Leo One Worldwide

Minimum Reading

www.leoone.com

LEO One Satellite

Status	FCC license expected by the end of 1997 with commercial service beginning in 2000
Cost	US$250 million
Orbit	48 LEO satellites arranged in 8 orbital planes at an altitude of 950km. Satellite lifetime of 5 years, with 7 years of consumables.
Uplink	148-150.05 MHz
Downlink	137-138 MHz and 400.15 – 401 MHz
Data rate	Subscriber Uplink 2.4 to 9.6 Kbps, Downlink 24 Kbps Gateway: 50 Kbps
Owners	dBX Corp
Services	Vehicle tracking, status monitoring, emergency alerting, messaging, paging, positioning. Fixed and mobile applications can be served.
Coverage	Leo One will provide store and forward coverage of all points between the Arctic and Antarctic Circles and near real-time service to the most populated regions of the Earth.
Market	Leo One will provide low-cost real-time, mobile and fixed service for industrial, business and personal data communications.

A combination of random access and frequency division multiplexing (FDM) is used for subscriber uplinks. Time division multiplexing (TDM) is used for the other links. All links use shaped offset-QPSK (OQPSK – offset quadrature phase shift keying) modulation in combination with forward error control (FEC) coding.

8.3.22 Movisat

Status	Operational. Another satellite (Morelos-3, based on HS 601HP satellite bus) will be launched at the end of 1998 to replace the aging Morelos-2.
Cost	
Orbit	Three GEO satellites, Solidaridad 1 and 2 & Morelos 2
Uplink	
Downlink	
Data rate	
Owners	Satelites Mexicanos SA.
Services	Mobile services, rural telephony, messaging, GPS.
Coverage	Mexico, southern USA, Caribbean and Latin America.
Market	Target market is high end-users who need communications in remote areas. The phone is approximately briefcase sized.

8.3.23 M-Star

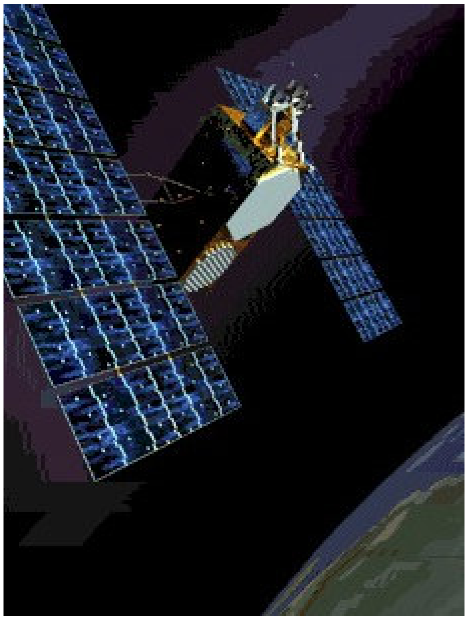
Status	Absorbed by the Celestri project.
Cost	US$6.1 billion
Orbit	72 LEO satellites.
Uplink	
Downlink	
Data rate	Data rates of up to 51.84 Mbps.
Owners	Motorola Inc.
Services	Backhaul and high-capacity truncking to networks will be served by M-Star, whereas interactive multimedia services will be served by the Celestri LEO constellation.
Coverage	Global coverage
Market	M-Star will be incorporated into the Celestri project. The M-Star project is intended to target multinationals with global broadband communications needs.

8.3.24 Odyssey

According to http://www.comlinks.com/sys/odyssey.htm the project has been cancelled.

Minimum Reading

www.trw.com



Status	Current Status US license was granted in Jan 1995, and commercial service was expected to be operating by 2001. According to http://www.comlinks.com/sys/odyssey.htm the project has been cancelled.
Cost	3.2B$US
Orbit	12 satellites at altitude 10354 km with 7 ground stations. Satellite lifetime of 15 years.
Uplink	User uplink frequency: 1.61-1621.35 GHz Feeder uplink frequency: 29.1-29.4 GHz
Downlink	User downlink frequency: 2.4835-2.5 GHz Feeder downlink frequency: 19.3-19.6 GHz
Data rate	Voice: 2400 bit/s, data: 9600 bit/s.
Owners	TRW Inc, Teleglobe Inc.
Services	Fixed and mobile voice telephony, fax, digital data, short messages.
Coverage	Worldwide
Market	Odyssey will seek primarily to complement and extend terrestrial fixed and mobile services in remote areas.

The Odyssey MEO system was to create stationary ground cells by steering the satellite body. CDMA was chosen for the multiple access method.

Usually at least two satellites would be visible from the mobile terminal and the best link is selected at call set-up.

Earth stations connect the system to the PSTN. Each satellite can support 3000 to 9500 voice circuits depending on the ratio of mobile to fixed terminals.

