

# LEOs - THE COMMUNICATIONS SATELLITES OF THE 21<sup>st</sup> CENTURY

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## INTRODUCTION

Traditionally, communications satellites have operated in geo-stationary orbit (GSO), 35,000 km above the equator, and low Earth orbit (LEO) satellites have been used for weather monitoring, resource mapping, and Earth sensing. By the start of the new millennium, in five years, a revolution will have occurred in the communication satellite industry with LEO satellite networks becoming key pathways of the information superhighway.

Low Earth orbits are generally considered to be those with altitudes between 500 km and 2,000 km. Lower altitudes in quick reentry and higher altitudes are subject to severe radiation from the Van Allen Belts. The round trip delay using LEOs is a small fraction of the ½ second required for communication via GSO satellites. By their very nature, LEOs are global systems, capable of providing service to all areas of the world.

The evolution from geo-stationary to low-Earth-orbit (LEO) satellites has resulted in a number of proposed global satellite systems, which can be grouped into three distinct types - Little LEOs, Big LEOs, and Broadband LEOs. These systems can best be distinguished by reference to their terrestrial counterparts: paging, cellular, and fiber, as shown in Table 1.

On the ground, paging, cellular, and fiber services are complementary, not competitive, because they offer fundamentally different kinds of services. Similarly, the Little LEOs, Big LEOs, and Broadband LEOs are complementary rather than competitive because they are providing distinctly different services targeted at

different markets, and have different pricing structures.

**Table 1. Terrestrial Counterparts**

	Little LEO	Big LEO	Broadband LEO
Example Systems	ORBCOMM Starsys	IRIDIUM Globalstar ICO	Teledesic
Terrestrial Counterpart	Paging	Cellular	Fiber

Typical applications of the various types of LEO systems are shown in Table 2. Of course the Big LEOs can support the Little LEO applications, and the Broadband LEOs can support both the Big and Little LEO applications. However, the economics will tend to discourage this from happening.

**Table 2. Typical Applications**

Little LEOs	Paging E-mail Fax
Big LEOs	Voice Telephone Low Speed Data
Broadband LEOs	Multimedia Conferencing Internet Access Video Conferencing Video-Telephony High Speed Data

## **LITTLE LEOS**

The Little LEOs provide paging extension. Their subscriber links operate in the VHF and UHF bands. The ORBCOMM and Starsys systems are described below. Other systems are VITA and the so called 2<sup>nd</sup> Round systems (Leo One USA, Final Analysis Communication, CTA Commercial Systems, GE Americom, and E-SAT).

### ORBCOMM

ORBCOMM is a joint venture of Orbital Sciences Corporation and Teleglobe. The ORBCOMM constellation consists of 36 satellites at an altitude of 775 km, in six orbital planes. Two of the planes are polar, with two satellites each, and the remaining four, with 8 satellites each, are inclined at 45° to the equator. The inclined planes are spaced 135° apart at the points where they cross the equator. The satellites have a 43 kg mass and 160 W of solar array power.

The ORBCOMM system uses a modified Aloha multiple access scheme for subscriber uplinks and a dynamic channel activity assignment system (DCAAS) to share its subscriber uplink spectrum with the land mobile service. The ORBCOMM subscriber uplinks operate in the 148 - 150.05 MHz band and the downlinks in the 137 - 138 MHz band. The Gateway Earth Stations use the same bands with 500 W uplink transmissions and 3 W downlink transmissions.

The first two satellites, in one of the polar planes, were launched in April 1995 and are operational today. The two satellites in the 2<sup>nd</sup> polar plane will be deployed in early 1997, followed by three of the inclined planes later that year. The 8 satellites in the 4<sup>th</sup> inclined plane will be deployed depending on demand to provide increased coverage. An entire plane of 8 satellites can be deployed using a single Pegasus air launched booster.

ORBCOMM subscriber communicators are being built by Elisra Electronic Systems, Panasonic Industrial Company, and Torrey Science Corporation.

### GE Starsys

GE American Communications (GE Americom) recently acquired 80% of Starsys Global Positioning, Inc. The system has been renamed GE Starsys.

The GE Starsys constellation consists of 24 satellites in six equally spaced planes of four satellites each with 53° inclination. The orbit altitude is 1,000 km.

The subscriber uplinks use spread spectrum (CDMA) to share the 148 - 149 MHz band with the land mobile service. The downlinks are narrowband (TDMA) in the 400.15 - 401 MHz band. Gateway uplinks are narrowband in the 149.9 - 150.05 MHz band and downlinks are spread spectrum in the 137 - 138 MHz band.

The mass of the GE Starsys satellites is 120 kg. They provide 50 W of payload power. The satellites will be compatible with various small launchers supporting both single and multiple satellite launches. Full deployment is anticipated by the year 2000.

