Worldwide Satellite Communications for the Energy Utility Industry

TR-111052

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REPORT SUMMARY

This report examines advances in communications satellite systems that could have a high impact on an energy company's ability to manage resources located in remote areas. While satellite relevance to the energy industry has been known for a long time, only recently has new technology addressed the economic and technical constraints that have limited their use by a majority of companies.

Background
A new generation of communication satellites, now being put into commercial service, will bring new and innovative communications capabilities to energy companies. These capabilities are well aligned with trends toward management of expanding distributed energy and information assets, improved two-way customer communications, and business expansion beyond traditional boundaries both nationally and globally. The increasingly complex and data-intensive energy systems of the future will demand communications requirements far beyond current capabilities. The ability to rapidly deploy and then control and monitor technology in remote locations with relatively inexpensive infrastructure is a unique property of satellites. Satellites are thus directly applicable to remote monitoring, metering and control, and portable communications in support of future energy systems.

Objectives
- To present technical and business reasons for energy companies to reconsider satellite communications—from their viewpoints as users and as potential investors.
- To show how advancement of the state of the art in satellite design and development will radically extend the scope of economic deployment into the energy sector even where near-real-time critical system performance is demanded.

Approach
In recognition of the business trend in the energy industry towards better asset utilization, the study examined the capabilities and limitations of new constellations of satellites now in the early stages of development and deployment. This report is written with an emphasis on relevance to business strategists rather than communications engineers; it deals with technical aspects with sufficient detail for

strategic analysis but without full scientific rigor. The focus is on U.S. domestic systems using low-earth orbiting (LEO) satellites.

Results

Utility applications of future satellites are unprecedented since cost and propagation delay (which have so far limited their extensive use in energy industries) will be greatly improved by emerging technologies. Advancement of the state of the art in satellite design and development will radically extend the scope of economic deployment into the energy industry even where near-real-time critical system performance is demanded. So-called "Big LEOs" are briefly compared as emergent communications vehicles that are likely to meet many of the broadband needs of energy companies.

EPRI Perspective

This report shows that new generations of satellites are creating more options for solving many of the economic and technical problems of dispersed, low-intensity data communications. In addition, the report illustrates that utilities intending to diversify their businesses through investments in telecommunications have many opportunities to do so in the satellite sector. Of special interest to utilities (and the focus of the study) are constellations of low-earth orbit satellites known as "Little LEOs." With specialized development of their core technologies, these satellites could be capable of meeting many strategic and operational business objectives in distributed energy system management and customer information services. The recently concluded round of FCC licensing has introduced new entrants into this field, opening up the prospects for new forms of business alliance.

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Interest Categories

Customer communications systems
Utility information systems
Home automation & energy management
Energy management & controls, office automation

Keywords

Satellite communications
Low-earth orbiting satellites
Data communications
New business opportunities
Metering
Mobile data communications

ABSTRACT

Recent and future generations of low earth orbiting (LEO) satellites are promising new possibilities for using space communications to achieve operational improvements and business expansion in energy supply and delivery industries.

The ability to reach remote locations with relatively inexpensive devices and infrastructure is a unique property of satellites. Applications include remote monitoring and control of distributed resources and emergency and personal communication.

Satellite systems are emerging as a significant opportunity for investment minded utilities. Over a dozen groups are planning to launch a total of 1200 LEOs in the period from 1996 to 2006, at a probable cost of over $20 Billion. This large number of systems can provide a worldwide mix of narrow band and wideband services including data, voice, video and Internet access.

These investments are driven by the huge growth potential of worldwide Internet access, the current trends to embed intelligence into "things" and because, at present, there are only 800 million phones in the world for a population of six billion. The main competition to Big LEOs for voice service is the cellular phone industry. Current satellite voice services are very expensive but Big LEO satellite rates are forecast to be well below GEO satellite rates. Little LEOs providing narrowband data services will compete with terrestrial alternatives in the more densely populated areas of the world with well developed communications infrastructure.

London-based market research firm Ovum predicts the number of subscribers who will use hand-held devices to access satellite-based voice and data services will skyrocket from 130,000 in 1998 to 8 million in 2002. Ovum expects the worldwide market to grow to $8.5 billion a year, with the Asia/Pacific region accounting for 40 percent of worldwide revenue, followed by the Americas with 27 percent, and Western Europe with 13 percent.

In the domestic data-only market, today only Orbcomm is operational; it's two Little LEO satellites provide intermittent two-way paging and other data services in North America and other parts of the world. Orbcomm plans to spend $350 million to add 26 more satellites. New entrants into this segment of the market have just received FCC approval. For example, Leo One USA is planning to invest in excess of $400 million to provide continuous worldwide coverage for data services.

This paper examines the two primary factors which have limited applications in the energy industry: cost and propagation delay. The former has so far limited the technology to fixed communications with a few important sites such as remote substations. The latter has rendered the technology unsuitable for applications where critical protection mechanisms are involved. These constraints are effectively countered by the emerging LEO systems. Big LEOs will be used for voice service, Little LEOs will be the systems of choice for most utility data applications.

We conclude that there are good technical and business reasons to reconsider future satellite communications as an option for meeting certain strategic business objectives in power system management and customer oriented information services.

> *From our preliminary analysis there are investment and partnership opportunities for energy companies in addition to the many uses for the next generation of satellites.*

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Recent and future generations of satellites are creating new communications solutions matching the trends in energy industries toward distributed resources, two-way customer communications and business expansion. In addition utilities intending to diversify their businesses through investments in telecommunications have many opportunities to do so in the satellite sector.

This paper is written with an emphasis on relevance to business strategists rather than engineers; it deals with technical aspects with sufficient detail for strategic analysis but without scientific rigor. The focus is on US domestic systems using low earth orbiting (LEO) satellites.

The ability to rapidly deploy technology to reach remote locations with relatively inexpensive infrastructure is a unique property of so-called “Little LEO” satellites. They are directly applicable to remote monitoring and control, emergency and personal portable communications.

The two primary factors which have in the past limited satellite use in the energy industries, cost and propagation delay, are discussed at length because of their significance to data applications. The former has so far limited the technology to fixed communications with a few important sites such as remote substations. The latter has rendered the technology unsuitable for applications where critical protection mechanisms are involved.

We conclude that there are now good technical and business reasons for energy companies to be considering satellite communications, especially those of continuous-coverage Little LEOs, as an option for meeting a broad range of strategic and operational business objectives in energy system management and customer oriented information services. Big LEOs are an emerging broadband communications vehicle which are likely to meet the more advanced needs of utilities well into the next decade.

1

ENERGY INDUSTRY BUSINESS CONTEXT

For any communications technology to apply widely in the energy industry market it must meet demanding standards of reliability and availability. It must meet these basic objectives at a life-time cost that is more attractive than terrestrial alternatives such as telephone cable circuits and RF options at VHF, UHF and microwave bands. Satellites have unique advantages of broad coverage with distance insensitive circuit costs, immunity to terrestrial emergencies, and they can be advantageously combined with terrestrial systems to provide for overall economic coverage meeting diverse needs. Mobile workforce management at PG&E for example is accomplished by a combination of 70% terrestrial wireless data network services and 30% Little LEO services.

Operations and Growth

This technology assessment is framed by two business imperatives – keys to survival for many companies.

1. The first is the issue of cost. We assert here that cost reduction can be directly related to utilization of physical and human assets. Asset utilization in turn is dependent on information about system state and the ability to control that state. To reduce costs the power transmission and distribution systems and the mobile workforce of the future will become highly instrumented.

   Through improved sensing and data processing we might in the near future expect several orders of magnitude more remote data to be captured and communicated. The trend toward distributed generation will likewise dramatically increase the number of sites and the amount of information required for monitoring, diagnostics and control.

2. The second is the issue of new sources of revenue. Wide area communication technologies, and especially satellites, provide opportunities for innovative ways to expand customer base and services. Utilities are no longer constrained by their traditional service areas and strategic plans for additional revenues derived from both national and international expansion are not uncommon.

With these assumptions about the future comes the realization that an information infrastructure will become more critical in enabling both operational and strategic objectives. At the same time information technology will, in some instances, impose new limits on what is technically and economically feasible.

Communications Tradeoffs

In architecting any information infrastructure there is the classical dilemma of what and where information should be stored, processed and communicated. For example, deciding how much autonomy should a remote device have as opposed to involving communications with a remote control center.

Optimum designs tend to vary over time with technical developments sometimes favoring communications, sometimes processing. The scenarios we are considering will have potentially very large numbers of remote distributed elements. For example, one could imagine every insulator or valve having a built-in processor and communications device. Such a topology means that the communications infrastructure elements will always have a major, even dominant, influence on what is economically feasible. Terrestrial communications infrastructure costs are often prohibitive for many utility applications.

The unique ability of Little LEO satellite communications to provide low cost data coverage over a wide area rapidly and with minimal capital investment and operational costs makes recent developments of special interest to the energy industries.

2

APPLICATIONS

Satellites lend themselves to a wide range of core business utility applications as well as providing more advanced support for applications two-way customer communications and Internet access.

Utility primary internal communication needs are for SCADA telemetry, metering and for mobile messaging and data communications in support of asset management and workforce automation.

Telemetry and Metering

Telemetry applications typically involve either one-way monitoring or two-way monitoring and control modes. There are definite trends in the utility industry today that will involve telemetry; a short list is as follows: (an expanded list and descriptions would be of value if possible)

1. Out-of-area expansion, distributed generation
2. Real-time pricing
3. National account marketing
4. More refined sensing of power flows and quality
5. Communications with field personnel for dispatch, reporting and access to AM/FM database updates

The need for a low-cost communications infrastructure to support such capabilities is evident and satellites seem ideally suited. In some instances there are no viable alternatives. For example, Canadian oil and gas companies are employing satellite communications technology to monitor oil wells in remote locations. These oil fields are in areas where telephone wires do not reach and even cellular communications are unavailable. The costs are five times higher than cellular services, but the service is invaluable to companies that need to closely monitor the pressures, temperatures, gas and liquid rates of their wells. They are able to open or close down wells and adjust the flow rates remotely. Hardware costs range from $3000 to $5000 and usage rates start at $100 per month. The “new” Little LEO systems should offer service and equipment at significantly lower cost than that quoted here. Little LEOs seem ideally suited to serve as next-generation, lower-cost service providers.

Metering and connect/disconnect services are conventional telemetry examples. High-cost metering typically requires a disproportionate amount of time and resources and is clearly a prospect for satellite communications. In a typical utility with remote terrain as little as 3% of the meters can account for nearly 20% of the meter reading cost.

A useful web site is that of the AMRA at <www.amrahq.com>

Mobile Data Communications

Another satellite service provides fleet managers the ability to communicate with drivers instantly using a combination of satellite and land-based networks. The voice dispatch service provides a push-to-talk communications channel for mobility management.

It is now realistic for a manager to have a display of fleet activity by having vehicles equipped with GPS and a satellite transmitter which will route data via a satellite and then directly or via the Internet to the managers' desktop computer. At least one utility has conducted a detailed business case for an investment in the technology and shows an 18 month payback.

Satellite Imaging Systems

There are new possibilities for detailed mapping of utility service areas with resolutions as fine as 5.8 meters (6.3 yards) and in the near future as fine as 1 meter (1 yard) black and white and 4 meters (4 yards) color.

Satellite imaging combined with AM/FM field data and GPS becomes a powerful combination for asset management, field inspections, compliance reporting, calibration and maintenance, on-site engineering and fleet management. Adding interpersonal messaging to mobile workers with laptop computers or PDAs will allow for work management which will be especially important under emergency situations.

Imaging satellite networks will be taking advantage of the boom in terrestrial PCS build-out. At the Wireless '97 show in early March, Spot Image Corp. (Reston, Va.) and Istar S.A. (Sophia Antipolis, France) announced a HotSpots program to provide targeted digital maps for digital cellular and PCS base-station planning. Spot, a French imaging-satellite system which has sold images through several database specialists, can offer 3-D digital elevation models as well as standard topographical maps, due to the stereographic images taken by the Spot satellite system.

Space Imaging — EOSAT in Thorton, CO, provides detailed mapping of service areas to the gas industry. Their web site is <www.spaceimaging.com>

Internet Access

There are a variety of applications for satellite-based data communications, the most popular being Internet access and connecting remote sites to corporate networks. The potential of push technology as a tool for workforce management is only beginning to be considered. Sophisticated use of off-peak periods will require store-and-forward techniques that will be built on push technology. It will be used in a time-shifting send/store strategy to replace "download-on-demand and streaming." The ability of PCs to accommodate this will distinguish them from network computers.

Some satellite systems allow users to browse Web pages and download data at 400 kbps through a 21-inch, roof-mounted satellite dish connected to a PC via an ISA interface card. This can become a valuable communications tool for extending a utility corporation's enterprise network to remote offices across the world. Linking PCs to satellites can involve TV programs, pay-per-view movies, and other content as well as business related Internet pages.

Many utilities are basing their enterprise strategy on Intranets (use of Internet technologies on a private network). The value of the Internet as a research tool and customer communications vehicle will likely expand exponentially. In many instances a corporation's campus fixed network has the bandwidth, but remote offices, customers mobile workers probably do not. Because Intranets generate heavy, unpredictable traffic, they require powerful servers and sophisticated networking. Many companies with Intranets gain time, cost efficiencies and ease of use. But if they haven't boosted bandwidth, network performance will be unacceptable to users.

One issue is the collapse of the old 80-20 rule: 80% of traffic is within a local work group, and only 20% is beyond that. With Intranet traffic, "that's out the window," says Dave Passmore, president of network consulting firm Decisys Inc. in Sterling, VA. "So much traffic is going to Intranet servers, or out to the Internet."

These hurdles include the explosion of the Internet and the Web, multimedia, streaming video, audio downloads, and the almost total acceptance of remote workers. Now the Internet has pushed terrestrial access bandwidths of the "last mile" to their breaking point, the prospect of a massive bandwidth satellite-based Internet service looks very appealing. If a company pays 300 percent more for its Internet access, but realizes a 10-fold increase in its Internet bandwidth, then the cost equations might make sound economic sense.

If future satellite Internet access does usher in bandwidths that many satellite experts are talking about, then business users could really start interconnecting their local area networks (LANs) across their Intranets as a virtual private switched network, at high speeds, and at lower costs they currently pay for public data services.

Telcos are just starting to become aware of the potential of satellite Internet services and are becoming aware that even their services could be undercut by a company with sufficient clout to get a satellite network up and running in a sensible period of time. Once the Big LEOs have sold a firm amount of reserved bandwidth to their users we might expect them to offer cut rate bandwidth on a non-guarantee best effort basis not unlike the way terrestrial frame relay services have been priced.

Many other satellite ventures, such as Hughes' Spaceway and Loral Space & Communications' CyberStar, are focusing on the Internet. Those plans don't come with timetables for commercial rollout before 1999, however, and cable and telephone companies will have deployed more competing fiber and local microwave capabilities by then.

Internet One-Way

Satellite-based Internet downstream delivery is likely to expand through efforts of one of the most prominent satellite services provider Hughes Network Systems, which offers the DirecTV cable-television alternative. Its DirectPC satellite system lets users browse the Web and download information at 400 kbps through a 21-inch dish mounted on the roof and connected to the PC via an ISA board. The Hughes scheme delivers Internet content to users very rapidly, but does not offer uplinks; users must keep their telephone line modems to send data upstream. An upload-capable version of DirectPC is expected in 1998, but the uplink at 2400 or 4800 bps is much slower than today's 56 kbps analog modems.

"Delivery of Internet content is the great question mark right now," says Alan Gifford, president of GeoSat Communications, a division of the Chandler, Ariz. reseller Random that is currently handling direct marketing and sales for DirectPC. "Schools, institutions and businesses want content, and this is a great solution for fast access."

Linking PCs to satellites can involve TV shows, pay-per-view movies, and other content as well as existing Internet pages, however. The most recent announcement of a new satellite service comes from Europe, where Intel Corp. and Corporation Societe European de Satellite have formed European Satellite Multimedia Services, a Luxembourg-based company that plans to offer space-to-PC delivery of multimedia content by the end of 1997.

Similarly, Adaptec has announced a PCI board called the ABA-1010 Satellite Receiver, which links a desktop or living-room computer to DirecTV's DSS system. The card supports sustained data rates of 30 Mbps, fast enough for MPEG-2 video. The receiver will initially be sold to OEM PC customers, including IBM and Gateway 2000. During last year's holiday season, Gateway tapped into the converging worlds of television and the Internet by bundling coupons for a free EchoStar satellite dish with its Destination and Family PC systems. Adaptec plans to complement the DSS board with another receiver, to be compatible with EchoStar's Digital Sky Network (DISH) Network.

The most recent announcement of a new satellite service comes from Europe, where Intel Corp. and Corporation Societe Europeenne de Satellite have formed European Satellite Multimedia Services, a Luxembourg-based company that plans to offer space-to-PC delivery of multimedia content by the end of 1997.