8.3.25 ORBCOMM

Minimum Reading

http://www.orbcomm.com/

Status	The first two satellites have been launched and are operational. The full system is expected to be operational by 1998.
Cost	US$350 million (completely financed)
Orbit	28 LEO satellites orbiting at 775km. 8 additional satellites may be added if there is sufficient demand. Satellite lifetime: 4 years
Uplink	148-149.9 MHz
Downlink	137-138 MHz and 400.05-400.15 MHz
Data rate	Data rate : up to 2400 bit/s (typically 300 bit/s)
Owners	Orbital Sciences Corp., Teleglobe Inc, Technology Resources Industries Bhd
Services	Messaging, email, fax, GPS
Coverage	Worldwide
Market	Orbcomm aims to provide high availability, low-cost, two-way, on-the-move communications over the entire globe.

Orbcomm provides worldwide two-way data and messaging services. It includes Orbital Science Corp., Teleglobe, and Technology Resources Industries. It will track vehicles, trailers, shipping containers and monitor utility meters, pipelines, storage tanks, and heavy equipment.

Two satellites are in a near-polar orbit and the rest will be placed in three planes (of 8 satellites) inclined at 45^o.

These small satellites (50 kg) can be deployed eight at a time by the air launched Pegasus rocket. The upink operates at 148 - 150.05 MHz and the downlink at 137 - 138 MHz.

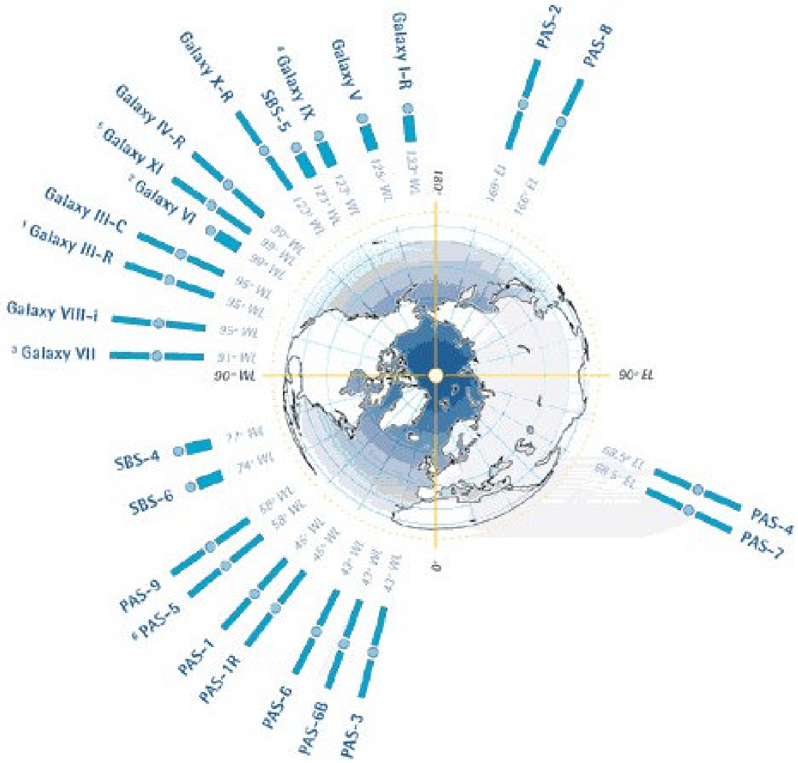
3.3.26 PanAmSat

☞ **Minimum Reading**

http://www.panamsat.com/

The PanAmSat system contains 21-satellites and covers the Americas, Europe, Africa, the Middle East and Asia.

Satellite	Spacecraft Design	Orbital Location	Launch Date	Ku-Band Payload	C-Band Payload	Coverage
Galaxy I-R	HS 376	133° WL	February 19, 1994	-	24 x 36 MHz	US
Galaxy III-R	HS 601	95° WL	December 14, 1995	16 x 27 MHz, 8 x 54 MHz	24 x 36 MHz	US, Latin America
Galaxy III-C	HS 702	95° WL	2001	TBD	TBD	US, Latin America
Galaxy IV-R	HS 601 HP	99° WL	2000	24 x 36 MHz	24 x 36 MHz	North America
Galaxy V	HS 376	125° WL	March 13, 1992	-	24 x 36 MHz	US
Galaxy VI	HS 376	99° WL	October 12, 1990	-	24 x 36 MHz	US
Galaxy VII	HS 601	91° WL	October 27, 1992	16 x 27 MHz, 8 x 54 MHz	24 x 36 MHz	US
Galaxy VIII-i	HS 601 HP	95° WL	December 8, 1997	32 x 24 MHz	-	Latin America
Galaxy IX	HS 376	123° WL	May 23, 1996	-	24 x 36 MHz	US
Galaxy X-R	HS 601 HP	123° WL	2000	24 x 36 MHz	24 x 36 MHz	North America
Galaxy XI	HS 702	99° WL	1999	24 x 36 MHz, 16 x 27 MHz	24 x 36 MHz	North America, Brazil
SBS 4	HS 376	77° WL	August 30, 1984	10 x 43 MHz	-	US
SBS 5	HS 376	123° WL	September 7, 1988	10 x 43 MHz, 4 x 110 MHz	-	US
SBS 6	HS 393	74° WL	October 12, 1990	19 x 43 MHz	-	US
PAS-1	GE Astro Series 3000	45° WL	June 15, 1988	6 x 72 MHz	6 x 72 MHz, 12 x 36 MHz	Americas, Caribbean, Europe
PAS-1R	HS 702	45° WL	2000	36 x 36 MHz	36 x 36 MHz	Americas, Caribbean, Europe, Africa
PAS-2	HS 601	169° EL	July 8, 1994	12 x 54 MHz, 4 x 64 MHz	12 x 54 MHz, 4 x 64 MHz	Asia-Pacific
PAS-3	HS 601	43° WL	January 12, 1996	12 x 54 MHz, 4 x 64 MHz	12 x 54 MHz, 4 x 64 MHz	Americas, Caribbean, Europe, Africa
PAS-4	HS 601	68.5° EL	August 3, 1995	16 x 27 MHz, 6 x 54 MHz, 2 x 64 MHz	12 x 54 MHz, 4 x 64 MHz	Europe, Africa, Middle East, Asia
PAS-5	HS 601 HP	58° WL	August 27, 1997	24 x 36 MHz	24 x 36 MHz	Americas, Caribbean, Europe
PAS-6	Loral FS 1300	43° WL	August 8, 1997	36 x 36 MHz	-	South America
PAS-6B	HS 601 HP	43° WL	December 21, 1998	32 x 36 MHz	-	South America
PAS-7	Loral FS 1300	68.5° EL	September 16, 1998	30 x 36 MHz	14 x 36 MHz	Europe, Africa, Middle East, Asia
PAS-8	Loral FS 1300	166° EL	November 4, 1998	24 x 36 MHz	24 x 36 MHz	Asia-Pacific
PAS-9	HS 601 HP	58° WL	2000	TBD	TBD	Americas, Caribbean, Europe
PAS-10	HS 601 HP	TBD	2000	TBD	TBD	TBD