User terminal costs will be below \$200. Yearly service fees are planned to be less than \$100 with a per message charge of \$0.25.

## **BIG LEOS**

The Big LEOs provide cellular extension. Their subscriber links operate in L-band and S-band. The IRIDIUM, Globalstar, and ICO systems are described below. Other systems are Odyssey (a 12 satellite MEO CDMA system being developed by TRW), Constellation (formerly Aries, a 48 satellite CDMA system), and Ellipso (an elliptical orbit, 7800 km apogee, 520 to 7800 km perigee, CDMA system).

### IRIDIUM

Motorola Satellite Communications Division is the developer, system integrator, and prime contractor for the IRIDIUM system. IRIDIUM's constellation of 66 satellites is divided into 6 planes of 11 satellites each. The planes are inclined at 86.4° and the satellites are at an altitude of 780 km.

The subscriber uplinks and downlinks will operate in the 1616 - 1626.5 MHz band using time division duplex (TDD) and a combination of Frequency Division Multiple Access (FDMA)

and Time Division Multiple Access (TDMA). Gateway links will use the 29.1 - 29.3 GHz band for uplink and the 19.4 - 19.6 GHz band for downlink.

IRIDIUM uses inter-satellite cross-links to hand off calls between satellites in the same or adjacent orbital planes. These links operate in the 23.18 to 23.38 GHz band. The satellite mass is 689 kg.

Gateway Earth stations interconnect the IRIDIUM constellation to the public switched telephone network. This allows communication between an IRIDIUM telephone and any other telephone in the world.

Hand-held user terminal cost is anticipated to be \$2,500. Subscriber rates will be around \$3.00 per minute. System operation is scheduled for 1998.

### Globalstar

Globalstar is a limited partnership founded by Loral and QUALCOMM. The Globalstar constellation consists of 48 satellites in 8 orbit planes with 6 satellites per plane. The planes are inclined at 52° and at an altitude of 1410 km.

The subscriber uplinks will operate in the 1610 - 1626.5 MHz band and the downlinks in 2483.5 - 2500 MHz band. Feeder links will use the 5091 - 5250 MHz band (uplink) and the 6875 - 7055 MHz band (downlink).

Space Systems/Loral is the prime contractor for Globalstar. A total of 56 satellites will be developed and launched, including 8 in-orbit spares. The satellites will weigh 450 kg each, and have a total transponder power of 1 kW.

Globalstar will begin launching satellites in the 2<sup>nd</sup> half of 1997, commencing initial operations with a 24 satellite constellation in 1998. Full 48 satellite coverage will occur in the 1<sup>st</sup> half of 1999. System cost is \$2.2 billion. The satellites will be launched using a mix of Delta-II, Zenit-2, and Long March 2E/TS launchers.

Globalstar's wholesale price to its service providers will average \$0.35 to \$0.53 per minute. The service providers will establish retail pricing. Mobile and portable subscriber units will cost approximately \$750. Public

telephone booth units are expected to cost between \$1,000 and \$2,500.

### ICO

Previously known as Project 21 and Inmarsat-P, the ICO satellite system is being developed by ICO Global Communications. The name, ICO, comes from Intermediate Circular Orbit. Like the Odyssey system, ICO will operate at medium earth orbit (MEO), that altitude band between the upper and lower radiation belts.

ICO is a commercial venture spinout of Inmarsat, the 79 member-country international organization that uses geo-stationary satellites to provide global mobile communications for ships, aircraft, and land applications. It has investors from over 40 countries spanning six continents.

The ICO constellation consists of 12 satellite, 10 operational and two spares, at an altitude of 10,355 km above the earth's surface. The orbits are inclined at 45° to the equator. Each satellite has the capacity to handle 4,500 simultaneous phone calls through its 163 spot beams.

The subscriber uplinks will use the 1980 - 2010 MHz band and the downlinks the 2170 - 2200 MHz band. Feeder links will operate in the 5150 - 5250 MHz band (uplink) and the 6975 - 7075 MHz band (downlink).

The satellites are being built by Hughes Space and Communications International under a \$1.4 billion contract, this is slightly more than one-half of the \$2.6 billion total system cost. They are expected to weigh about 2,000 kg and have end-of-life solar array power of 8 kW. The satellites are compatible for launch by Atlas II, Delta-III, Proton, Zenit, Arine-5, and H-II launch vehicles. The first ICO satellite is scheduled for launch in 1998, with interim service in mid 1999, and full operation in 2000.

Service will cost \$1 to \$2 per minute. The quality of service (QoS) goal is to setup and complete 90% of all calls, with an average duration of two minutes, at the first attempt.