Microsoft Corp. has designed a Windows 95-like graphical interface, dubbed Television Explorer, that could serve as an interactive programming guide to these systems' new data and video channels.

Internet access via GEO satellites might suffer due to several limiting factors. For instance a direct line of sight to the southern sky is required to receive the satellite's signal. This makes satellite service impractical for most urban and many suburban customers. Multi-satellite systems such as Teledesic may provide more options when they're finally up and orbiting.

GPS

GPS applications are far more diverse than the familiar car, boat and hiker systems. Vehicle navigation, booming in Japan and Europe, is only taking off mildly in the United States, said David Hall, vice president and general manager of Trimble's software and component technologies group. By contrast, innovative GPS applications in fleet management and network time-stamping (both of keen interest to utilities) seem to be emerging as much from North America as from other nations.

Combining navigation and communication functions would allow position-fixing in case of emergencies. Such a system would have been a boon to the rescue workers who struggled for days in January to find a Nebraska woman, lost in blizzard conditions, with whom they maintained cellular-radio contact. Integration of GPS and cellular in single units also would allow automotive map displays to be embedded in hands-free mobile phones.

Cellular and GPS markets reinforce each other in many ways. Trimble's Hall said that using GPS for precise synchronization of a variety of voice and data networks could turn into one of the largest vertical markets for GPS, providing timing accuracy as great as atomic clocks at a fraction of the price. Satellite and GPS will likewise reinforce one another.

> *Accurate timing can be of considerable benefit to improvements in the management of the electric power grid by virtue of having accurate time stamping of data recording anomalous behavior of the grid.*

The commercial GPS industry continues to rely on government-financed support facilities such as a primary control operation at Falcon Air Force Base in Colorado and numerous ground stations operated by the U.S. Coast Guard and other agencies. This support is expected to continue in the near term.

3

SATELLITE COMMUNICATIONS - AN OVERVIEW

There are three classes of satellites of particular interest to the utility community: Little LEOs, Big LEOs/MEOs and GEOs, where LEO stands for low Earth-orbiting and GEO stands for geosynchronous orbit. These classifications are defined by orbit altitude, operating radio frequency (RF) and bandwidth allocation. These features in turn affect their performance and cost. For point of reference, the classes can be defined as follows:

Table 3-1

	Little LEOs	Big LEOs	GEOs
Altitude (km)	typically 750 to 1500	750 to 11,000	36,000
Operating Radio Frequency	VHF and UHF below 500 MHz	L and S microwave 1.6 and 2.5 GHz	K band 19 and 29 GHz
Bandwidth	narrow	wide	broad
Coverage	global	global	regional

To better appreciate the changes taking place in satellite communications, some of the key technical considerations will next be described.

Line of Sight

Objects in space must be visible from locations on earth so that within the area of visibility, radio frequency (RF) communications becomes possible. Because of its line-of-site nature, space communication avoids much but not all of the unpredictable nature of terrestrial communications.

Line-of-sight means that neither the curvature of the earth nor terrestrial objects may obstruct the propagation path. At VHF and UHF used in Little LEOs there is some latitude since these frequencies can penetrate foliage and some building structures. At the microwave frequencies of 1 GHz and above used by the larger satellites at higher altitudes (Big LEOs and GEOs) an unobstructed view of the satellite from the antenna on the ground is essential.

Satellite Altitude

The following figure depicts the range of altitudes used by satellites.

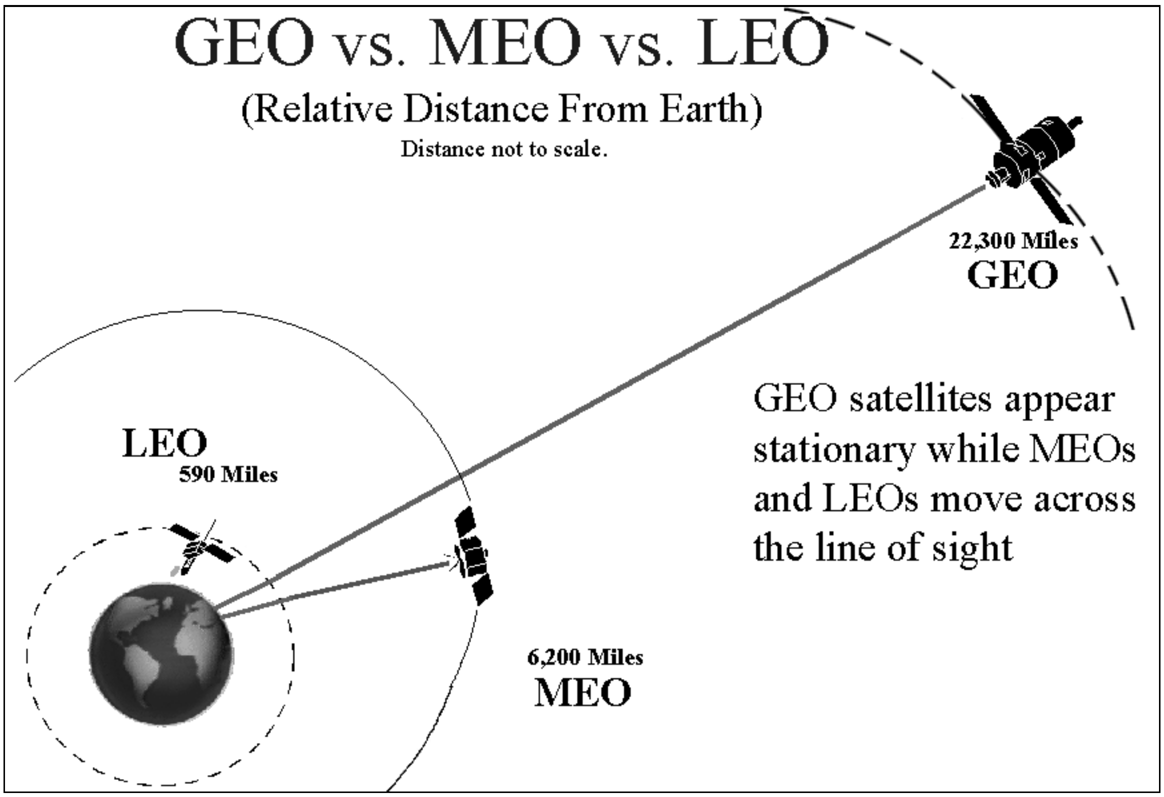


Figure 3-1
Classes of Satellites are Defined by their Altitudes.

Altitude is important for many reasons:

Signal Attenuation

RF energy spreads as it travels away from the source. Arriving at the receiver the transmitted signal has been attenuated in proportion to distance squared. Loss of signal power ultimately has a major impact by limiting the maximum achievable data throughput. There is approximately a 30 dB path loss difference between low altitude LEOs and GEOs. To offset the high path loss, GEO satellite systems must use large antennas on the ground and typically use directional arrays in space. Path propagation loss is correspondingly reduced at lower altitudes and antennas can be simple, some can be as small as a simple whip antenna as in a cellular phone. Satellite voice service from a hand held terminal using only a small whip antenna will be possible only via low altitude LEOs.

Propagation Delay

The RF signal traveling at the speed of light (3*10 ^8 meters per second; or yards per second) incurs a delay in reaching the satellite and returning to earth. For a GEO satellite the one-way single hop time delay is at least 0.23 seconds and, because of other signal processing delays, may be much longer. This amount of delay detracts from quality voice communications and can cause problems with data communications. Path delay is correspondingly less at lower altitudes. Delay at any altitude tends to be the controlling issue for consideration in the most time sensitive applications such as utility SCADA.

Table 3-2

	Typical Satellite Altitudes, km/miles	One-way Propagation Delay, msec
GEOs	35,785/22,300	230
MEOs	9951/6200	66
LEOs	947/590	6.3

From this simple comparison can be seen the potential of low altitude satellites to meet the needs of utility applications tending toward real-time control requiring sub 60 Hz cycle response times (one 60 Hz cycle equals 17 msec).

The Importance of Latency

Latency is the cumulative delay incurred as a result of propagation, and data processing. It will clearly define the limits of real-time telemetry. To an end user, however, it will be most evident in response to a mouse click or cursor movement. The acceptability of latency today might be observed by the level of tolerance by the average teenager to “click time” delay in a fast acting video game. Without knowing for certain all the applications and data protocols your company will be called upon to accommodate in the 21st Century, it is prudent to take special note of the issue of latency.

The majority of data communication protocols running over the Internet and Intranets are adversely affected by high-latency connections. Two of the most important standards in computing today provide examples. TCP is the standard transport protocol for networking; and the Worldwide Web, the fastest growing network application in history, is widely recognized as a new medium for collaboration and commerce.

TCP and WWW protocols are intrinsic to the Internet and Intranets; problems arise when these are used over non-standard networks with high latency, such as geostationary satellite links. Each part of a Web page – the text, each graphic, sounds, etc. – are fetched using independent TCP transactions. The actual data delivered by each of these transactions can be quite small – a tiny graphic of only a few dozen bytes, for example. In these circumstances, the overhead caused by protocol set-up quickly overwhelms any delay from actually sending data. All TCP connections, including Web transactions, require at least two round-trip delays for setting up a connection. The Web protocol will then add at least one additional round-trip delay, and will add more in many circumstances. All of this is overhead that's separate from the time it takes to actually transmit data over a communications channel.

With a minimum of three round-trip delays, each lasting at least 500 milliseconds, protocol set-up will take at least 1.5 seconds per Web transaction over geostationary satellite links. Displaying any Web page can involve dozens of different transactions, each one requiring a separate protocol set-up, and each one incurring the delay penalties. When these individual 1.5 second delays are aggregated together, Web pages downloaded over a geostationary satellite can take tens or hundreds of times longer than connections made over networks that provide fiber-like delays.

Alternatively, as a result of orbiting much closer to earth, Little LEOs benefit from better propagation and less signal attenuation. This makes little LEO systems which offer continuous coverage and availability good candidates for narrowband utility applications with a low tolerance for latency.

Coverage

Satellites at the highest practical altitude are GEOs, orbiting the earth at 35,785 km (22,240 miles) over the equator. In this unique position, a satellite appears stationary with respect to the earth. At this altitude it is possible to provide continuous coverage from a single satellite to approximately 34% of the earth's surface. This is known as a geosynchronous orbit (GEO). At lower elevations and in other orbits, satellites rotate with respect to points on the earth and individually they can not provide continuous coverage to any point on earth.

The fourth affect of altitude is that the lower the orbit the more satellites required to provide continuous coverage. Low earth orbiting satellites (LEOs) operate in groups known as constellations at altitudes typically between 400 to 1400 km (250 miles to 900 miles). Due to the asynchronous nature of the orbits, each satellite is visible only intermittently and for short periods of time.

Low altitude constellations providing continuous coverage of a given area require multiple satellites and some form of hand-off or message storage. For example consider a theoretical LEO satellite system where each satellite is visible once every 10 hours for 12 minutes. Each satellite provides (24/10) * 12 = 28.8 minutes of coverage per day. For continuous coverage 24 * 60/28.8 = 50 satellites will be needed. Actual LEO systems are likely to require approximately this number of satellites or more.

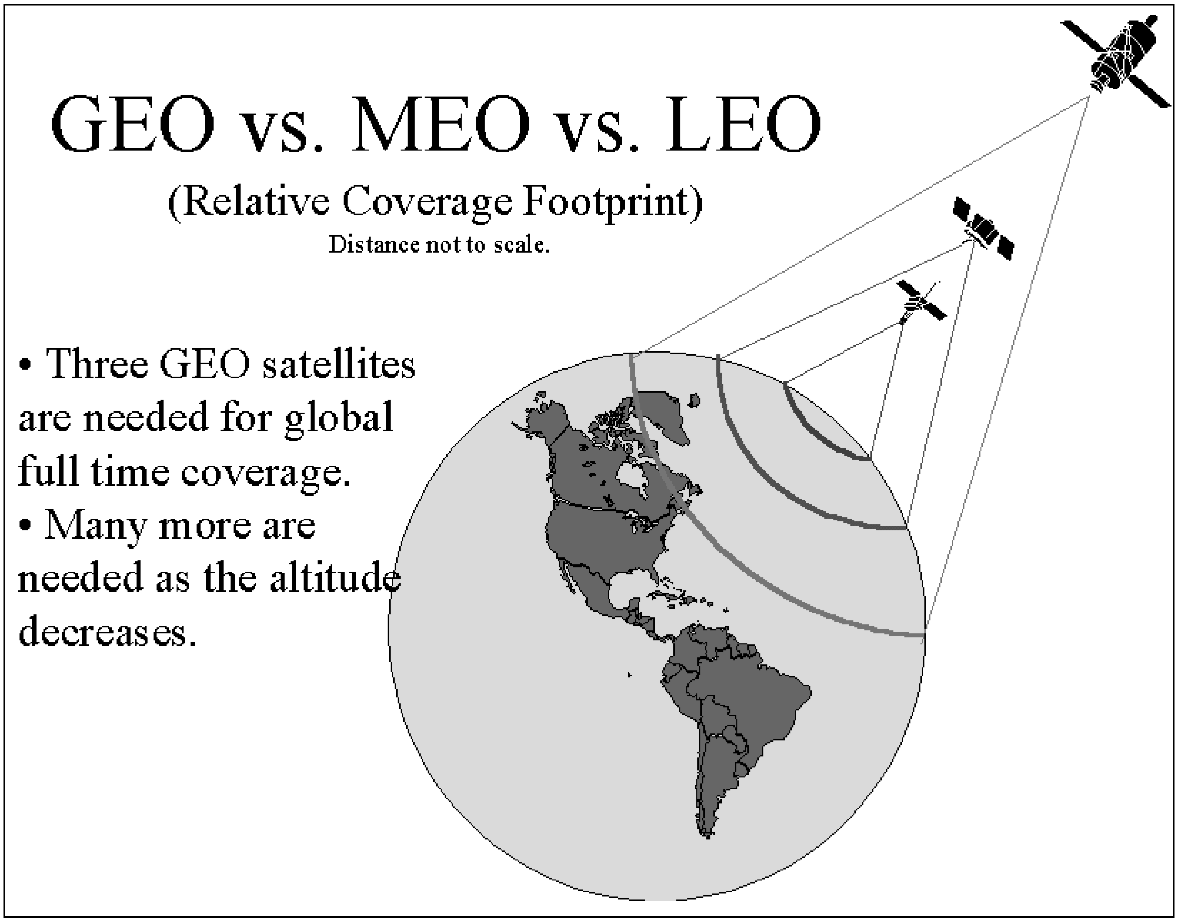


Figure 3-2
Satellite "Footprints" as a Function of Altitude.

Life Span

Satellites tend to have a shorter life span at lower altitudes because of the faster use of on-board resources needed for keeping the satellite in the proper orbit; they also tend to be cheaper to build, launch and operate than satellites at high altitudes. The industry tends to quote 5-7 years for LEOs and 10 years for those at higher altitudes. At high altitudes much more cost is involved in hardening the space craft to withstand radiation damage, catastrophic failure is arguably more likely and restoration is more difficult.

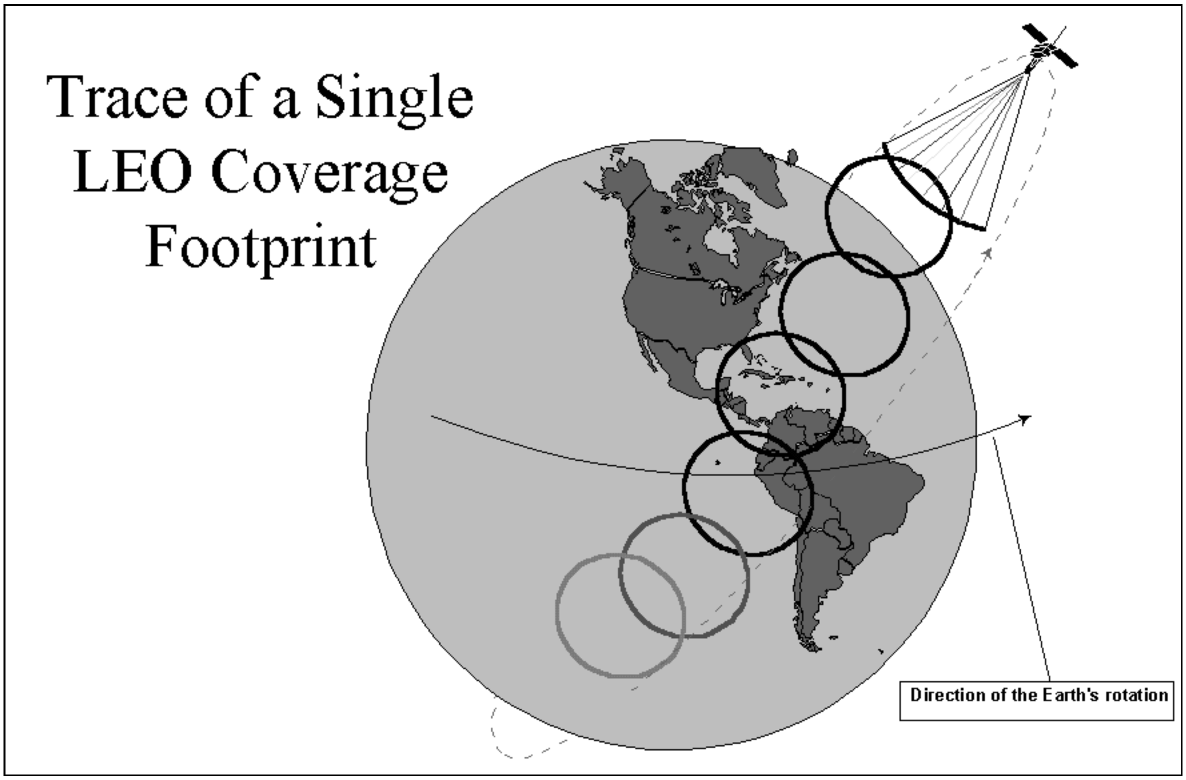


Figure 3-3
A Single LEO has a Moving Footprint as it Circles the Earth.