8.3.27 Satphone

Appears to be on hold according to http://www.comlinks.com/sys/satphon.htm

Status	The first satellite is scheduled for launch at the end of 1998. Expected to be in service in September 1999
Cost	US$1.7 billion
Orbit	Three GEO satellite systems manufactured by Lockheed Martin.
Uplink	
Downlink	
Data rate	
Owners	Lockheed Martin Telecommunications, Advanced Technology Fund Inc., M.O.Al Amoudi Corp
Services	Mobile & fixed voice
Coverage	The Middle East, Northern Africa and the Mediterranean.
Market	Looking to complement and extend terrestrial fixed and mobile services.

8.3.28 SkyBridge

☞ **Minimum Reading**

SkyBridge Brochure

www.skybridge.com

http://www.skybridgesatellite.com/

http://www.alcatel.com/space/

Status	SkyBridge is expected to enter service in 2001 with half of its 64 satellites in operation. Full operation is expected in 2002.
Cost	US$4.1 billion.
Orbit	80 LEO satellites using frequency in Ku band (12 -15 GHz). No inter-satellite links are required.
Uplink	
Downlink	
Data rate	16 Kbps to 2 Mbps uplink, and 16Kbps to 20 Mbps downlink
Owners	Alcatel Espace, Loral Space & Communications.
Services	Interactive multimedia, high data rates and real time applications
Coverage	Worldwide
Market	It is primarily aimed at providing broadband access in areas with low or moderate density populations. SkyBridge will be marketed together with Cyberstar.

The SkyBridge LEO system provides access to high data rate multimedia services.

The constellation consists of 80 Ku band satellites inclined at 53°.

There will be about 200 gateway stations, each with a coverage radius of 350 Km to connect to the PSTN.

The uplink operates at 12.75 - 14.5 GHz, and the downlink at 10.7 - 12.75 GHz. Circular polarization helps to facilitate frequency reuse. Each satellite supports 18 spot beams. These are steered to create fixed ground cells.

8.3.29 Spaceway

Minimum Reading

http://www.spaceway.com/

Status	The first regional system is expected to go online as early as 2000
Cost	US$3.2 billion.
Orbit	Nine HS702 GEO satellites lifetime: 15 years
Uplink	27.5 - 30.0 GHz
Downlink	17.7-20.2 GHz
Data rate	16 Kbps up to 6Mbps
Owners	Hughes Communications Inc.
Services	Fixed voice, video, audio, data and multimedia and VSAT applications
Coverage	Most of the major continents will be covered except for parts of Asiatic Russia. The bulk of the inhabited world will be covered.
Market	Spaceway is expected to provide services in areas where the infrastructure is inadequate to meet the needs. The first target markets are likely to include North America.

8.3.30 Teledesic

☞ **Minimum Reading**

http://www.teledesic.com/

Status	First launch expected in 2000, with operational service expected to commence in 2002.
Cost	$9 billion.
Orbit	Believed to be 288 (rather than 840) satellites in a circular low earth orbit. Lifetime of satellites: 10 years
Uplink	
Downlink	
Data rate	16 Kbps to 2.048 Mbps or higher
Owners	Bill Gates, Craig McCaw, Boeing Co
Services	Will offer broadband data and voice services
Coverage	Worldwide. It is expected to cover 95% of the Earth's surface and 100% of populated areas.
Market	It aims to provide broadband digital access at an affordable cost to information workers anywhere in the world from fixed terminals. Internet/intranet access is likely to be key markets.