## **BROADBAND LEOs - TELEDESIC**

Broadband LEOs provide fiber extension. The first such proposed system is Teledesic.

Teledesic was founded in 1990 with headquarters in Kirkland, Washington, a suburb of Seattle. Teledesic's principal shareholders are Craig O. McCaw and William H. Gates III. Mr. McCaw, who leads the company as its Chairman, is the founder of McCaw Cellular Communications, which he built into the world's largest wireless communications company before its 1994 merger with AT&T. Mr. Gates is the co-founder, Chairman and CEO of Microsoft Corporation, the world's largest computer software company.

Teledesic plans to begin service prior to the year 2002. Teledesic does not intend to market services directly to end-users. Rather, it will provide an open network for the delivery of such services by others. The Teledesic Network will enable local telephone companies and government authorities in host countries to extend their networks, both in terms of geographic scope and in the kinds of services they can offer. Ground-based gateways will enable service providers to offer seamless links to other wireline and wireless networks.

Teledesic uses small, "earth-fixed" cells both for efficient spectrum utilization and to respect country's territorial boundaries. Within a 53 by 53 km cell, the Network will be able to accommodate over 1,800 simultaneous 16 Kbps voice channels, 19 simultaneous T1 (1.544 Mbps) channels, or any comparable combination of data rates. This represents a significant system capacity, equivalent to 20,000 simultaneous T1 lines worldwide, with the potential for graceful growth to higher capacities. The Network offers high-capacity, "bandwidth-on-demand" though standard user terminals. Channel bandwidths are assigned dynamically and asymmetrically, and range from a minimum of 16 Kbps up to 2 Mbps on the uplink, and up to 28 Mbps on the downlink. Teledesic will also be able to provide a smaller number of high-rate channels at 155 Mbps to

1.2 Gbps for gateway connections and users with special needs.

The Teledesic constellation is organized into 21 circular orbit planes that are staggered in altitude between 695 and 705 km. Each plane contains a minimum of 40 operational satellites plus up to four on-orbit spares spaced evenly around the orbit, for a total of 924 satellites. The orbit planes are at a sun-synchronous inclination (approximately 98.16°), which keeps them at a constant angle relative to the sun. The ascending nodes of adjacent orbit planes are spaced at 9.5° at the Equator. The Teledesic satellite uplinks operate in the 30 GHz band (28.6 - 29.1 GHz) and the downlinks operate in the 20 GHz band (18.8 - 19.3 GHz).

Design, construction, and deployment of the Teledesic Network is estimated at \$9 billion. The Teledesic Network represents the first time that satellites and their associated subsystems will be designed and built in quantities large enough to be mass produced and tested. These substantial economies of scale enable a cost structure comparable to that of wireline service in advanced urban areas. To minimize launch costs and scheduling constraints, Teledesic's satellites will be compatible with more than 20 launch systems around the world and will be self-stacking so that several satellites can be deployed by a single launch vehicle.

## CONCLUSION

Within five years, LEO satellite networks will have become key pathways of the information superhighway. LEOs provide low delay and global coverage.

Little LEOs provide paging extension, Big LEOs provide cellular extension, and Broadband LEOs provide fiber extension. These three system types are complementary, rather than competitive. They provide distinctly different services to different markets.

## REFERENCES

The following web sites were used in preparing this paper:

### Title

### Address

Ellipso Mobile Satellite System

<http://www.jagunet.com/prism/ellipsat.html>

Globalstar	<a href="http://www.wp.com/mcintosh_page_o_stuff/globals.html">http://www.wp.com/mcintosh_page_o_stuff/globals.html</a>
ICO Global Communications	<a href="http://www.i-co.co.uk/index-page.html">http://www.i-co.co.uk/index-page.html</a>
Iridium LLC	<a href="http://www.iridium.com">http://www.iridium.com</a>
Leslie Taylor Associates, Inc.	<a href="http://www.lta.com/high/lta.htm">http://www.lta.com/high/lta.htm</a>
Lloyd's Satellite Constellations	<a href="http://www.ee.surrey.ac.uk/Personal/L.Wood/constellations/">http://www.ee.surrey.ac.uk/Personal/L.Wood/constellations/</a>
Mobile Satellite Telecommunications	<a href="http://www.wp.com/mcintosh_page_o_stuff/tcomm.html">http://www.wp.com/mcintosh_page_o_stuff/tcomm.html</a>
Orbcomm	<a href="http://www.orbcomm.net">http://www.orbcomm.net</a>
Tor E. Wisloff's Big LEO Tables	<a href="http://www.ee.vt.edu/liank/LEOs1.html">http://www.ee.vt.edu/liank/LEOs1.html</a>
VITA Information Department	<a href="http://www.vita.org/info/infodept.html">http://www.vita.org/info/infodept.html</a>