Choice of RF Spectrum

The operating frequency and associated spectrum allocations have a direct bearing on the technical capabilities, cost and revenue potential of a satellite system.

Table 3-3

Band	Bandwidth	Up/Down Link	NGSO Allocation	Class	Sharing
137 – 138 MHz	1 MHz	Down	NVNG MSS	Little LEO	Land Mobile Met Sat
148-149.95 MHz	1.95 MHz	Up	NVNG MSS	Little LEO	Land Mobile
149.95-150.05 MHz	0.1 MHz	Up	NVNG MSS	Little LEO	Land Mobile RNSS Land Use Only
399.9-400.05 MHz	0.15 MHz	Up	NVNG MSS	Little LEO	RNSS Land Use Only
400.15-401.0 MHz	0.85 MHz	Down	NVNG MSS	Little LEO	Met Sat
455-456 MHz	1.0 MHz	Up	NVNG MSS ITU Region 2	Little LEO	Land Mobile
459-460 MHz	1.0 MHz	Up	NVNG MSS ITU Region 2	Little LEO	Land Mobile
1227.6 MHz	20.46 MHz	Down	RNSS / GPS		
1575.42 MHz	20.46 MHz	Down	RNSS / GPS		
1602-1615.5	13.5 MHz	Down	RNSS / Russian GLONASS		
1610-1626.5 MHz	16.5 MHz	Up	NGSO MSS		Aeronautical, Navigation, Radio Astronomy
2483.5-2500 MHz	16.5 MHz	Down	GSO MSS		Fixed, Mobile, Radiolocation
17.6-18.6 GHz	1000 MHz	Down	NGSO FSS		Secondary to GSO, Mobile
18.8-18.9 GHz	100 MHz	Down	NGSO FSS *		Fixed, Mobile
18.9-19.3 GHz	400 MHz	Down	NGSO FSS		Fixed, Mobile
27.6-28.4 GHz	800 MHz	Up	GSO FSS		Secondary, LMDS, Fixed, Mobile
28.6-28.7 GHz	100 MHz	Up	NGSO FSS *		Fixed, Mobile, Earth Exploration
28.7-29.1 GHz	400 MHz	Up	NGSO FSS		Fixed, Mobile
37.5-40.5 GHz	3.0 GHz	Down	GSO FSS (NGSO Proposed)		Fixed, Mobile Space Research, Earth Exploration
47.2-50.2 GHz	3.0 GHz	Up	GSO FSS (NGSO Proposed)		Fixed, Mobile
59-64 GHz	5 GHz	ISL	ISL		Fixed, Mobile, Radiolocation
65-71 GHz	6 GHz	ISL	ISL *		Earth Exploration, Space Research, Fixed, Mobile

The spectrum bandwidth and effective radiated power allocated for satellite communication is regulated by international and national agreements, by the ITU and the FCC. The table above illustrates spectrum allocations. Note that the microwave bands above 1000 MHz have much wider allocations than those in the VHF and UHF bands.

* ITU Worldwide Pending WRC-97 Resolution – currently U.S. only.
ITU Bands are allocated, but not necessarily authorized by U.S.
FSS – Fixed Satellite Service
ISL – Inter-satellite link
ITU Region 2 – includes U.S. Canada, Central & South America
Land Mobile – Land Mobile Radio
MSS – Mobile Satellite Service
Met Sat – Meteorological Satellite
NGSO – Non Geostationary Satellite Operations
NVNG – Non-Voice, Non-Geostationary
RNSS – Russian Navigation Satellite System

Within these options the choice of frequency has a major impact on the link signal and noise power budget, including the free space loss and various system gains and losses and noise figures. In the earth-space path at frequencies of 10 GHz and above allowances also have to be made for the occasional additional RF attenuation due to rain and fog.

The lower the frequency the lower the directional gain of antennas of a given dimension. Conversely the higher the frequency the higher the gain available from directional antennas of practical size. The net effect of allocated bandwidth and gain is that there is much more traffic capacity available in satellites using the higher frequencies. This has led to a broad distinction between satellites as “Little” for those below 1 GHz with narrow bandwidths and “Big” for those above 1 GHz with much higher capacity. The label “Mega” has been given to constellations of LEOs where several hundred complex wideband satellites are involved.

> *The ultimate channel information carrying capacity is defined as Shannon's Law and is proportional to the signal to noise ratio and bandwidth for the link. Practical channel capacity will determine the range of possible applications and to a large degree the cost and revenue potential of satellite systems.*

Transponder Capabilities

When the space component acts only on the RF signals it is known as a “bent pipe repeater.” Bent pipe repeaters simply shift the up-link signals to a different band to provide full duplex communications. Most satellite systems in operation today are of this kind, they may carry out demodulation and have some data storage capability but not complex signal processing in space. When signal content is processed in space (Iridium as an example) the space component is called a transponder. Transponders can become very complex, for instance, providing switching and inter-satellite message routing in space.

One of the biggest technical challenges in deploying a large number of complex low-orbiting satellites is adequate bandwidth for inter-satellite communication. The current trend is to use millimeter technology for communication e.g. 37.5 - 40.5 GHz and 47.2 - 50.2 GHz to obtain the high bandwidth satellite to satellite connectivity. Iridium inter-satellite links (ISLs) are at 23 GHz and support a 25 Mbps inter-satellite rate. Iridium only offers voice and some data. M-Star has inter-satellite links at 64 GHz that can support up to 800 Mbps.

A few companies, such as AstroTerra Corp., are working on high-speed infrared links to provide speeds as fast as 620 Mbps for inter-satellite communication. Such high-speed links should help provide seamless roaming for users anywhere in the world.

Little LEOs use relatively simple transponder technology in the VHF and UHF range below 1 GHz. The combination of narrow allocated bandwidth and low gain antennas limit customer terminal data rates to a few Kbps. Their use of low data rates makes them appropriate for non-voice telemetry and store-and-forward services. Many utility applications are in this category.

4

STRATEGIC TECHNOLOGY OPTIONS

The following figure illustrates a wide range of services of most interest to utilities and provides the basis for comparing satellite options.

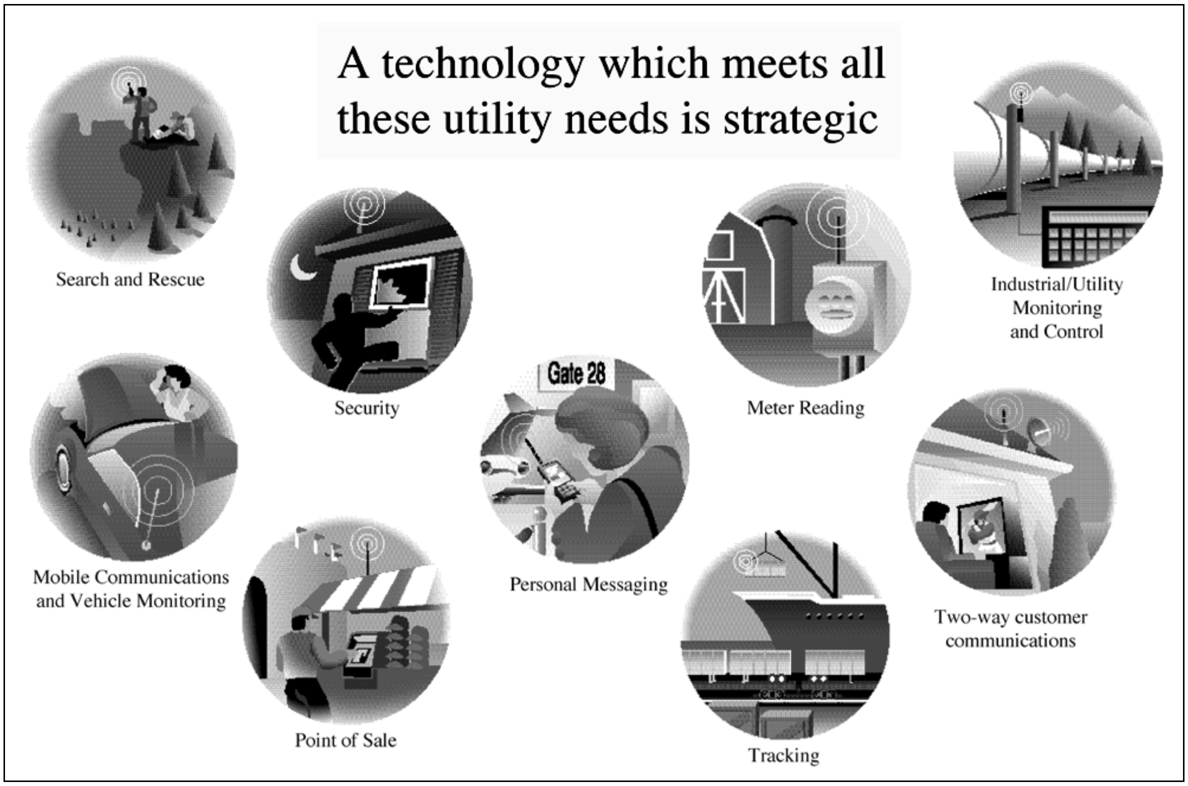


Figure 4-1
A broad range of utility applications.

The following comparison can be made at some risk of over simplification.

Little LEOs offer the best solution to a broad range of bi-directional data communications requirements where:

- The total amount of information to be transmitted is relatively small.
- The length of individual messages is short, typically less than 500 characters in length.

- Ubiquitous coverage is needed across a region or across the globe.
- Low-cost terminal equipment and usage are necessary.

Big LEOs offer the best solution for

- Mobile voice communication.
- Data communication where the amount of data to be transmitted is significant and warrants the inherent cost of communication link set-up and take-down time.
- Ubiquitous coverage is needed across a region or across the globe.
- Applications which can justify higher-cost terminal equipment and service rates of $3.00/minute.

GEOs will be the satellite system of choice where:

- Continuous service or bandwidth-on-demand is needed
- Very high data rates, 1.544 Mbps and above, are required.
- Applications do not require mobility.
- Dish antennas of 1-3 meters (1-3 yards) can be accommodated.
- Terminal prices of up to $25K and monthly continuous service rates of $50-100k are justified.

The following table summarizes Little LEO, Big LEO and GEO attributes and the affect of these attributes have on various performance parameters.

Table 4-1

		Little LEOs	Big LEOs /MEOs	GEOs
Satellites	Altitude (km)	750 to 1500 typical	750 to 11,000	36,000
	Bands	VHF and UHF below 500 MHz	L and S microwave 1.6 and 2.5 GHz	K band 19 and 29 GHz
	Weight	40 to 125 kg (88 to 275 lbs)	350 to 500 kg (772 to 1102 lbs)	Some as heavy as 1200 kg (2643 lbs)
	# of satellites	Typically 2 to 48	Typically 12 to 66 but as high as 288	Typically 1 to 12
	Complexity	Low	High to very high	Variable low to high
	Cost to build, launch, operate	Low	Very high	High to very high
Terminals	Power required	Low	Low	High
	Type	Hand held or embedded	Hand held fixed and portable	Fixed and portable
	Antenna	Whip, helix or dipole	Helix	Dish or phased array
	Location and orientation limits	Medium	High	Very high
Propagation	Rain attenuation	Low	Medium	High
	Foliage penetration	High	Low	Low
	Building penetration	Medium	Low	Very low
	Multipath interference	Medium	High	High
	Noise background	High	Medium	Medium
Services	Position location	Yes	Yes	Yes
	Fixed terminals	Yes	Yes	Yes
	Mobile terminals	Yes	Yes	Yes
	Data Comm.	Yes	Yes	Yes
	Voice Comm.	No	Yes	Yes
Cost	Terminals	$50 - $500	$2000+	$2000+
	Monthly services	Low	High	High

Little LEOs

Because Little LEOs are capable of meeting the majority of utility needs they are described in detail. Little LEOs are small satellites which operate at altitudes of around

805 km (500 miles)(very low by satellite standards). Since at these altitudes the satellite moves with respect to the earth's surface a single satellite is only intermittently accessible for a short periods of time (typically 12 minutes once every ten hours). To obtain continuous coverage of any spot on the earth a constellation of satellites is required. The actual number of satellites for worldwide coverage will depend upon altitude, inclination and other factors. An example configuration would be six satellites in eight planes for a total of 48. Continuous coverage of the CONUS would also require roughly this same number of satellites.

Little LEOs are designed for reliable, low-cost, fixed and mobile data communications. These attributes are obtained through the use of frequencies in the VHF and UHF bands which are less susceptible to poor propagation conditions than the microwave frequencies used by the Big LEOs and GEOs. Little LEOs utilize very simple and economical terrestrial terminals and satellite hardware.

Little LEOs offer the best solution to a broad range of bi-directional data communications requirements where:

- The total amount of information to be transmitted is relatively small.
- The length of individual messages is short, typically less than 500 characters in length.
- Ubiquitous coverage is needed across a region or across the globe.
- Low-cost terminal equipment and usage are necessary.

Applications of possible interest to utilities include:

- Meter reading and load management
- SCADA
- Field personnel messaging
- Industrial monitoring and control
- Vehicle monitoring
- Asset tracking and status reporting
- Emergency communications
- Security and other alarm monitoring
- Point of sale, vending
- Return path for direct to home interactive services

Applications such as these have the dual potential to improve operational efficiencies in the core energy businesses as well as offering new revenue opportunities.

The promise of Little LEOs is to provide a ubiquitous and cost effective means for providing data communications connections to millions of "things" as well as people. Most communications systems are sized for voice communications or broader bandwidth applications like multimedia. To date, most narrowband data requirements have been addressed by relatively costly customer owned radio telemetry systems or manual systems with high field labor costs.

The size of the market to be addressed by Little LEOs is easily underestimated due to our preoccupation with sizing demand for telecommunications services based on human population. An important trend that will shape this market is the explosion in the growth of embedded computer chips in all kinds of products. The world population of 200 million computers is tiny in comparison to the 6 billion chips not in computers and that gap is growing rapidly. This ever increasing population of "things" with embedded intelligence is in the process of being connected so they can interact with other devices, systems or people. Even our cars have become local area networks with from seven to over twenty CPUs on board for process and control functions. Little LEOs represent one of the most promising technologies for connecting those devices which are not fixed or which are too remote for terrestrial alternatives to be practical.

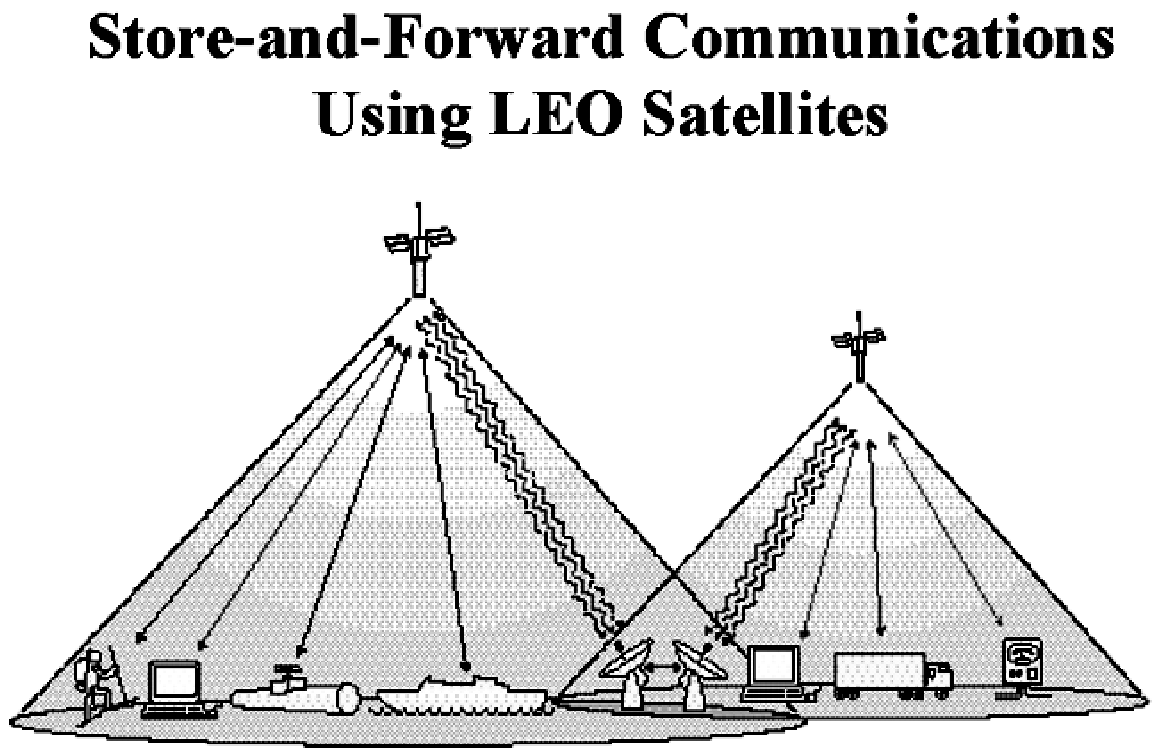
The perceived value of making "things" intelligent and recruiting them to participate in the growing network of communications we call the Web grows with each successive application. The more participants attached to a network, the more valuable the network becomes to each participant. What is starting as a little noticed trend will burst on to the scenes as a movement with tremendous momentum, much like the adoption rates for the Internet, fax machines and even Microsoft.