Teledesic Constellation.

The Teledesic satellite system is a very ambitious systems. It will use 840 satellites in 21 a sun-synchronous orbital planes and provide high data rate fixed and mobile service. Data transmission is to use a fixed length [512 bt], fast packet approach.

The network consists of 16 Kbps channels, which can be aggregated to form a 2 Mbps link. Gateway connections consist of DS-3 and OC-1 links.

Phased array antennas are used to create 53.3 sq km fixed footprints. When the beam angle becomes severe, all traffic is handed off to the next satellite assigned to that cell. This requires fewer handoffs than a moving cell system. Each satellite is linked with up to 8 other satellites via a 155.52 Mbps link.

The satellites are intended to orbit in a sun synchronous orbit at 700 km and inclination of 98.2°. Each orbital plane contains 40 satellites and 4 spares.

The mobile links will operate in the Ka-band. The system can use load sharing between the satellites.

Subscriber data rates range from 16 Kbps to 2.048 Mbps. The mobile terminal antennas have a diameter ranging from 8 cm to 1.8 meters, and an average output power ranging from 0.01 W to 4.7 W.

For Advanced Students

8.3.31 VITAsat

http://www.vita.org/

Status	The first satellite was destroyed during launch in 1995, and a replacement was expected to be launched by the end of 1997. In the meantime, PoSat-1 is being used on an interim basis.
Cost	US$10 million.
Orbit	Two LEO satellites orbiting at 1000km
Uplink	
Downlink	
Data rate	
Owners	Volunteers in Technical Assistance, Final Analysis Inc.
Services	Email and data transfer capability.
Coverage	Worldwide on a store and forward basis.
Market	VITAsat is designed specifically for developing countries. VITA is a non-profit making organization.

8.3.32 WorldSpace

WorldSpace Brochure

http://www.worldspace.com/

8.4 Canadian Communications Satellites

Minimum Reading

http://www.telesat.ca/

Anik A Series

Anik is an Inuit term meaning “little brother”. Anik A1 was launched in 1972, and was the world’s first geostationary domestic communications satellite.

	Anik A1	Anik A2	Anik A3
Satellite Type:	Hughes HS333	Hughes HS333	Hughes HS333
Weight:	560 kg	560 kg	560 kg
Transponders:	12 C-band	12 C-band	12 C-band
Launched:	November 9, 1972	April 20, 1973	May 7, 1975
Vehicle:	Delta Rocket	Delta Rocket	Delta Rocket
Retired:	July 15, 1982	October 6, 1982	November 21, 1984

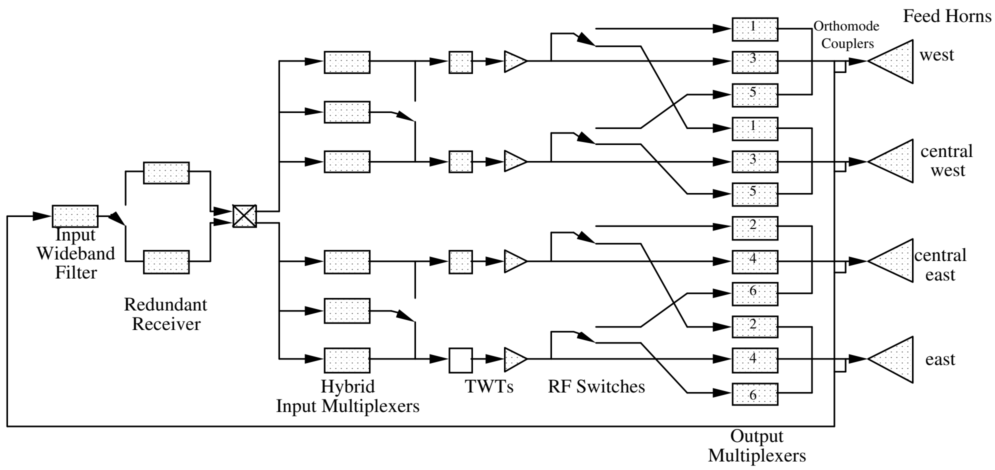
8.4.1 Anik-B

The Canadian Anik-B satellite is in geostationary orbit. It has 6 channels, each of which is 72 MHz wide. There is an 8 MHz guard band between each channel.

The uplink frequency band is approximately 14 - 14.5 GHz and are vertically polarized [north - south orientation]. The down link band is 11.7 to 12.2 GHz and the carriers are horizontally polarized [east - west orientation].

The satellite utilizes four antennas, each of which is used for both reception and transmission. The combined reception pattern covers almost the entire country, but the transmission pattern consists of four spot beams.

Anik Satellite



The uplink signals from all antennas are coupled from the horn antennas to the receiver section by orthomode couplers. These respond only to the vertically polarized signal. The received signal is then amplified and down converted to the downlink frequency band.

On retransmission, the odd channels can be switched by the master ground station to either the west or central west antennas. Likewise, the even channels can be switched between the east and central east antennas.

All telephone traffic on the Anik satellite is passed through transponder four and routed to the Ottawa ground station. Consequently, all telephone calls take two hops through the satellite to reach their destination.

Anik B1

Satellite Type:	RCA Astro Satcom
Weight:	920 kg
Transponders:	12 C-band 6 Ku-band
Launched:	Dec 78
Vehicle:	Delta Rocket
Status:	Retired: Dec 86

Anik C Series

	Anik C1	Anik C2	Anik C3
Satellite Type:	Hughes HS376	Hughes HS376	Hughes HS376
Weight:	1160 kg	1160 kg	1160 kg
Transponders:	16 Ku-band	16 Ku-band	16 Ku-band
Launched:	Ap 85	June 83	Nov 82
Vehicle:	SST Discovery	SST Challenger	SST Columbia
Status:	Operational	Retired: Jan 98	Retired: June 97

Anik D Series

	Anik D1	Anik D2
Satellite Type:	Hughes HS376	Hughes HS376
Weight:	1240 kg	1240 kg
Transponders:	24 C-band	24 C-band
Launched:	Aug 82	Nov 84
Vehicle:	Delta Rocket	SST Discovery
Status:	Retired: Dec 91	Retired: Jan 95

Anik E Series

When Anik E1 was launched in 1991, it was the most powerful commercial satellite in North America. It could carry 56 television channels instead of the usual 16. However, it failed in 1996.

Anik E satellites use three-axis stabilizers instead of the spin-stabilized method used on Anik A-D satellites.

Currently, the Anik E2 satellite system carries virtually all of Canada' s television broadcast traffic, in addition to voice, data, and image services.

	Anik E1	Anik E2
Satellite Type:	GE Astro 5000	GE Astro 5000
Weight:	2930 kg	2930 kg
Transponders:	24 C-band 16 Ku-band	24 C-band 16 Ku-band (2 analog TV channels each)
Launched:	Sept 91	April 91
Vehicle:	Ariane 4 Rocket	Ariane 4 Rocket
Status:	Failed 1996	Operational 2003

It should be noted that the site http://www.ualberta.ca/TELEHEALTH/satellite.html repots that the Anik E1 failed in 1996, however the site http://www.telesat.ca/satellites/ states that it is still operational.

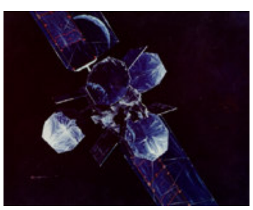
Anik E2 EIRP Ku Contours

Anik E2 C Band Contours

Anik F1

Minimum Reading

http://www.telesat.ca/satellites/anikf1.html



The new Anik F1 satellite is expected to be in service in the year 2000 and provide coverage throughout North and South America. It will have 48 Ku-band and 36 C-band transponders.

Satellite Type:	HS 702
Weight:	5200 kg
Transponders:	36 Ku-band 48 Ku-band
Vehicle:	Ariane 4 Rocket e
Status:	Under construction
Service Life:	15 years

Nimiq

Minimum Reading

http://www.telesat.ca/satellites/nimiq.html

Nimiq, an Inuit word for an object or force that unites things together, will be Canada's first DBS and will contain 32 Ku-band transponders.

Satellite Type:	LM A2100AX
Weight:	3600 kg
Transponders:	32 Ku-band
Vehicle:	Russian Proton D-1-e
Status:	Operational
Service Life:	12 Years

8.4.2 MSAT

MSAT is a geostationary satellite that provides mobile telephone, radio, facsimile, paging, position location and data communications.

http://www.tmi.ca/

Status	Operational.
Cost	
Orbit	HS601 GEO satellite. MSAT is providing back-up capacity for AMSC. Service life expected to be 12 years
Uplink	User frequency: 1.6315 - 1.6605 GHz Feeder frequency: 13.0 - 13.15 & 13.2 - 13.25 GHz
Downlink	User frequency: 1.53 - 1.559 GHz Feeder frequency: 10.75 - 10.95 GHz
Data rate	Data rate: 4800 bps
Owners	TMI Communications, Telesat Canada GTIS, Glentel, Infosat, Mobility Canada Satellite.
Services	Mobile & fixed voice, fax, data.
Coverage	North and Central America
Market	Targeting high end-users that need communications in remote areas.

MSAT uses the HS 601 satellite bus.

It can support 2000 channels, depending on the type of antenna and bandwidth assigned. The L-band is used to communicate between end-users and the satellite. The 29 MHz L-band transponders are divided into eight channels. The satellite L-band EIRP is 57.3 dBw.

Four L-band spot beams cover North America and a separate beam serves Alaska and Hawaii. The Caribbean beam includes Puerto Rico, the U.S. Virgin Islands, and Mexico.

Ground stations use Ku-band to communicate with the satellite and each other. The satellite antenna diameter is 0.75 meters and has an EIRP of 36 dBw.

Power is provided by a 3 kW solar panel array and a 4 kW nickel-hydrogen battery. The satellite uses 3 axis stabilization and has a design life span is about 12 years

	L-Band	Ku-Band
Main Transponders	16	1
Backup Transponders	4	2
Power [watts]	38	100
EIRP [dBw]	57	37

The transmission bit rates are 6400 bps for voice and 2400/4800 for data.