The Store-and-Forward Mode

Data transfer via Little LEOs takes place in a store-and-forward mode. A sender's message goes to the nearest in-view satellite where it is re-translated to a gateway center on earth for validation and optimal routing. Where appropriate, the message is then returned to the satellite and stored briefly until the intended receiver is in view. At that point the message is delivered to the recipient. Alternatively, the gateway center uses the terrestrial infrastructure, Internet, leased line, etc. to link the message to its intended destination.

A gateway can relay messages via other satellites in the constellation or via terrestrial connections for faster delivery. When send and receive terminals are within the same footprint of a single satellite it is also possible to relay messages directly between them for expedited delivery.

Since data transfer via Little LEOs takes place in a store-and-forward mode the inherent delay will impose limits on applications which require real-time communications. The term "real-time" is intended here to mean sub 60 Hz latencies, i.e., less than 17 milliseconds. Near real-time delay means delays in the order of minutes. A word of caution: not all Little LEOs are targeting the same market applications. Several Little LEO systems have been designed such that near real-time communications are impossible. In fact, delays of up to several hours will be experienced regularly. Such systems will be useful for a limited list of applications. Only a few Little LEO systems have been designed with the full spectrum of utility communication needs in mind; these are "continuous service" systems capable of offering near real-time service. EPRI is investigating how such systems' design can be tuned to achieve minimum delay (sub 60 Hz latencies) for telemetry applications.



The sender's message goes to the nearest in-view satellite, where it is linked to the local gateway for validation and optimal routing. The message is then returned to the satellite and stored briefly (until the intended receiver is in view of the satellite) for delivery to its recipient. If necessary, gateway Earth stations relay messages between satellites for faster delivery.

Figure 4-2
Store-and-forward Communications.

For some utility power system operations, sub minute or sub second delays will be required and, while technically possible, this segment of the market has yet to be defined.

Optimal design of Little LEO systems for lowest practical delay may be viewed as a leadership and investment opportunity within the energy industry.

Little LEOs address different market needs from those of other satellite systems and involve lower technical and financial risk. Their market is for systems which emphasize access over throughput, an alarm system being a prime example. As with any market based communications product, market penetration drives overall revenue. The service provider is insentivized to offer equipment at the lowest cost, even to the point of subsidizing, to achieve broad acceptance.

Little LEOs use proven technology. The simple and inexpensive chip sets mean that handsets and elemental terminals can be easily manufactured by the many existing vendors of VHF and UHF equipment. They do not require sophisticated RF and power elements in space. Store-and-forward messaging designs and operations are simpler and cheaper to achieve relative to voice-capable systems. VHF channels have reliable propagation.

The market risk is low since there are no cost effective substitutes for fixed and mobile message applications with ubiquitous coverage of a region. They are unique in their ability to cover large areas such as the CONUS with distance independent pricing of services. Relative to terrestrial systems they require no investment in physical infrastructure other than the gateways and satellite control centers. They are less susceptible to terrestrial hazards and coverage can be deployed very rapidly to unserved areas.

LEO Market Segmentation

The following graphic depicts the market positioning of Little LEO systems, both continuous and non-continuous, and Big LEO systems. Little LEOs designed for continuous access can economically provide the broadest range of services, exceptions being voice and high-speed data communications.

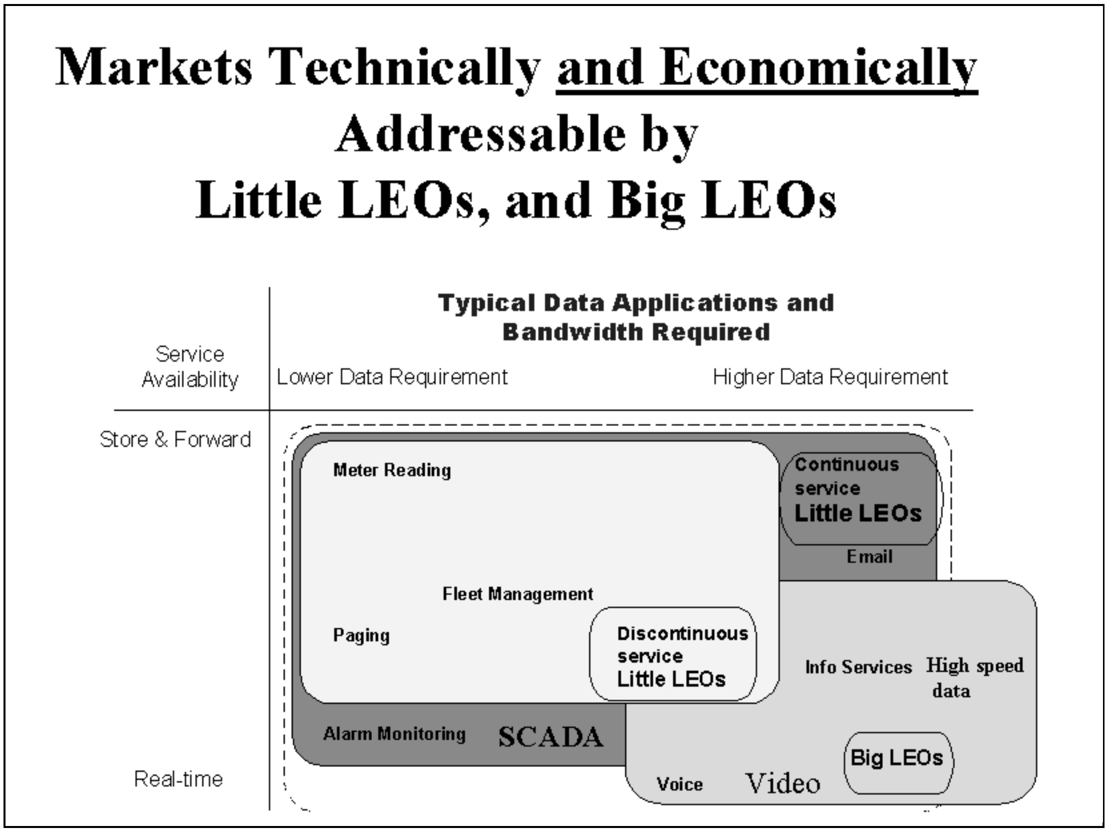


Figure 4-3
Market Positioning of Competing Big and Little LEO Systems.

Big LEOs

Big LEOs are also non-synchronous satellites which operate at altitudes from about 700 km to 1400 km (450 miles to 900 miles) and use spectrum in the 1 to 3 GHz range. Big LEOs carry several transponders on board which can provide the bandwidth equivalent of 2000 to 4000 full duplex voice circuits. Satellites in medium orbits (MEO) are at an altitude of around 10,000 km (6214 miles) and, compared to LEOs, fewer are required to provide continuous coverage. Peer to peer communications between different space craft in a group (constellation) may also be involved in the design for continuous coverage of a desired area.

Big LEOs represent an opportunity for major financial investments by utilities, they are also likely to have a major impact on broadband utility applications in the future. For example at least one vendor is describing sub station automation as requiring 100 Mbps communications in the future. This capability at remote sites is very likely to come from big LEO systems in the five to ten year time frame.

GEOs

GEO satellites are geared for intercontinental voice and modest data communications. As such they do not hold much application or investment interest for utilities.

Satellite System Cost and Financing

In general there seems a wide divergence between the optimistic outflow of billions of dollars by the satellite industry and respected commentators in the telecommunications field. Commenting on the Iridium technology, Andrew Seybold, editor of "Outlook on Communication and Computing," a newsletter in Boulder Creek, CA said "I have mixed feelings about how viable this technology will be in the long-term. But we aren't going to know until they get the system up and running."

Big constellations are going to have to create a market capable of supporting their enormous capital and operating costs. As one view of what this means consider that each Iridium satellite in orbit will cost around $30 M and there are 66 of them with a life expectancy of 10 years. That equates to $200 Million a year just to replace the space component, add this to the cost of original capital recovery and other operating costs and you have a challenging number of minutes of use to generate.

> *The ultimate test for geostationary technology is going to prove to be whether it becomes less expensive than terrestrial wireless systems such as cellular phone systems and newer low-earth orbiting technology.*

Telco Competition

There are many physical and wireless alternatives to LEO satellites. Apart from cost, the main contest is over four factors Mobility, Availability, Connectivity and Bandwidth. Although bandwidth is important, many applications within the utility industries will emphasize the first three factors.

Physical choices such as copper and fiber cables commonly used for telephone and TV are of course fixed in nature. They are not optimized for data communications and are not available in many remote locations. When available they are usually overkill for low data rate applications and are hence costly. All physical systems are vulnerable to natural and man made disasters.

Terrestrial RF systems include paging, cellular, private radio, dedicated data networks and PCS. While some of these can be attractive options for low data rate dispersed communications in some instances, none are likely to compete where reliable, wide area telemetry coverage at low-cost are the drivers.

Digital Subscriber Lines

Utility telecommunications managers are struggling to give users sufficient bandwidth. The drivers include the explosion of the Internet and the Web, multimedia, streaming video, audio downloads, and more-and-more the almost total acceptance of remote workers. While internal LANs are tending toward the 100 Mbps range remote users often are downloading large files over a 28.8-kbps modem. Even ISDN's 128 kbps is hardly comparable to the office connectivity.

The availability of ISDN is finally becoming a reality for customers in metro areas but it is considered to be too little too late and too costly by some. Bell Atlantic ISDN service for example is priced as follows.

Table 4-2

HOURS per month	COST $
20	31
60	45
140	60
300	90
500	120
Unlimited	249

While ISDN offers more than twice the throughput, 56-kbps modems are fast enough for individual Internet access and some business remote-access applications. The designation of 56 Kb can be misleading as this will apply only in the downstream direction and only where the local Telco has a digital central office. They can be considerably cheaper than ISDN as they typically will not have the monthly and per-minute charges of ISDN. Standards for these modems are currently being contested by a patent holder and likely won't appear until 1998, but unlike with ISDN, installation should happen practically overnight. The use of 56-kbps modems in business, within the limits of their coverage, will offer fast and economical work-from-home service.

Frame relay services from the long haul carriers have been around for many years, but frame relay is just reaching a popularity peak that will last until it is gradually and invisibly replaced by asynchronous transfer mode (ATM) networks after the turn of the century. Frame relay is a permanent virtual circuit WAN digital service that puts data into packets, then sends those packets through a series of interconnected switches to their destinations. It offers flexibility, reliability, and economy.

Large institutions and governments maintain their own frame-relay networks, but most organizations subscribe to frame-relay services from a local or long-distance telephone company or from a specialized data carrier, such as CompuServe Network Services or IBM Global Network a wide range of speed options is possible. The carriers price frame relay to use their circuits efficiently, so they price it at a flat charge for a committed information rate capability well below that of leased lines and below comparable ISDN connections. Users enjoy a statistical probability that their communications will be able to exceed the committed information rate.

Now in the country's largest markets, local carriers are about to offer the ability to access corporate networks and the Internet using competing digital subscriber lines (DSL) and cable modem technologies and new high-speed microwave wireless technologies. The battle for the last mile is on.

This battle will become increasingly important with the advent of the NC and network PC, and with companies moving more applications off local processors and onto the public network run by carriers and Internet service providers. More bandwidth should let companies experiment with new technologies. Expect remote employees to start receiving streaming video, audio, and even multimedia from corporate and outside sources.

By adding equipment at the phone companies' central switching office and the customer's site, the service lets carriers achieve as much as 6 Mbps of bandwidth down the copper network.

High speed digital transmission on common copper connections to the local switch relies on lines which provide a graceful increase of attenuation of signal energy as the frequency of the signal increases. Unfortunately connections over 18,000 feet often do not behave this way because of inductors (loading coils) added to the cable pairs to improve voice frequency quality.

The industry is trying to both engineer around the copper pair limitations and to reduce the costs of DSL modems from about $1000 a user to under $500. That's starting to happen. Last fall, four of the Bells agreed on a standard for DSL that should drive down the cost of developing the technology. And new local carriers and Internet service providers are rolling out their own DSL services, putting more pressure on the Bells to cut costs.

DSL technology has been described as the "last gasp for the existing telephone network" DSL technology may become a victim of it's own success, the carriers will have trouble scaling it and integrating it into existing network systems.

Gigabit Ethernet systems, shipping in 1997, will merge Fast Ethernet's big pipes into aqueducts of data within the LAN and among LAN segments in a campus network.

Unlike ATM, this technology is emerging as a mature solution with a purpose. Gigabit Ethernet will be the campus and enterprise backbone beyond 1999.

Also, new alternatives are likely to emerge. By 2005, more than 20 million phone lines-nearly 8% of all -will provide fixed wireless access to the telephone network, predicts the Institute for the Future in Menlo Park, Calif. Similarly, the Strategis Group in Washington predicts that 40% of U.S. households will use some form of wireless communications by 2001. In recent months, the FCC has stimulated the industry with new licensed and unlicensed allocations for high-speed wireless services.

The biggest change that businesses will see in their WANs in the next five to ten years will be packet switched virtual networks using asynchronous transfer mode (ATM) which will employ a combination of terrestrial and satellite channels replacing leased lines and ISDN connections.

Bell Communications Research Inc., the research arm of the regional Bells, sees demand for bandwidth increasing at least 20-fold in the next five to 10 years. Chalk it up to more folks working at home, on the road, and in satellite offices; new, bandwidth-hungry applications such as live video; and telecommunications deregulation, which lets a growing number of companies compete with what were monopoly carriers. Remote networking is also likely to increase as version 6 of the Internet protocol comes out with features that make it easier for remote workers to securely connect to corporate networks via the Internet.

> *Fiber systems are unlikely to be widely available for a long time. For broadband services in the near term the betting is on fixed and mobile broadband wireless technologies where the battle will be between terrestrial infrastructures and satellites.*

CableTV Competition

Cable television was introduced long ago to provide basic TV service to isolated communities. Cable companies have been dreaming about new services for years and now with high speed Internet access as the “killer App” two dozen cable companies are betting that coaxial cable can do a better job than telephone lines and satellites. They include Time Warner, Continental Cablevision, and @home, jointly owned by TCI, Comcast, and Cox Communications. Reasons include cable’s “always-on” access to the Internet and its support for multiple connections over one line into the home - neither of which is practical with analog telephone-line connections.

The local telephone companies thus face pressure from cable-TV companies rolling out high-speed data access services based on new cable-modem technology. Time Warner’s service, for example, lets viewers download information at 10 Mbps for about $40 a month. The company estimates that by year’s end, 4.5 million U.S. households will be cable-ready for this service.

Many early users of cable modems praise the technology for example Howard Grannick, VP of Strategic Relations at NetPlay Inc., a San Diego on-line gaming service, uses his Motorola CyberSurfer modem to download files at 10 Mbps and upload files at 768 kbps. He hopes cable modems will eventually let NetPlay enrich its content with live pictures and sound. “It’s awesome,” says Grannick.

For Todd Benson, a cable modem makes the Internet a “complete other world.” Benson, president of Castco Communications Inc., a small advertising and direct-mail firm in Elmhurst, III., says the value of the Internet as a research tool has “expanded exponentially” since he upgraded from 28.8 kbps to his Motorola CyberSurfer modem. “The Internet has become a multimedia show as opposed to a sit-and-wait.

Yet cable modems aren’t perfect, their reliability is questionable. Also the cable channel is like a LAN where users are in contention for the bandwidth. If an entire neighborhood is on-line, depending on how the network is engineered, performance could slow down. Cable-TV companies are not known for good customer service and providing Internet service requires new skills which the cable companies do not have.