8.5 GPS

The Global Positioning System is a communications system of sorts. The system consists of orbiting radio stations broadcasting on the L1 and L2 bands, and is capable of identifying the location of a receiver.

It consists of 21 active satellites. Three satellites are in a parking orbit, and 4 on the ground as spares. It is expected that 4 to 10 satellites will be in the sky anywhere in the world at one time.

GPS Constellation

These satellites are in circular orbits at an altitude of 20,200 Km, and travel at about 4 Km per second.

GPS broadcasts two pseudo-random binary codes: the C/A code and P code. The P (precise) code has a 267-day long sequence, and is broadcast on both L bands. It consists of weeklong segments, and each satellite is given a portion of it to broadcast. This supports position accuracy to within 10 meters.

The C/A (clear access) code, is used for coarse acquisition has a one millisecond long sequence and is broadcast on the L1 band. It was meant for commercial applications and was to be accurate within 100 meters. In practice, the C/A code allows positioning to within 20 meters. Since this is perceived as a military threat, an artificial clock error has been introduced to reduce the accuracy to 300 meters.

Surveyors have developed sophisticated techniques to get around these restrictions and can determine an accuracy of less than a meter. This requires using two receivers used to make differential carrier wave measurements, and a great deal of time to take the satellite readings.

To determine position, the time delay to a at least 3 satellites must be made. In practice, a fourth satellite is needed, to help compensate for slight errors.

For Advanced Students

8.5.1 GLONASS†

This Russian military system, which consisting of 24 satellites in 3 orbital planes at an altitude of 19100 Km is plagued with financial difficulties. As of 1999, there were only 13 operational satellites.

GLONASS Satellite

GLONASS Orbits

GLONASS Fact Sheet

http://www.rssi.ru/SFCSIC/SFCSIC_main.html

http://www.nz.dlr.de/gps/glonass.html

http://www.oso.chalmers.se/~geo/glonass.html

8.5.2 Galileo

Satellite

http://www.galileo-pgm.org/

† GLObal NAvigation Satellite System

This is a non-military European initiative. It is expected to be operational by 2008. There are two different proposals being put forward:

9 geostationary and 21 MEO satellites (24000 Km) or

30 MEO satellites

There are three service offerings being considered:

OAS – Open Access Service, a free service offered to the general public

CAS 1 – Controlled Access Service Level 1, a fee-paying service for commercial applications

CAS 2 - Controlled Access Service Level 2, a fee-paying service for military and safety-critical applications

8.6 Satellite Microwave Channels

8.6.1 Access Methods

There are three techniques used to gain satellite access:

- FDMA - frequency division multiple access
- TDMA - time division multiple access
- CDMA - code division multiple access

FDMA is a simple where each ground terminal is assigned specific up and downlink frequencies. The most common modulation method is FM. Although this requires more bandwidth than AM, it has a better S/N ratio and constant power level.

Since the transponder and channel bandwidth is fixed, only a limited number of customers can gain access. To increase utilization, satellites often have multiple spot beams. This allows frequencies to be reused in different parts of the service area,

With TDMA, each ground terminal is assigned a time slot. As demand increases, more time slots can be added, thus gradually slowing down the overall response time. This creates a soft limit to the maximum number of customers that can be handled. If the customer is made aware of the delay, they can make the decision to either wait in the queue or to try again at some other time.

The data frame period is usually a multiple of 125 µSec to correspond to the PSTN.

CDMA is sometimes referred to as SSMA[†]. Individual radio carriers can be spread out over the entire satellite bandwidth. This would normally prevent any other station from using the facility, but there are ways of minimizing this conflict:

- DS–CSMA: direct sequence CSMA - the station address is superimposed on the carrier along with customer data.
- FH–CSMA: frequency hopping CSMA - the station address is used to continually change the carrier frequency.

† Spread Spectrum Multiple Access

8.6.2 Satellite Frequency Bands

The C-band occupies the 4 to 8 GHz frequency range and generally requires a 2-3 meters antenna. The Ku-band is from 11 to 17 GHz band and uses 0.5-meter antennas. The Ka-band goes from 20 to 30 GHz and uses even smaller antennas.

Band	Uplink [GHz]	Downlink [GHz]	Comments
L	.821 - .825	.866 - .870	MSAT
C	5.9 – 6.4	3.7 – 4.2	Fixed ground stations
X	7.9 – 8.6	7.25 – 7.75	Military mobile radio
Ku	14 – 14.5	11.7 – 12.2	Broadcast and fixed point
Ka	27 – 30 30 – 31	17 – 20 20 – 21	
V/Q	50 – 51	40 – 41 41 – 43	Broadcast and fixed point
V	54 – 58 59 – 64	54 – 58 59 – 64	Inter-satellite

Most communication satellites are simply high altitude repeaters. In the past, ground stations performed all routing and switching functions. Newer satellites can sometimes perform these functions, thus reducing transmission delay.