The biggest drawback of cable modems is a lack of coverage. Cable networks will also run into bandwidth and noise limitations and must be re-designed for two-way communications. So far, only about one in five cable networks can operate in two-way mode and the cost is staggering. For cable technology to survive in the competitive Internet-access arena, time to market is critical, says Patti Reali, Senior Analyst at the Delran, N.J.-based research firm DataPro. “A lot is going to be determined by how fast cable companies can get their systems built and optimized for two-way, symmetrical connections,” she says.

To compensate, some vendors are rolling out a hybrid approach: modems that use the high-speed cable network to download files, then use traditional 28.8-kbps modems on the phone network to upload them. Another alternative may involve cable-TV and telephone carriers adding fiber-optic lines to their networks, essentially deploying the high-speed lines into a neighborhood, then using DSL technology for the last few thousand feet.

For residential users cable modem service could provide 1 Mbps to 2 Mbps of usable bandwidth, hardware and installation charges of about $150, and a monthly cost of about $35 to $50–about the same as current costs for ISDN access, a much slower technology. While those costs will need to be lower to attract the general population, cable companies stand to make money on Internet access as incremental business. Their focus is shifting away from the pay-per-view movie. The people who are now spending $20 a month to their local ISP are prime candidates.”

Cable companies will encounter the same competition from wireless solutions as do the telephone companies. It is already happening. Bloomberg Information Television in New York uses CellularVision’s wireless service to deliver its business channel to

100 local customers. “This offers better-than-cable quality,” says Jonathan Fram, Bloomberg TV’s general manager.

Winstar Communications in McLean, Va., plans to bring a wireless 45-Mbps service to 42 cities by the end of next year. Advanced Radio Telecom in Bellevue, Wash., is rolling out microwave-based local loop service in 47 cities. Associated Communications, in Alexandria, Va., a startup led by former AT&T president Alex Mandl, plans to offer wire- less Internet access. Also, AT&T has announced it will begin testing a wireless service in Chicago later this year with two voice channels and a 128-kbps data channel per household. “This is real, it’s not smoke and mirrors,” says Bill Frezza, president of Wireless Computing Associates in Yardley, Pa., who has done consulting for AT&T’s partners.

> *Satellite proponents are betting that broadband Telco or Cable solutions won’t reach the masses for some time. “We’re looking at a minimum of two years until cable modems are really cool, but they’re kind of spotty right now,” says Stacy Hand, product marketing manager for Gateway 2000’s Destination PCs.*

Terrestrial Wireless Competition

Terrestrial wireless systems have often been thought of being limited to point to point and mobile communications. LAN-WAN integration, interactive entertainment, video and music, telecommuting and information services provide the main drivers for broadband bi-directional access. The demands of these services range from 2 Mb/s to over 25 Mb/s. Such services are of interest to utilities intending to enrich the information exchange with their customers or invest in a growth segment of the telecommunications industry. These services have generally been beyond the capabilities of terrestrial wireless solutions because of their limited spectrum allocations. This situation can change radically as result of a bewildering array of new spectrum allocations made by the FCC, some as recently as 1997.

Competition to future satellite services will come from a variety of narrowband and wideband wireless systems including specialized wireless data networks, paging , PCS and a variety of microwave distribution systems. It is beyond the scope of this paper to provide a detailed analysis but in summary none can match the combination of unique satellite capabilities for area coverage, fast deployment, low infrastructure costs, minimal exposure to terrestrial emergencies. A more detailed comparison of terrestrial wireless systems can be found in EPRI TR-111023, *“Utility-Customer Communications: Options for the “Last Mile.”*

5

SATELLITE INDUSTRY ISSUES

Launch Issues

In this section an overview of current issues and plans for launching new commercial satellites is provided. LEOs are the focus of this assessment because their capabilities are more applicable to utility data communications. Some examples of the problems associated with the launching and maintaining satellites in orbit are described. Problems of this sort could be significant if certain utility projects became dependent on satellite availability under emergency conditions. For maximum assurance reserve launch facilities will be required at short notice.

The problem of limited rocket launch capability is exacerbated because of the new constellations of LEOs. Many original commercial communication systems were in Geostationary orbit, relying on a handful of satellites hovering in one location synchronous to the earth. This meant fewer satellites, but it also meant long voice delays, and a necessity for ground terminals that were large and heavy. Even with the advances made in very small aperture satellite terminal (VSAT) sizes, Geostationary systems could not be used for low-cost telemetry or truly portable personal communications.

> *Note here that EPRI several years ago developed a VSAT terminal for use in T&D applications at a cost per terminal in the range of $7 to 10 K.*

The limitations of GEOs have given rise to “Big and Little LEO” systems, represented by Big LEO examples Iridium and Globalstar and Little LEO examples Orbcomm and Leo One USA. What will be gained in low delay and small size of terminals in a LEO voice and data environment is lost in the “footprint” of the earth covered by a signal. This means that many satellites must exist in a single constellation, (66 satellites in the case of Iridium, 48 in the case of Globalstar) and even with 8 satellites per launch that implies lots of launches. The projected worldwide growth of LEOs thus compounds the concerns about launch capacity.

Rocket Failures

The McDonnell Douglas Delta II rocket series has had a perfect record for 11 years, they have carried 260 payloads into space without incident. Spoiling this record in the January 1997 launch there was an explosion seconds after lift-off. A $40 million global positioning satellite from Lockheed Martin was on board. Fortunately for Iridium and others none of their satellites were on board. No one was injured in the explosion.

Earlier a total of four Iridium launches were canceled, because of various technical reasons — two of which were related to the rocket itself. One launch was called off due to the failure of the thermal protection that surrounds the fuel tank of the rocket.

Iridium's flight originally scheduled to blast off January 7 but a problem occurred with ground system software. Then January 9, "technical issues on the range" involving the failure of one of the two command modules that link the rocket and ground control, caused that day's setback.

Iridium's flight on January 10, 1997 was stopped just 23 seconds before lift off, because of a problem with a water flow tank that controls sound suppression. Iridium is not entirely dependent on the Delta rocket. They (Iridium) have worked with other space vehicle providers to launch all of its 66 satellites by 1998. At the time of this writing (July 1997) Motorola had launched 12 of it's constellation of 66. Officials are optimistic the system will be operational by its target date.

Globalstar Telecommunications' first launch is scheduled to lift off in September 1997. Globalstar aims to put 56 satellites in orbit, with its system going on-line in the fourth quarter of 1998. Globalstar officials also said the current Delta II problems won't affect their goal to have their system on-line.

Teledesic Corp. proposes a 288 satellite system offering high data rate service to customers with fixed tracking dishes. Teledesic is negotiating with Russian companies to use SS-18 rockets to provide enough launchers to develop the satellite system by the end of the decade. A Teledesic spokesman said that the negotiations with Askond over use of the SS-18s are one of several options Teledesic is pursuing and that the company foresees no delays from the Delta and Proton launch problems.

Although the satellite operators remain optimistic, critics such as John Pike, Space-policy Project Director at the Federation of American Scientists, have warned LEO schedules depend on questionable assumptions about launch reliability. The availability of launching capacity may yet become a pacing item for new satellite services.

Failures in Space

Space failures have been remarkably few, however a recent event served to remind us of the inherent dangers. NASA scientists said a solar storm caused the emission of a large amount of geomagnetic radiation that left the sun on January 6 and arrived on earth January 10 and 11.

Their theory is that this radiation caused the failure of The AT&T Telstar 401 satellite which failed at 6:15 am on Saturday, January 11. "We're looking at the geomagnetic activity," said Barbara Thompson, a research scientist at NASA's Goddard Space Flight Center.

In the past, such solar radiation has affected other satellites and even caused power outages on earth. While the earth's atmosphere deflects most of the particles heading our way from the sun, satellites aren't so lucky. While manufacturers build in protection against solar storms, it is difficult to insulate a sophisticated satellite against very large storms.

Intense radiation from solar flares is a well known but difficult to predict phenomenon. It is difficult to guarantee protection for sophisticated satellites against very large storms. What may have happened is that the storm caused sparking and short circuits inside the satellite. The craft failed suddenly and completely. Satellites at high altitudes are more exposed to radiation and space particles than those at low altitudes.

GPS Success Story

In spite of a few launch and space failures the remarkable success of global-positioning system (GPS) terminals in military, business and consumer markets has given great impetus to plans to develop a user market for personal-communications service (PCS) systems based on large constellations of LEO satellites. Lessons already learned from the very-small-aperture terminals (VSATs) for geosynchronous and mid-earth-orbit satellites, will make engineering issues for both handsets and ground terminals easier to solve.

Last year President Clinton announced the phasing out of GPS "selective availability" whereby the Department of Defense had access to more accurate four-dimensional signals (three bearings plus a precise time-stamp) than was offered to the civilian world. That has opened the floodgates for both precision GPS, used in surveying and geophysics, and commercial GPS, for position information in embedded consumer products. Improving fleet management via GPS and satellite communications is of distinct interest to utilities.

Everyone in the OEM supplier world has jumped into the subscriber-terminal fray in the past three years. Dedicated receiver chip sets were offered by Rockwell Semiconductor Systems Inc. (Newport Beach, Calif.) and startup Sirf Inc.(Santa Clara, Calif.); daughtercard modules were developed both by longtime navigational experts, such as Trimble Navigation Inc. (San Jose) and Magellan Systems Corp. (San Dimas, Calif.), and by such newcomers as Ashtech Inc. (Sunnyvale, Calif.). The market lines have blurred as Trimble has expanded from commercial systems to component and module sales; today, it's even licensing its chip-set designs to external manufacturers.

Standards

Full coverage of the many complex issues surrounding standards in the satellite arena would triple the length of this report and is not within the scope. The intent here is to provide insight into the most significant aspects of standards since they can have a very direct bearing on the marketability, life cycle cost and hence profitability of any venture into space. This is especially true for companies with international expectations for satellite communications.

Spectrum and Politics

The US has developed a wish list to submit to the World Radio Conference in Geneva this fall (Oct.27 to Nov. 21). This is the formal conference at which competing claims for spectrum allocations get resolved by the nations of the world. The US is proposing additional allocations at 405 MHz for Little LEOs, worldwide alignment on allocations in the bands 2010-2025 and 2160-2170 MHz, an additional 100 MHz of uplink and downlink spectrum at 18.8-19.3 GHz and 28.6-29.1 GHz , and new space allocations at 47-48 GHz for domestic and international broadband wireless services.

Three competing U.S. satellite consortia have announced that they will work together to divide up the available spectrum for their mobile telecommunications services. Globalstar LP, Iridium LLC, and Odyssey Telecommunications International Inc. plan to begin providing digital wireless communications services worldwide by the year 2000, the companies announced last month. They will offer their services using low-earth-orbit satellites (LEOs), for which they will need frequencies that are awarded by participating countries.

The companies are working together on spectrum division in an effort to win authorizations for the portion of the radio spectrum needed for their mobile phone services. So far the three systems have been given authorization to operate in the United States.

"The agreement conforms with the International Telecommunication Union's frequency authorizations and should simplify the regulatory process in countries where we seek to operate," according to a statement issued by the companies.

For the long term the International Telecommunications Union is working on a standard for Global Mobile Personal Communications Satellites. ITU representatives at the recent World Telecommunication Policy Forum discussed many issues. Although spectrum division was mentioned at the conference, attendees were most concerned with telecommunications regulations and international equipment specification, licensing and such issues as globalization, transborder use of GMPCS terminals, how mobile equipment will be approved and how customs should handle terminals travelers bring into a country, such as the waiving of customs duties and formalities for terminals that travelers temporarily bring into a country.

Whatever the form, GMPCSes are expected to be popular in areas where cellular coverage is poor or nonexistent for international business travelers: long-haul commercial vehicle operators crossing national and international borders, people traveling on yachts and other vessels, and field scientists.

Media Access Protocols

Despite their publicity the technical details of the major entrants into the Big and Mega LEO arenas remain cloudy. For instance the Iridium technology remains unclear. It is believed that handsets will use so-called “slipped slot” GSM (global system for mobile communications) technology.

The GSM digital phone standard is a terrestrial wireless communications standard based on time division multiple access (TDMA) techniques. GSM is in use in more than 70 countries and has been adapted for the US by some US PCS providers and called PCS-1900 with an associated standard known as IS-136. For technical reasons GSM only allows phones to operate at ranges of 35 miles from a base station. For satellite communications Iridium has adapted the GSM standard to allow the handsets to operate up to 700 miles away from the Iridium “base station” satellites.

By using TDMA-based GSM technology Iridium will allow its subscribers to use land-based GSM networks around the world on a roaming basis, using the LEO satellite network only when out of range of a terrestrial GSM network. This ensures that users only pay the assumed satellite network surcharge when out of reach of land based GSM services. The current plans for Iridium phones contemplate the use of cassette modules that will allow the phone to work on other terrestrial mobile standards (e.g., AMPS, CDMA, etc.) and will cost a few hundred dollars additional per cassette module.

GSM is challenged both terrestrial and for satellite services by a technology called Code Division Multiple Access (CDMA). CDMA is also described as a spread spectrum technology with the main technology driver being Qualcomm. CDMA has established an international standard specification for dual mode CDMA/Analog as IS-95. This standard contains many innovations such as a soft handoff mechanism for mobile units and variable bit rate traffic channels. In the US terrestrial PCS market the lead companies behind CDMA are Sprint Spectrum, PCS PrimeCo, GTE Mobilnet and

Ameritech. Their individual market coverage when added indicates a combined market size of 252 million population. For PCS -1900 the main players are Pacific Bell, American Mobile Telecom, Omnipoint, Western Wireless, BellSouth, and Powertel PCS. They have a market coverage of 105 million population.

In the satellite arena Iridium and ICO intend to use TDMA while Globalstar and Odyssey will use CDMA, these systems are incompatible with one another. Iridium, Globalstar and Odyssey have announced an agreement to share the spectrum so that CDMA and TDMA systems can coexist. The Teledesic Network uses a combination of multiple access methods (Frequency, Time and Space). The claim is their combination of Earth-fixed cells and multiple access methods will result in very efficient use of spectrum. The Teledesic system will reuse its requested spectrum over 350 times in the continental U.S. and 20,000 times across the Earth's surface.

Semiconductors for space-based PCS can be based largely on existing standard technology. For baseband components in LEO PCS handsets, developers can rely on lessons learned in terrestrial cellular and PCS. Mature baseband chips are available for TDMA and CDMA air interfaces. Similarly, the L band specified for uplinks (1.610 to 1.626 GHz) is close to terrestrial PCS bands, while the S band for downlinks (2.483 to 2.5 GHz) is close to unlicensed wireless LAN bands, making RF/IF component development a minor re-engineering of existing devices.

Datacom Protocols

Part of the problem is that Web traffic uses bandwidth inefficiently. It's burst-prone and graphic-intensive. Also, each click on a Web page entails setting up a new TCP/IP connection. A new release of HTTP, version 1.1, streamlines that process somewhat, but isn't widely deployed yet. One-way to ensure that important network traffic gets priority is to reserve bandwidth for key applications and user groups. Several vendors support reservation protocols that work across TCP/IP, including Cisco and Microsoft.

But in practice, some companies end up creating a high-priority subnet. Bankers Trust Co., a New York investment bank, does this to ensure uninterrupted network performance for its critical financial-trading applications. The company has put all its market data servers in one place, and it then uses features of its ATM network to make all other traffic go over another set of permanent virtual circuits. "We prioritize market-data traffic," says John Manville, managing director for network engineering.

The World Stage

Satellite communication raises many international issues that can indirectly affect companies in the US. For example international frequency allocations have implications domestically and the growth of the world market will ultimately determine technical standards and prices for terminals and services.

The International Telecommunications Union (ITU) is an arm of the United Nations with the responsibility for worldwide coordination of the use of the radio spectrum and international telecommunications standards. The ITU sponsors a World Radio Conference biannually to bring together representatives of the member countries and reach a consensus on spectrum allocations for particular purposes around the world. Satellite communications have become a major portion of the work at these conferences due to the inherent capability of a satellite to provide services across many geopolitical boundaries.

The regulatory issues surrounding low Earth orbiting satellites (LEOs) have received the most attention due to their inability to restrict operation over specific countries around the world. Launching such satellites is viewed as easy but not all governments are willing to let their public use them. Governments which have not privatized their telecommunications services fear the potential of satellites to bypass the public telecommunications networks and undermine their control and revenues. This is a particularly sensitive issue for voice and broadband communications services.

National Political Objectives

National matters such as licensing of systems and services represent an important part of the cost of doing business and a substantial element of risk. The future mobile satellite industry is thus faced with the question of whether or not they will have customers. Where the trend is toward privatization operators are racing to become fully operational. For example Constellation, Ellipso, Globalstar, Iridium, Leo One USA, Orbcomm and Odyssey, which are all U.S.-based, are in varying stages of signing up participating companies, operators and service providers. The fifth major player is London-based ICO Global Communications which has the only existing global mobile satellite network.

Current GEO satellite telephony tariffs are substantially higher than cellular charges. LEO services on the other hand are touted as a quick and easy alternatives to wireline, offering advanced telecommunications that would otherwise be cost-prohibitive especially in developing countries. Political views are often expressed with reservations or outright opposition, however. For example Aurora Rubio, chief of The Philippines telecomm policy and planning division, said “In developing countries, it is not easy for global mobile personal communications service (GMPCS) to be seen as a basic service. They can also be seen as subordinating sovereignty and should strike a balance between sovereignty and affordability.”

The free movement of terminals across national borders is a major issue and the ITU will likely have some regulatory role. There is need for further study, particularly with regard to the interworking with terrestrial networks and especially the contentious aspects of global-roaming.

There has not been the level of debate about the applications and potential benefits to underdeveloped economies as there has on the political issues. For example it would not be hard to imagine that the electric grids of those countries could be greatly expanded or improved using satellite technologies.

> *US utilities planning to expand overseas might well view the potential of satellites to reduce their cost of power system operations. It would also seem an opportunity for joint strategic investments on combined power and telecommunications.*

6

CONCLUSIONS AND RECOMMENDATIONS

This report has taken a broad view of satellite communications as a vehicle for utility internal use and possible strategic investment. The main classes of satellites have been compared with one another and with terrestrial communication options. The report provides sufficient background information for the preliminary selection of a satellite service provider as a strategic business partner.

The main conclusion reached is that there is ample opportunity for low risk internal applications which nevertheless can result in a competitive advantages. A secondary but also significant conclusion is that the time is right for equity investments.

In comparing satellite options there is a clear distinction to be made between systems which are optimized for low-cost, low data requirements - Little LEOs and those which are aimed at higher bandwidth applications - Big LEOs. The market and technical risks of the latter are formidable and moreover their services are not well aligned with the core business of energy generation and delivery at this point in time. Big LEOs however hold the key to broadband communications within the energy industries.

Within the category of Little LEOs there is a clear distinction between satellite systems designed for continuous coverage and those which by design will have significant gaps in communications.

> *A final conclusion is that Little LEOs meet many of the core telemetry needs of the energy industries now and will meet growing needs in the future. In this class those with continuous service will be the most applicable.*

A recommended follow up action to this report is for energy companies to more closely examine the plans and finances of LEO providers in light of their specific corporate needs and objectives and to develop a strategy for incorporating satellite solutions as and where they apply.

A

LITTLE LEO SYSTEM DESIGNS

Company Profiles

The following companies have or are expected to receive a license from the FCC for a Little LEO system:

- E-Sat
- Final Analysis
- Leo One USA
- Orbcomm
- VITA – 2-satellite, non-commercial, humanitarian-only system

Orbcomm is the only surviving commercial player from the first round of FCC licensing. For the second round now under FCC scrutiny there are three applicants (Leo One USA, Final Analysis and E-Sat). At the date of this report it is understood that Starsys, CTA and GE-Americom have withdrawn. Final designs were frozen by the FCC at the time of application.

Little LEO System Designs

	1st Round Licensees				2nd Round Applicants		
	Orbcomm	(1)	VITA	(2)	Leo One USA	FACS	ESAT
Total # Satellites	36	28	1		48	26	6
Subscriber D/L Data Rate (kbps)	9.6	9.6	28.8		6/24	9.6/19.2	0.1
Subscriber U/L Data Rate (kbps)	2.4	2.4	9.6/19.2		2.4/9.6	9.6/19.2	1
CONUS* coverage (15° mask angle)							
Capacity (kbps)	10	7.5	0.45		42	20	0.2
Visibility (%)	80	61	1		100	60	17
90th % Outage (minutes)	6	17	>350		0	10	>350
Maximum Outage (minutes)	125	180	>350		0	170	>350

* CONUS = Continental United States
Performance data is reported for a mid CONUS latitude of 40 degrees.
(1) Orbcomm's license is for 36 satellites. In its 9/96 debt offering, Orbcomm states its system, on orbit, will consist of 28 satellites.
(2) VITA is a non-profit organization planning to disseminate medical information to fixed stations at health facilities around the world.

Figure A-1
Final designs of Little LEO Systems.

Note that only Leo One USA has been designed for continuous coverage so their system is of special interest to energy companies and others with continuous service requirements.

E-SAT

One firm, Global Energy Metering Services (GEMS) Inc. of Mill Valley CA, has entered this section of the market. GEMS began to install and demonstrate prototype satellite terminals as early as 1993 in conjunction with ABB as a strategic partner. ABB has placed the satellite terminal technology under glass of a meter and calls this their "Alpha Stars System." In a joint venture with EchoStar Communications GEMS has formed a new company called E-Sat (refer to the second round LEO discussion above) to launch six Little LEO satellites. The intention is to expand GEMS services to include:

1. Two-way remote data collection
2. Packet validation
3. Data formatting to utility specifications
4. Electronic data delivery

The two-way communications via E-Sat will enable utilities to access remote sites and retrieve demand information for load management and power purchase decision making. Because of the relatively few (six) satellites in the E-Sat application, the availability for near real-time communications is constrained and gaps in availability in the CONUS are likely to be in the range of 5 to 6 hours.

Leo One USA

Because of it's unique design the Leo One system will be described in more detail than others. It has the following characteristics:

Space Elements

- 48 satellites, 6 in 8 orbital planes at 50 degrees inclination
- Altitude 950 km (590 miles)
- Small size and mass of 125 kg (280 pounds)
- Highest link capacity and availability of all Little LEOs
- Generous link margin of 19dB to combat fading building penetration loss and interference
- Simple RF and power technology
- Proprietary "isoflux" space antenna design for a more uniform power footprint
- Satellite and launch vehicle available within 72 hours
- Moderate total and individual satellite cost ($440/$3 million)
- Life time in space 7 years including de-orbiting

Terminals

- Two to four US gateways for coverage and redundancy
- Gateway configurations as low as $250 K
- VHF (148 to 150 MHz)and UHF (455-456 and 459-460 MHz) uplink,
  UHF (400.15 to 401 MHz) downlink
- Low-cost chipset for hand held and embedded applications

- Simple whip antennas
- Uplink data rates 2.4/9.6 kbps
- Downlink data rates 6/24 kbps
- Message size typically between 100 and 500 Bytes/characters

Note that both Orbcomm and Leo One USA will be sharing the same frequency band for the uplink. Interference between the satellite systems and other terrestrial systems will be mitigated by dynamic allocation airlink protocols that allow the systems to select different channels within the uplink band.

Cumulative Investment

The investment dollars have been adjusted to reflect current thinking as a result of accelerated FCC ruling.

Table A-1

Seed and licensing (through 12/97)	- $12 million
Stage I - System Development (through 6/98)	- $27 million
Stage II - Pre-operating (through 12/00)	- $137 million
Stage III - Final construction, deployment and operations (through 12/01)	- $467 million*

* An additional $20M thru 12/02 to cover working capital shortfalls

Award of the FCC license is critical and when approved will signal a new round of financing by the company. Update: The FCC has announced a Report and Order on 10/9/97 establishing a license for Leo One USA pending submission and review of certain compliance filings.

Communications Coverage and Capacity

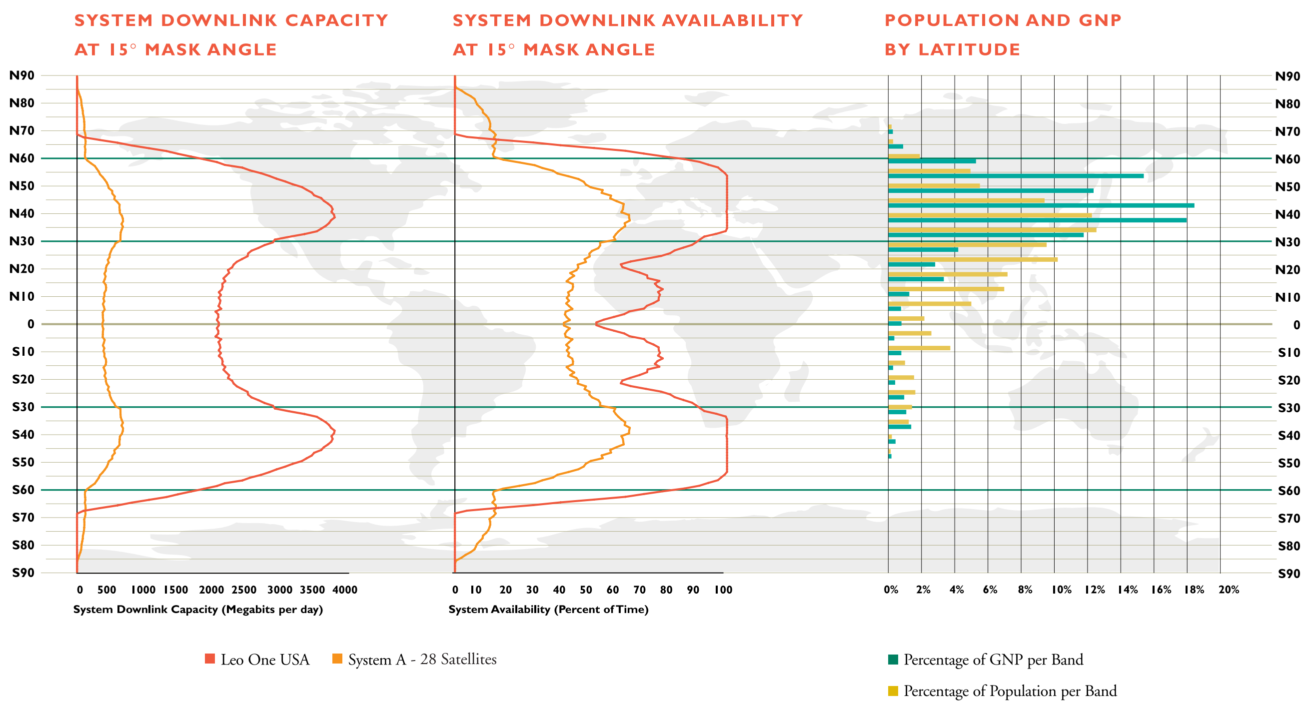
Continuous availability is valuable – and may at times be critical. Traffic carrying capacity has direct revenue implications. Because of these facts Leo One USA was asked to provide a comparison between their system and their nearest competitor. They supplied the following chart which illustrates coverage and traffic patterns across the globe.

The advantages of a 48 satellite system are apparent in this chart which shows availability of 100 % can be achieved over the range of CONUS latitudes.

Statements about availability assume line of sight and can be quoted at different angles of elevation to the satellite. Availability with a minimum 15 degree angle of elevation (as in this graph) is a more conservative claim than at 5 degree elevation which is sometimes given.

System Capacity and Availability Comparisons

48 Satellite System vs. 28 Satellite System



Updated to Reflect New Information

Figure A-2
Capacity and Availability Profile Comparisons.

Further detailed analysis of the company's market and ROI projections can be made available from EPRI. The company has a Web site at <www.leoone.com>

Orbcomm

The first commercial "Little LEO" in the US is that of Virginia-based, Orbital Sciences Corporation's Orbcomm. Orbital Sciences designs and markets space technology products and satellite-based services. They are in partnership with Teleglobe of Canada and TRI of Malaysia.

Orbcomm Technology

The Orbcomm constellation is designed for global two-way digital communications services suited to messaging, emergency alerts, position determination, and remote data collection. Orbcomm's goal is to become the first low-orbit constellation of satellites fully in service.

At this time Orbcomm Global has two low orbit satellites in space and plans to add one ring of eight during the 4th quarter of 1997 followed by two more rings of eight in the first and second quarters of 1998. The satellites are scheduled to be launched on the company's Taurus and Pegasus vehicles. The company has a license for up to 36 satellites in total and may deploy the full constellation in the future to gain more coverage primarily at equatorial latitudes. The Orbcomm system is fully licensed in the United States for four US Gateway Earth Stations.

Space to ground communications uses VHF; 148-150.05 MHz up-link and 137-138 MHz for the down-link. The ground terminals are typically small hand held units with whip antennas not unlike a cellular phone. They cost less than $500 and are capable of transmitting at a burst rate of 2400 bps and receiving at a burst rate of 4800 bps. Due to the airlink protocol the effective throughput is equivalent to a 300 bps modem.

The low throughput and intermittent nature of the Orbcomm system makes it applicable to a variety of industries in particular transportation and oil and gas. Messages will be sent via Orbcomm satellites to gateway stations on the earth. These gateways will then either forward them directly to the destination via some combination of leased lines, the Internet and paging systems or store-and-forward them via satellite on demand.

Orbcomm Business Posture

Orbcomm does not manufacture terminal equipment or sell services to end users. The firm operates via hardware vendors who develop a range of hand-held and fixed terminal devices in collaboration with domestic value added resellers. The VARs package the Orbcomm technology and transmission capacity for targeted applications.

Among the notable firms associated with the Orbcomm service are Scientific Atlanta, Trimble and Magellan.

In the first nine months of 1996 the company experienced a loss of $14.1 million with only $1.3 million in revenue. As dismal as this may sound Orbcomm officials expect to be profitable within nine months of having all 28 of its satellites in orbit. The company plans to profit from international sales, and claims a 2 to 3 year lead over its competitors who they believe will face higher costs and should not become profitable for a number of years. Orbcomm is now fully funded (Verify — we understand Orbcomm needs additional financing and will be returning to the capital market in 1998.) with the completion of a $170 million debt financing transaction earlier this year. As of August 1997, Orbital Sciences was trading on NASDAQ ORBI with a P/E ratio of 32 at a recent price of $17.50 in a 12 month range of $13 to 22.

To provide the reader with some insights into the global nature and evolution of Little LEOs the following material has been extracted from Orbcomm's press releases.

According to their announcements Orbcomm Global LP has signed agreements for the distribution of Orbcomm satellite-provided mobile data communications services in 40 European countries, Northwest Africa, and Southeast Asia. "The new distribution agreements complement the operational and financial progress Orbital is making toward the full deployment of the Orbcomm satellite constellation," said David W. Thompson, Orbital's chairman and chief executive officer.

According to the agreements, three new licensees will together commit approximately $30 million for franchise fees, ground facilities, other infrastructure costs, and marketing and related investments. These agreements cover the marketing, sales, and distribution rights of Orbcomm services in 47 countries with a total population of approximately 900 million people.

In 40 European countries, the satellite-provided mobile data communications services will be distributed by the newly formed Orbcomm Europe, a consortium made up of European telecommunications companies led by Nuova Telespazio, the space technology and services division of the giant Italian communications holding company, STET Group. The Orbcomm Europe consortium also includes companies from Great Britain, Germany, and Sweden.

In the Southeast Asia region, Cellular Communications Network Sdn. Bhd., a wholly owned subsidiary of Technology Resources Industries Bhd. (TRI) of Malaysia, will distribute and sell Orbcomm services in the fast-growing Pacific markets of Singapore, Malaysia, and Brunei. TRI is also an equity investor in Orbcomm Global LP. For Northwest Africa, Orbcomm Maghreb S.A. will supply Orbcomm services in Morocco, Tunisia, Algeria, and Mauritania.

As part of the licensee agreements, each regional distributor company will construct one or more gateway earth station and one central message processing control center in order to track and maintain communications with the constellation of 28 Orbcomm satellites circling the globe in low-Earth orbit, Thompson said. The ground facilities in each of the regions are scheduled to be operational by the end of 1997.

Each licensee will construct a central message processing Gateway Control Center, plus one or more Gateway Earth Stations that will track and connect satellites with the Gateway Control Centers. These ground facilities are scheduled to be installed and operating next year.

Each consortium plans to offer the full range of Orbcomm system services, from tracking and communications for trucks and field service operations, to personal e-mail type messaging services for recreational applications such as emergency reporting.

Malaysia's leading telecommunications company, Technology Resources Industries Bhd., has signed itself as an equity partner in a venture with Orbcomm. TRI will be responsible for emergency communications, remote industrial asset and environmental monitoring, and two-way e-mail links for laptop and palmtop computers.

Azhar Asnuni of TRI said the company invested US $45 million in the US $330 million venture and would spend another US $10 million on operational work. He expected the infrastructure for the system such as the gateway to be ready well in time for the launch of the service, scheduled for the end of 1998. TRI will build an Orbcomm earth station and message processing center in Malaysia to service subscribers in the region.

Orbital Science corp. will work with OEMs and partners to embed Orbcomm messaging into other systems. For example, Magellan has embedded Orbcomm messaging functions in its handheld GPS transceiver, the GSC 100.

> *In summary Orbcomm is the market leader and has little or no competition today. The company believes it has at least 3 years lead over new entrants and claim they are already planning their next generation of systems in order to stay ahead.*

Orbcomm has a www site at <www.Orbcomm.net>

B

BIG LEO SYSTEMS

Loral Globalstar/Cyberstar

Loral Space & Communications Ltd., headquarters in New York, concentrates on satellite manufacturing and satellite-based services. Loral recently announced an agreement to increase its ownership in Space Systems/Loral to 100 percent. Loral also manages and is the largest equity owner of Globalstar, in which it holds a 35 percent interest.