Typical C-Band Satellite Characteristics[11]

	Type of Coverage		
Parameter	Global	Regional	National
Tx Antenna Gain [dBi]	17 - 19	21 - 25	28 - 32
Rx Antenna Gain [dBi]	17 - 19	21 - 24	30 - 34
EIRP [dB]	22 - 24	26 - 31	30 - 34
Rx Noise Temp [^oK]	8000 - 2000	800 - 2000	800 - 2000
G/T [dB/^oK]	-17 to -14	-12 to -5	-3 to +5

Typical C-Band Earth Station Characteristics

	Type of Coverage		
Parameter	Global	Regional	National
Antenna Size [m]	4.5 - 32	4.5 - 25	3 - 30
Tx Antenna Gain [dBi]	47 - 64	47 - 62	43 - 63
Rx Antenna Gain [dBi]	43 - 61	43 - 59	40 - 60
EIRP [dBW]	46 - 95	46 - 74	45 - 84
Rx Noise Temp [^oK]	50 - 150	50 - 150	50 - 200
G/T [dB/^oK]	23 to 41	23 to 38	17 to 41
Tx Power [kW]	1 - 12	0.3 - 3	0.005 - 1

[11] Electronic Communications Handbook, A. F. Inglis, ed.

The high power and frequency characteristics of Ku band satellite systems, allow for the use of very small antennas. Some typical characteristics of these systems are:

- Spacecraft EIRP 35 - 50 dBW
- Spacecraft G/T - 3 to +9 dB/^{o}K
- Earth Station G/T 14 to 45 dB/^{o}K
- Transponder Bandwidth 36 - 72 MHz

There are two basic methods used to increase satellite frequency utilization:

- Beam polarization
- Multiple beams

Two beams of the same frequency can be distinguished from each other if their electric fields are orthogonal. This method is often used on terrestrial digital microwave links where the fields can be horizontally and vertically polarized. Both spacecraft and earth stations require about 30 dB of isolation between the two polarizations.

An alternative arrangement is to use circularly polarized fields. These can be oriented to the right or left. These methods are effective below 10 GHz, but in the 10 – 30 GHz region, non-spherical water droplets tend to affect the polarization, and this method doesn't work.

To minimize coupling between transponders using two polarizations, the frequency slots are interleaved so that the center of one transponder is located in the guard band of the other.

Another way to increase frequency utilization is by means of spot beams. These can be created in three ways:

- Multiple antennas
- Common reflector and multiple feeds
- Phase shift array

Consideration must be give to the amount of spillover from one spot to another. To increase the isolation between similar carriers on different beams, polarization may be used.

Multiple beams not only make better use of the spectrum, but it also allows satellites to perform switching function from one beam to another.

8.7 Satellite Details

Satellites are comprised of a housing, power system, antenna system, command and control system, station keeping system, and transponders.

8.7.1 Satellite Construction

The stabilization system determines the satellite's overall shape. The basic configurations are:

3-axis stabilized

Spin stabilized

Gravity gradient beam

Three-axis-stabilized satellites contain gyroscopes rotating at 4,000 to 6,000 rpm and often resemble a box. Since the body remains fixed with respect to the earth, the antenna does not rotate. However, the solar cells, must rotate since they must always the sun.

Spin stabilized satellites are generally cylindrical and rotate at 60 - 70 rpm. Solar cells are mounted on the surface and therefore do not require pointing. However, the antenna must be decoupled from the satellite.

Gravity gradient satellites extend a large boom towards the earth, and rely upon gravity to keep t pointing down.

The vast majority of satellites are powered by solar cells. These have a conversion efficiency of 15 - 20%. When the satellite is eclipsed by the earth, nickel-hydrogen batteries supply power.

Satellite antennas must support tracking, telemetry, and command functions in addition to telecommunications traffic. If TT&C is lost, the satellite is lost.

TT&C systems monitor the satellite operating parameters, telemetry circuits, interpret commands, and control the operation of the satellite.

Satellites will drift out of its orbital slot because of the gravitational effects of the sun, moon, and earth.

They are repositioned by hydrazine gas thrusters. When the gas is gone, the satellite will drift and be lost. This is what determines the life expectancy of most satellites.

The whole purpose of a communications satellite is to support a transponder or repeater. Such a satellites may have 12 - 24 transponders with an output power of 5 to 10 watts.

8.7.2 Galaxy Satellites

Many Galaxy satellites are versions of the Hughes HS 376 communications satellite. Each has 24 transponders in the 6/4 GHz band. Most Galaxy satellites are used for television.

Galaxy 393

Galaxy 601

Galaxy XI

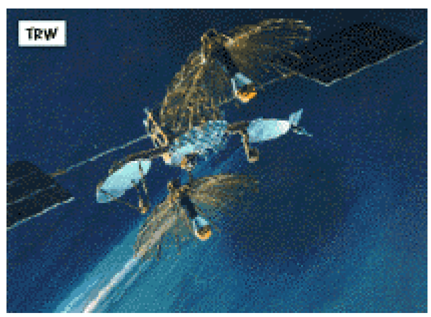
This is based on the Hughes 702 design.