Globalstar

Loral Aerospace and QualComm have developed Globalstar as a Big-LEO which will consist of 48 satellites and eight spares at an altitude of 1401 km (871 miles) equally divided into 8 orbital planes. The satellites will use traditional bent-pipe repeaters in the 1 - 3 GHz spectrum. Each satellite will weigh about 700 pounds (320 kg) and have the capacity for the equivalent of 2800 full-duplex voice circuits.

Globalstar's system, launch of which is due to begin this fall, will offer voice telephony, data, fax, positioning, and other services. Globalstar Canada is majority-owned by Canadian Satellite Communications Inc. of Toronto. The Canadian government has given Globalstar Canada approval to offer mobile wireless communications services across Canada.

The Globalstar partnership has opted for small, trapezoidal-shaped satellites, which will be easier to load in multiples on launch platforms. The three-axis attitude control uses GPS to track its orbital location and attitude. While Globalstar is relying in part on McDonnell-Douglas Delta launchers that could be delayed by the January explosion, it is also using Zenit-2 rockets from NPO Yuzhnoye (Kiev, Ukraine) and Soyuz vehicles provided by Starsem S.A. (Sureness, France).

In addition to using the CDMA channel-capacity-improvement algorithms provided by QualComm, Globalstar will use the rake receivers from CDMA designs to provide path diversity -a proprietary means of combining multiple signals from different satellites into a single coherent signal. The Globalstar partners already have conducted numerous ground tests of the path-diversity concept.

Like Iridium, Globalstar will rely on ground-based gateways to link the space PCS system to terrestrial AMPS and GSM cellular networks. Security features such as encryption and firewalling will be added at the gateway point. Priorities for multimode handsets will assure that attempts will be made to connect first through local cellular networks, then directly through Globalstar satellites, and finally through a relayed gateway to another terrestrial cellular network.

QualComm Inc. said it was awarded a $275 million contract by Globalstar, LP to supply gateways for deployment in Globalstar's worldwide satellite-based digital telecommunications system. The multi-year agreement could grow to approximately $600 million for QualComm as the Globalstar network is built out, officials said.

In addition to the Gateways, the contract provides for associated services and the supply of optional equipment to Globalstar LP. QualComm expects to begin shipping Gateways in fulfillment of the initial $275 million order in early 1998.

When completed, the $2.6 billion Globalstar system of 48 LEO satellites and a global network of ground stations, and will allow people around the world to make or receive calls using hand-held, vehicle-mounted mid fixed-site terminals. Globalstar will also provide data transmission, fax and position location services. Satellite launches are expected to start in the fall of 1997, and commercial service is slated to begin in late 1998.

CyberStar

In May 1997 the Federal Communications Commission (FCC) granted Loral Space & Communications Ltd. a license to build, launch, and operate a worldwide *Broadband*, GEO satellite delivered digital communications system.

The $1.6 billion CyberStar system, being designed and developed by Space Systems/Loral, is a Geostationary satellite-based digital telecommunications system expected to offer a variety of low-cost, high-speed, data and telecommunications services worldwide from leased Ku-band Transponders satellites. Start-up date for the leased portion of the system is expected late this year, with a dedicated constellation of geosynchronous Ka-band satellites expected to be in place starting in 1999.

According to CyberStar President Ron Maehl, CyberStar services will include low-cost, high-speed Internet access, Broadband interconnection, real-time streaming, video-on-demand, and other data services. Beginning in 1999, the services will be delivered to consumers, businesses, and private networks around the world through a network of local and regional service providers through a constellation of three interconnected Geostationary satellites positioned over the Americas, Europe and the Middle East, and Asia, Maehl said.

"High speed digital systems are driving the need for communications channels to become integrated," Maehl said. "We are designing CyberStar to be the most economically feasible way to bring the Global Information Infrastructure (GII) to the world's consumer and business markets."

Maehl said that Space Systems/Loral, headquarters in Palo Alto, California, will provide the CyberStar satellites. In addition to building the three CyberStar satellites, Space Systems/Loral is the prime contractor for Globalstar's constellation of low-earth orbit satellites, the N-STAR, Mabuhay, APSTAR, PanAmSat, Telstar, L-STAR, M-squared-A, INTELSAT FOS-II and CHINASAT communications satellites, as well as two digital audio radio satellites for CD Radio, the latest series of US weather-watch satellites, GOES (Geostationary Operational Environmental Satellite), and the Japanese MTSAT, the next-generation Japanese air traffic control and weather-watch satellite.

SkyBridge

Loral Space & Communications and Alcatel-Alsthom are cooperating to produce next-generation global satellite systems that will deliver high speed bandwidth for Internet access, video conferencing, and medical telecommunications. Loral will be a partner in the Alcatel-Alsthom's $3.9 billion SkyBridge project, which includes 64 low-earth orbit satellites, while Alcatel will invest in Loral's CyberStar project, featuring up to four satellites in high-earth orbit. If the cooperation proves successful, the projects may be integrated into a single system, scheduled to begin phasing into full operation in 2000-2002. Loral and Alcatel had proposed technologically different and wholly separate satellite systems, but the two companies have a history of cooperating in other areas. The SkyBridge system will compete with those from Hughes Electronics, Lockheed, AT&T, GE, and PanAmSat, as well as the Teledesic low-earth-orbit satellite system, backed by Microsoft.

Skynet

Loral Space & Communications Ltd. has completed the acquisition of AT&T's Skynet Satellite Services. The purchase price, adjusted to reflect the sudden on-orbit loss of Telstar 401 in January, was $478.1 million.

Loral Chairman and Chief Executive officer, Bernard L. Schwartz stated "We envision expanding Skynet into an international network of Geostationary satellites which will connect with other networks to provide seamless, multimedia accessibility to the information superhighway. "We welcome Skynet's employees and its customers to the Loral Space & Communications family, and look forward to adding resources and expanding Skynet's markets through a vigorous growth plan," Mr. Schwartz continued. The acquisition, announced last September, is the first for the "new" Loral and, together with Loral's existing satellite activities, creates one of the world's largest satellite-based businesses.

Skynet is a leading U.S. satellite operator specializing in the distribution of entertainment and educational programming to mass audiences throughout the nation via a network of C- and Ku-band geosynchronous satellites known as the Telstar series. The company also operates two state-of-the-art satellite telecommunications control stations and an advanced research and development facility.

Among Loral Skynet's customers are AT&T and EchoStar, and some of the strongest content providers in the broadcast industry, including ABC and Fox. Additionally, Skynet leases satellite capacity to direct-to-home service provider AlphaStar.

Loral Skynet headquarters is in Bedminster, NJ. It has two operations centers, one based in Hawley, Pa., and the other in Three Peaks, Calif. Loral Skynet's research and development operation is currently based in Holmdel, NJ.

Motorola, Iridium and Celestri

Iridium Objectives

Iridium is Motorola's Big LEO comprising 66 satellites in 6 equal planes at an altitude of 785 km (490 miles). The objective is a worldwide wireless service for voice, data, fax, and paging planned to begin commercial operation in 1998.

Iridium has joined with many terrestrial-cellular networks on the project. Iridium will track the location of subscribers' phones and allow communication between any two points in the world. The hand-held phones will connect to notebooks, personal digital assistants, and palmtops. One service will allow the same handset to be used for cellular communications on these networks, with switch-over to Iridium's network for out-of-range users.

The company will offer the ability to send alphanumeric messages to pagers and other data-transmission capabilities, at a relatively low data rate of 2400 bps. Iridium will aim its service at large corporate customers, said Michelle Lyle, a spokeswoman at Iridium. By using $3000 handsets and paying $3 per minute, users will be able to communicate via voice, paging and electronic mail from anywhere in the world, Lyle said. Governments and users in remote areas without cellular capabilities also will be targeted, she said.

Critical Achievements

Iridium is owned by an international consortium of 17 investor organizations. Motorola is the primary contractor. Iridium has filed for an initial public offering. The consortium has already secured in $2.65-billion funding for the project and will file for 10 million shares with price per share going between $19 and $21 per share. The first five satellites were launched in May 1997 with 7 more in June.

Technology

Iridium uses new techniques of on-board satellite to satellite links to circumvent the need to down link voice and data traffic to intervening hub stations. The 25 Mbps cross links operate between 22.55 and 23.55 GHz. The on-board processing and cross satellite links in space add complexity and weight. Iridium's satellites weigh 1100 pounds (500 kg) and have the equivalent capacity of 3840 voice circuits. Iridium satellites are complex since they must send tightly focused beams to the ground, and communicate with up to four satellites in space via special crosslinks. Motorola claims that its 23-GHz crosslink system is unique in the PCS industry, allowing faster inter-regional hand-off than any other space-based or terrestrial PCS.

While Iridium will use a Siemens D900 telecomm switch as a gateway to the public-switched-telephone network, calls can also take place based on direct links between handset and satellite. The Iridium mobile phone will function in the same way as a conventional mobile phone. The user will have a single phone number which remains unchanged no matter where he or she happens to be. Only voice transmission will be available during the initial phase — fax and data services will be supported at a later stage.

Scientific-Atlanta supplied the earth terminals, computer systems that will link to satellite dishes, forming a communications gateway in Phoenix serving North America. The gateway will provide the link between the ordinary phone network and Iridium's satellite network.

Raytheon is currently under contract to develop and produce eighty (80) satellites worth of Main Mission Antennas (MMAs). The Main Mission Antennas is a phased array antenna which provides the L-Band RF links to the Individual Subscriber Units (ISU). The addition of the MMA panels for the twenty-five satellites brings the current contract total to $272.9M. The first delivery of the production antennas occurred in December 1995, with the last delivery expected in October 2000.

Gensym Corp. is providing software for network management in a $5 million agreement with Motorola Satellite Communications Group for use in the Iridium satellite communications system. Motorola will use Gensym's G2 and Fault Expert software products which are designed for intelligent network management, including root-cause fault diagnosis and analysis and operator decision support. Motorola's G2-based Integrated Network Management application was recently recognized at Object World Frankfurt. Motorola won first place in the "Best Implementation of a Distributed Application Using Object Technology" category at the Object Application Awards.

Iridium has a web site at <http://www.iridium.com>

Motorola's Broadband Projects

Since the Iridium system is designed for relatively Narrowband uses, it's too slow for Web access. That's why Microsoft CEO Bill Gates and telecommunications pioneer Craig McCaw have big hopes for their Teledesic, a broad-band mobile communications network. Teledesic, which is lagging behind Iridium's deployment schedule, relies on a constellation of hundreds of low Earth-orbit satellites. While Iridium is meant for short messaging, Teledesic is designed for "fiber-like" wireless telecommunications services, including interactive Internet access, voice, data, and video conferencing.

Presumably to counter the Broadband competition Motorola announced plans June 18, 1997 that it will offer a new system for "high capacity data communications anywhere on the globe." The 63 -LEO satellite network is called Celestri and will compete head-to-head with Teledesic (described later in this report). According to the application Celestri will use 63 satellites at 1400 km (870 miles) altitude in seven orbital planes inclined at 48 degrees with respect to the equator. Another seven satellites will be in-orbit as spares.

Motorola claims that Celestri will support video, data and voice with small low power low-cost earth terminals for residential small business and large multinational corporations. Specifically Motorola identified four services:

1. Point to point real-time symmetric connections from 64 Kbps to 155 Mbps for video conferencing,

2. Point to point bursty asymmetric services up to 16 Mbps for Internet access,

3. Broadcast and multicast services,

4. Interactive and integrated broadcast and real-time response services.

Their plans involve use of frequencies in bands ranging from 18.8 to 30 GHz but no technical details have been released.

Motorola also has M-star at $6.1 billion — 72-satellite network for super-high bandwidth transmissions and Millennium at $2.4 billion — 4 high-capacity, broadcast style satellites. None of these systems are operational and have no customers.

It took Teledesic three years to get licensed. It remains to be seen how long it will take Celestri. Motorola is hoping to have it operational by 2002 which happens to be the same target for Teledesic.

TRW, Odyssey

TRW and Teleglobe Inc., of Canada, are founding shareholders in Odyssey Telecommunications International Inc., (OTI) which will develop the Odyssey satellite-based system and provide personal communications services worldwide. The Odyssey Telecommunications International Inc. group, which received an FCC license in January 1995 will build the system.

TRW Inc. is an international company, listed on the New York, London and Frankfurt stock exchanges, with 1996 sales of US $9.86 billion. With headquarters in Cleveland, the company provides advanced technology products and services to the automotive, space and defense, and information markets worldwide.

Teleglobe Inc., based in Montreal, with 1995 revenues of Cdn $1.5 billion, is a public company listed on the Montreal, Toronto and Vancouver stock exchanges. Teleglobe is one of the largest North American intercontinental telecommunications companies and provides services to more than 230 countries and territories through a network of satellites and coaxial and fiber optic submarine cables.

Odyssey Objectives

OTI will operate as a wholesale provider of personal communications services to national service operators, who in turn will provide Odyssey services to retail consumers. Odyssey mobile phones will be available with dual-mode capability, allowing Odyssey subscribers to place calls over existing cellular networks or via satellite whichever is available. Note that Teleglobe is also a partner in Orbcomm.

Odyssey Technology

The Odyssey design comprises a constellation of 12 satellites at a medium earth orbit (MEO) altitude of 10,354 km (6435 miles) equally divided into 3 orbital planes. While few are required to cover the globe this comes at the expense of weight, each satellite weighs 2703 pounds (1250 kg). At these altitudes satellites need larger antennas, solar arrays and shielding to protect against increased space radiation levels. These satellites have an equivalent capacity of 2300 voice circuits.

The Odyssey design will establish a PCS service using the L and S bands specified by the World Administrative Radio Conference. Odyssey uses a simple repeater architecture in its satellites, leaving all advanced processing to its ground stations. The system design includes seven gateway earth stations linked by a wide-area network.

TRW Inc. has received a third US patent protecting its invention of Odyssey, a satellite-based global cellular phone system. Claims of the patent issued Sept. 3 (No. 5,551,624) cover two aspects of the Odyssey system. The claims cover TRW's invention of a system for using a mobile phone to communicate via medium-Earth-orbit satellites to another phone. Other claims in the patent protect Odyssey's medium-Earth-orbit-based 24-hour coverage over predetermined latitudes of the Earth.

The European Patent Office has issued a patent for the Odyssey system design effective in the United Kingdom, France, Germany and through the year 2012. "This patent extends to key European countries the protection Odyssey already enjoys under patents in the United States and elsewhere," said Bruce Gerding, TRW vice president and managing director of the company's Odyssey Services Organization. Gerding noted that in the past two years, TRW has received patents for Odyssey in the United States and Taiwan and been issued utility models in Germany, which afford patent-like protection there.

The claims of the European patent (No. EP 0 575 678 B1) cover a satellite-based cellular telecommunications system having satellites in a medium-earth orbit. The system connects a mobile cellular phone with another phone through one of the satellites and a gateway station, and assigns a call originating from within a service region to one of the satellites in accordance with predetermined criteria. TRW filed for the patent in September 1992.

The U.S. Federal Communications Commission has granted TRW Inc. final approval to build and operate the Odyssey global, satellite-based cell phone system. The approval followed the FCC's recent adoption of a frequency band allocation plan that made spectrum available for use by satellite feeder links and other radio systems. Odyssey's links between satellites and Earth stations use the newly designated spectrum, and TRW's license for those links had been conditional pending completion of the FCC's plan.

Teledesic

Moved from earlier section: As we have discussed elsewhere in this report Teledesic aims at becoming the Internet-in -the- sky solution. "It's like getting a 1.544-Mbps T1 line anywhere on the face of the earth," says Tren Griffin, a Teledesic VP.

Judging by the amount of press coverage, the Teledesic project is by far the most ambitious and controversial of all the developments. Teledesic is certainly the most interesting from the points of view of it's service potential and it's technology. Teledesic Corp. (Kirkland, Wash.), is a private company principally financed by Craig McCaw, the cellular pioneer, and Bill Gates, the Microsoft chairman. Teledesic will join forces with Boeing and to deploy Teledesic's Internet-in-the-sky venture by 2002.

Boeing will invest up to $100 million to own 10 percent contributing $50 million to the project immediately and the remainder after completion of design work. The Teledesic partners do not rule out adding more investors (as they still need more financing and manufacturing partners to reach Globalstar or Iridium levels of viability) and is considering a public offering, but it has no customers yet for its service.

Teledesic Objectives

Teledesic will provide global switched, broadband network connections through service partners in host countries. The Teledesic network is being designed to provide a quality of service comparable to today's modern terrestrial communication systems, including fiber-like delays, bit error rates less than 10^{-10}, and a link availability of 99.9% over most of the United States. The 16 Kbps basic channel rate supports low-delay voice coding that meets "network quality" standards.

The initial Teledesic constellation will support a peak capacity of 1,000,000 full-duplex 2 Mbps connections, and a sustained capacity sufficient to support millions of simultaneous users. The system will provide 24 hour seamless coverage to over 95% of the Earth's surface and almost 100% of the Earth's population.

The intent is to offer primarily fixed Internet connectivity and other services, such as video conferencing, interactive multimedia and real-time two-way data flow worldwide, through a satellite network for which network connections would be provided by service partners in host countries worldwide.