Cu Band	24 x 36 MHz – 20 Watt Output Uplink 5.925 - 6.425 GHz Downlink 3.700 - 4.200 GHz
Ku-band	24 x 36 MHz – 75 Watt Output 16 x 27 MHz – 140 Watt Output Uplink 14.0 - 14.500 GHz Downlink 11.700 - 12.200 GHz

Galaxy XI Footprint

8.8 NASA Satellites

TDRS



Minimum Reading

http://samadhi.jpl.nasa.gov/msl/QuickLooks/tdrssQL.html
http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/sts-jsc-comm.html
http://www-pao.ksc.nasa.gov/kscpao/nasafact/tdrs.htm
http://www.gsfc.nasa.gov/gsfc/earth/tdrs/presskit.htm
http://spaceflightnow.com/atlas/ac139/000626tdrsh.html
http://nmsp.gsfc.nasa.gov/tdrss/tdrshij.html
http://nmsp.gsfc.nasa.gov/tdrss/oview.html
http://www.astronautix.com/craft/tdrs.htm

_____ Notes _____

For Advanced Students

8.9 Satellite Launch Vehicles

•There are several different launch vehicles:

Boeing Delta-5

http://www.boeing.com/defense-space/space/delta/deltahome.htm

Lockheed Martin Atlas rocket

http://www.lmco.com/

Sea Launch

http://www.sea-launch.com/

Pegasus air-launched vehicle

http://www.orbital.com/

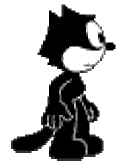
Russian Khrunichev Proton rocket

European Ariane rocket

http://www.arianespace.com/

China's Great Wall Long March 2C

Assignment Questions



Quick Quiz

1. VSAT networks use satellites placed in [geostationary, polar] orbits.
2. MEOS systems use highly elliptical orbits. [True, False]
3. Although SPADE is a FDMA system, it uses TDM CSC signaling. [True, False]
4. LEOS satellites travel [faster, slower] than MEOS satellites.
5. The ratio G/T is unitless. [True, False]

Analytical Problems

Composition Questions

It may be necessary to do some research to answer some of these questions.

1. What is the furthest north that a geo-stationary satellite ground station can be placed?
2. Define EIRP.
3. List three applications for PCSS systems.
4. What are the two basic methods of code division multiple access?
5. Check the internet for the latest information on the various satellite systems mentioned in this section.

For Further Research

Gagliardi, Robert M; *Satellite Communications*, Lifetime Learning Publications, Belmont, California, 1984

Prichard & Sauulli; *Satellite Communications Systems Engineering*

MSAT Phase B Final Report; Dept. of Communications Gov't of Canada, Cat. No. Co22-77/1987E

Special Series on VSAT; IEEE Communications Magazine, July, September 1988

Series on Satellite Communications; MSN & CT November 1986

"Satellite Communications", Electronics & Wireless World December 1985

"Communications Satellites move to Higher Frequencies", High Technology November 1984

Special Series on Satellite Communications, IEEE Communications Magazine May 1984

"Air and Sea Rescue via Satellite Systems", IEEE Spectrum March 1984

Web-sites:

http://www.spacenet.com/

http://www.looksmart.com/eus1/eus317829/eus317861/eus65317/eus87531/eus149569/eus149572/r?l&

http://www.satsig.net/index.htm

http://www.atmdigest.com/satellit.htm

http://www.satcomms.com/

http://www.lland.demon.co.uk/sisfiles/sis.html

http://www.comlinks.com/

Satellite Industry Association

http://www.sia.org/index.htm

http://www.skyreport.com/index.htm

http://www.comsat.com/

http://itre.uncecs.edu/misc/sj/sj.html

http://www.funet.fi/index/esi/skyguide.html

http://www.funet.fi/index/esi/satnews.html

http://www.funet.fi/index/esi/TELE-Satellite.html

http://www.tele-satellit.com/tse/

http://www.satellitetelephone.com/

http://www.satnews.com/

http://www.fas.org/spp/index.html

http://members.aol.com/wsnspace/

http://www.nasa.gov/hqpao/space_agencies.html

http://www.yahoo.com/Government/Research_Labs/NASA/

ICO:

www.i-co.co.uk/

http://www.nec.com.au/ico1.htm

Globalstar:

http://www.globalstar.com/

www.wp.com/mcintosh_page_o_stuff/globals.html

Iridium:

www.iridium.com

Teledesic:

www.teledesic.com

Canadian Satellites

http://www.cancom.net/

http://www.telesat.ca/

US Satellites

http://www.ussbtv.com

European Satellites

http://www.funet.fi/index/esi/

DBS

http://www.primestar.com/

http://www.lookup.com/Homepages/95191/cvn.html

http://www.dbs-online.com/

http://www.directv.com/

http://www.echostar.com

http://www.expressvu.com

http://www.dbsdish.com/

Astasat

http://www.astrasat.co.za/index.htm

Hughes

http://www.hcisat.com/

Space Innovations Ltd.

http://www.sil.com/

http://www.sat-net.com/uk-satellite/

http://www.intelsat.com/

http://www.panamsat.com/

http://www.tdrss.com/

http://www.loralskynet.com/

http://www.comlink.com/satellite.html

http://www.comlinks.com/satcom/satmenu.htm

Aries

http://www.llnl.gov/gonii/aries/aries.html

Space Systems Loral

http://www.ssloral.com/

Satellite Communication Systems

http://www.satellite-commsys.com/

http://www.casbaa.com/frameset.htm