Through global partnerships, the network will provide digital connections between users of the network, and via gateways to users of other networks." In each host country, the end-users will be served by more than one or more local service providers and terminals at the network gateway and user sites will communicate directly with Teledesic's satellite-based network and through gateway switches to terminals on other networks. According to David Montanaro, Vice President, strategic locations with Teledesic, "the Teledesic network will extend the terrestrial fiber optic-based infrastructure to provide advanced information services anywhere on the earth," he said.

Critical Achievements

Teledesic received important approvals for its system in November 1995-when the World Radio Conference approved global allocation of spectrum for Broadband LEOs - and in July 1996, when the FCC approved 28-GHz spectra adjacent to local multipoint distribution service bands. The FCC adopted a domestic band plan, designating that spectrum for primary use by non-Geostationary fixed satellite services (NGSO FSS) such as Teledesic's.

The Federal Communications Commission approved Teledesic's license application to build and operate the network on March 14, 1997. The FCC license, made Teledesic the first satellite communications network approved by the FCC which will allow the company to offer worldwide access to "fiber-like" telecommunications services, including Broadband Internet access, video conferencing, and interactive multimedia.

The FCC license will allow Teledesic to build and launch the Teledesic Network, as well as make use of 500 megahertz (MHz) of domestic radio frequency in the 28 Gigahertz (GHz) band, the uplink portion of the Ka-band, and a corresponding 500 MHz of downlink spectrum.

The FCC license for Teledesic to use part of the 18 GHz band of frequencies for its planned satellite network ended the struggle between Teledesic and Associated Communications. Associated will give up a portion of the 18 GHz frequency band so that Teledesic and the government can operate satellite communication without interference. In return, FCC gave Associated 400 MHz in the 24 GHz band for terrestrial Broadband communications services. The FCC's decision gives both Teledesic and Associated Communications free spectrum that is equivalent to that held by all the US radio and television stations.

"The innovative satellite constellation will comprise an 'Internet in the sky' " the FCC said in a statement. Critics contend that the government could collect billions of dollars by auctioning the frequency band. NTIA contents that the deal is intended to eliminate possible interference between Associated's equipment and the government's satellite earth stations, which are critical for national security. Telesdesic's proposed satellite communications system is unlikely to cause interference.

Selecting Boeing as a prime contractor and gaining regulatory approval to build and operate the network has cleared the way to begin deployment. "Our relationship with Teledesic is the perfect catalyst for bringing together all of our historical investments in the space business with our recent and planned investments in Sea Launch, Rockwell and McDonnell Douglas," said Condit, who is leading Boeing's merger with McDonnell Douglas and the recent acquisition of Rockwell International Corp.'s aerospace and defense businesses.

The boards of directors of both companies have approved the agreement, which was signed by Alan Mulally, president of Boeing Defense and Space Group, and David Twyver, Teledesic's chief executive officer. "With our FCC license in hand, we now have the regulatory certainty to move forward and begin building the network," Twyver said. "After almost seven years of development, the Teledesic Network finally has the green light."

Teledesic evidently selected Boeing as the prime contractor because of its pioneering work in space; its experience in managing large, complex global alliances; its commitment to aggressive cost and schedule goals; and the companies' shared vision. According to Twyver, the Teledesic Network will provide switched, Broadband network connections through service partners in host countries worldwide. The network emulates distributed network features of the Internet, he said, while adding the benefits of high-quality service and location-insensitive access.

Teledesic Technology

In comparison to Iridium and Globalstar which have been designed primarily for voice services and Little LEO systems which carry short-message services, and data services similar to circuit-switched cellular, the Teledesic system is designed for high speed data access *primarily from fixed terminals*. The satellites would use a 30-GHz uplink and 20-GHz downlink to provide up to 28 Mbps aggregate throughput on the downstream channel and up to 2 Mbps on the return path.

Teledesic initially proposed a constellation of 840 low-earth-orbit satellites but Boeing officials said their design proposal will allow Teledesic to provide the same coverage and capacity with fewer satellites. The scaled-back plan, to be implemented by the year 2002, calls for about 288 satellites providing the same coverage and capacity as the earlier plan. Under the Boeing proposal, Teledesic's $9 billion price tag is also expected to remain the same.

Boeing officials are considering a number of launch vehicles to boost the network into orbit. Launch capacity remains a "longer lead item," said a spokesman for Boeing. "We'll make some commitments on launchers later this year," he said.

The only feasible frequency band internationally allocated to Fixed Satellite Service that meets Teledesic's requirements is the Ka band. High rain attenuation, terrain blocking, and other terrestrial systems in this band make it difficult for earth terminals to communicate reliably with a satellite at a low elevation angle. The Teledesic constellation uses a high elevation mask angle to mitigate these problems. A low orbit altitude is used to meet the requirements for low end-to-end delay and reliable communication links that use low power and small antennas. The combination of low altitude and high elevation mask angle results in a small coverage area per satellite and a large number of satellites for global coverage.

Each satellite in the constellation is a node in the fast packet switch network, and has intersatellite communication links with eight adjacent satellites. Each satellite is normally linked with four satellites within the same plane (two in front and two behind) and with one in each of the two adjacent planes on both sides. This interconnection arrangement forms a non-hierarchical "geodesic," or mesh, network and provides a robust network configuration that is tolerant to faults and local congestion.

Each interconnected satellite will provide coverage over a small portion of the Earth's surface, with each satellite capable of projecting multiple beams within its footprint. This topology is designed to provide efficient use of the radio frequency spectrum and support high-capacity services.

Teledesic promotes its ability to handle asynchronous transfer mode (ATM) and TCP/IP packet traffic - a capability that is virtually impossible in geosynchronous systems because of delays in delivering TCP acknowledgment packets. Teledesic uses 64-byte packets within each data stream but concentrates streams between ground-based terminals in ATM/SONET standards from the 155-Mbit/s OC-3 to the 1.244-Gbit/s OC-24 rate. Terrestrial networks involve fixed Broadband links, network operations and control centers, and constellation-operations control centers.

Teledesic terminals can support multiple simultaneous network connections. In addition, the two directions of a network connection can operate at different rates. The links are encrypted to guard against eavesdropping. Terminals perform the encryption/decryption and conversion to and from the packet format. The uplinks use dynamic power control of the RF transmitters so that the minimum amount of power is used to carry out the desired communication. Minimum transmitter power is used for clear sky conditions. The transmitter power is increased to compensate for rain.

The Teledesic network accommodates a wide variety of terminals and data rates. Standard terminals will include both fixed-site and transportable configurations that operate at multiples of the 16 Kbps basic channel payload rate up to 2.048 Mbps (the equivalent of 128 basic channels). These terminals can use antennas with diameters from 16 cm to 1.8 m (6 inches to 2 yards) as determined by the terminal's maximum transmit channel rate, climatic region, and availability requirements. Their average transmit power varies from less than 0.01 W to 4.7 W depending on antenna diameter, transmit channel rate, and climatic conditions. All data rates, up to the full 2.048 Mbps, can be supported with an average transmit power of 0.3 W by suitable choice of antenna size.

The Network also supports a smaller number of fixed-site GigaLink Terminals that operate at 155.52 Mbps and multiples of this rate up to 1.24416 Gbps. Antennas for these terminals can range in size from 28 cm to 1.6 m (11 inches to 2 yards) as determined by the terminal's maximum channel rate, climatic region and availability.

One benefit of a small satellite footprint is that each satellite can serve its entire coverage area with a number of high-gain scanning beams, each illuminating a single small cell at a time. Small cells allow efficient reuse of spectrum, high channel density, and low transmitter power. However, if this small cell pattern swept the Earth's surface at the velocity of the satellite (approximately 25,000 km (15538 miles) per hour), a terminal would be served by the same cell for only a few seconds before a channel reassignment or "hand-off" to the next cell would be necessary. As in the case of terrestrial cellular systems, frequent hand-offs result in inefficient channel utilization, high processing costs, and lower system capacity. Teledesic uses a novel "Earth-fixed" cell design to minimize the hand-off problem.

Controversial Cost and Market Size

Some analysts think that the huge amount of satellites required by such aggressive Broadband LEOs may make the systems difficult to justify. Herschel Shosteck of Shosteck & Associates suggested that because many regions of the world have access to wireline systems that can provide Broadband channels more cheaply than a space-based wireless system like Teledesic, "the payoff for very big up-front investment is not obvious."

"It's a pipe dream," says Iain Gillott, director of wireless communications at Framington, Mass.-based IDC Corp. "I think Teledesic is fundamentally flawed" Gillott thinks there's the question of market size, which, in light of advancements in terrestrial wired and wireless networks, he doubts is large enough to sustain a project of this magnitude — costs are often quoted as exceeding $9 billion.

Nevertheless Teledesic continues to build momentum, becoming the first satellite plan of its kind to be licensed by the U.S. Federal Communications Commission. And the company has been able to attract some of the nation's strongest space companies e.g. Boeing and industry's brightest minds among them is Teledesic chief executive officer David Twyver, formerly the president of Northern Telecom's global wireless operation.

"This may seem flaky at first glance," says Twyver, "but if you look at the market, we think the demand for interactive Broadband communications, particularly Internet communication, is just growing exponentially."

Twyver says Teledesic is targeting two very specific markets. "One is actually in Canada and the U.S., where it turns out the terrestrial Broadband facilities that are being developed — cable modems, ADSL and LMDS — are only going to be economic within a few miles of their hubs.

"Then there's the developing world, where they've not yet had time or the capital to build Broadband infrastructures. We'll be able to provide instant infrastructure in those countries and for companies wanting to do business there."

Others believe that the market in North America may be too limited, since constantly expanding wired and wireless Broadband networks may be able to service most of the population before Teledesic is operational — sometime in 2002. With future competition expected from other low-earth orbit (LEO) and medium-earth orbit (MEO) multi-satellites all these billion-dollar systems will be competing aggressively for a worthwhile return on investment.

Today, the competition has been just as intense to find financial and strategic partners. Says John Ledahl, director of the wireless program at San Jose, Calif.-based Dataquest: "Gates and McCaw are willing to fund it in the short term, but not in the long term by themselves."

In the meantime, one can expect Twyver will continue to defend the Teledesic vision. Teledesic's Web site is at <http://www.teledesic.com>

The Indian Connection

With its satellite launching capabilities, after the successful launch of the Polar Satellite Launch Vehicle (PSLV) last year, the Indian Space Research Organization (ISRO) is expected to be a major partner in the Teledesic project.

Besides the Teledesic, India also figures prominently in the plans of major global consortia like Iridium, Globalstar, ICO Global Communications and Afro-Asian Satellite Communications, who, among others, plan to provide the new generation of mobile satellite telecomm services. Further discussion of the Indian connection is provided in the following coverage of ICO.

The Intel Viewpoint

Chip manufacturer Intel Corp. has invested in an initiative that will use Geostationary satellites to deliver multimedia content to European desktops. Expect Intel to seek to partner with a U.S. company (possibly Teledesic) to bring similar service to North America.

"Over the next two years, major satellite systems will begin to offer data services," said Avram Miller, Vice President of business development for Intel, in Santa Clara, Calif. "But don't think of it as being Internet services. It is a broadcast service; it only works if there is a one-to-many situation where many people consume the same information. Satellite transmission may be appropriate for global companies that need to spread information to geographically isolated areas where it may be too costly to lay lines."

Intel and the Societe Europeenne de Satellites are the initial investors in the newly formed European Satellite Multimedia Services S.A., of Luxembourg. By leveraging the SES satellite infrastructure to which 64 million European homes subscribe, ESM will make its ASTRA-NET communication platform available to businesses later this year.

Using SES' ASTRA satellite systems, the service will send DVB (Digital Video Broadcasting)-compliant transmissions to a small satellite dish at the user site. The transmission connects to a Pentium PC equipped with an add-in DVB card, officials said.

ICO

Inmarsat, the government backed international marine satellite consortium that developed several Geostationary services, hopes to update its network with a system similar to Odyssey. An affiliate company ICO Global Communications was established in January 1995 to provide a new generation of satellite-enabled personal mobile global communications services. ICO intends to provide digital voice, data and facsimile services as well as basic messaging and information services in India and worldwide. The company intends to begin full commercial service worldwide in the year 2000.

Controversial Player

The formation of ICO (which stands for intermediate circular orbit) has caused consternation among competitors such as Motorola and TRW because of the US government's involvement in Inmarsat. Analyses by the US Dept. of Justice, the GAO, and the Dept. of Commerce have found that ICO could enjoy certain privileges such as exemption form taxation and immunity from law suits and easier access to spectrum which will provide market advantages.

At their May 28, 1996 meeting the ICO shareholders agreed to amend ICO's organizing documents to incorporate the GAO recommendations. The ultimate organization behind ICO has yet to be settled but this does not seem to deter the company from moving ahead. Current plans call for 10 satellites and 12 earth stations in the ICO-P system and international agreements are being formed.

Significant Partners

Kokusai Denshin Denwa Corporation (KDD) and subsidiary Satellite Phone Japan have signed an agreement with ICO Global Communications for the provision of a Network Management Center and Backup Satellite Control Center. The two centers, to be built in Japan, will work with ICO's planned low earth orbiting satellite system that will provide mobile telephone services worldwide.

ICO Global Communications, has placed a major order with Ericsson, together with Hughes Network Systems and NEC Corporation. The $1 billion calls for NEC to supply the ground segment of ICO's global satellite network, which will handle calls from mobile users almost anywhere on the earth. Under the agreement signed in Tokyo, the consortium will be responsible for the design, manufacture, construction, installation and testing of ICO's own ground network, which will be known as ICOnet.

Videsh Sanchar Nigam Ltd. (VSNL) and ICO Global Communications have signed an agreement to establish a satellite access node (SAN) for global mobile communications services in India. ICO will establish one of its twelve global SANs in India. ICO will invest over US $ 50 million in the SAN facility at VSNL's existing facility at Chattarpur, near Delhi.

ICO- Technology

The basic terminal will be a hand-held device, similar in size, weight and design to current cellular units. These hand-held units will be dual mode, capable of working with both satellite and cellular/PCS networks. These small handsets, will communicate with the satellites in asynchronous orbit, 10,000 kilometers (km) (6215 miles) above earth. Note this is an intermediate orbit above the Big LEOs and below the GEOs. At this altitude there are the advantages of needing fewer satellites compared to Iridium and Globalstar without the long delay associated with the GEOs. This medium earth orbit is designed for voice mobiles, pagers, and mobile data terminal users.

Earth stations, which will send signals from and to the satellites, will be stationed in Australia, Brazil, Chile, India, Indonesia, Germany, Mexico, South Africa, South Korea, the United Arab Emirates, United States, and China.

Plans call for ICOnet to consists of twelve Satellite Access Nodes (SANs) located around the globe, two network management centers and related ground facilities. Each SAN complex will consist of five high performance tracking antennas and associated control and switching equipment to provide the space-to-earth interface for ICO's global telecoms network.

Each SAN will in turn be connected to the existing public telephony and land mobile networks in their respective regions. All 12 SANs in the ICO global network will be connected with each other through high performance digital lines. Installation of the ground system will begin in September of this year and should be completed by August 2000, however such estimates tend to be unreliable for some of the reasons given earlier.

The main Network Management Center for the system will be based in the KDD Building in Tokyo. It is the core of the ICO system and operators control all aspects of the service, including the 12 planned earth stations, from it. A backup center will be located in London.

The Backup Satellite Control Center will provide control of the 12 satellites in the fleet, should the primary center in London go down. The two centers will have a staff of around 30 engineers and technicians, said KDD.

Rory Buckley, Ericsson's public systems' managing director, said that the ICO contract is the Swedish telco's first order for infrastructure for a mobile satellite system and "demonstrates the strength and flexibility of GSM technology in meeting future mobile consumer needs."

VSNL will provide site infrastructure and operations support for the SAN in India consisting of five high performance tracking antennae dishes and associated control and switching equipment to provide the space-to-earth interface for ICO's global telecom network. The Chattarpur SAN will be a special node in that it will be one of ICO's six centers worldwide that will host satellite control (tracking, telemetry and control or TT&C) facilities that are vital to managing the space assets.

Lockheed Martin Astrolink

Lockheed Martin, Bethesda, Md., plans to begin offering service on their proposed Astrolink system from 9 GEO satellites in the second half of 2000. Initial service will be provided in either the United States or Europe depending on the precise placement of the company's first satellites. The Astrolink network will use the latest switching and transmission technology, including ATM, to offer anywhere from two-and-a-half to three times the capacity of the largest satellites currently in operation, said Sig Dekany, manager of marketing communications at Astrolink.

The company will seek to partner with major communications companies around the world to help sell its Astrolink services directly to end users and to help it gain landing rights for satellite receiving stations in different parts of the globe.

Lockheed Martin Telecommunications is developing the Ka-band GEO satellite system that will provide ATM-based, variable bandwidth data services. Betting that the demand for communications bandwidth among corporate network users will be insatiable the Astrolink system will provide services ranging from 128 kbps for low-cost portable terminals to 155 Mbps at central sites located near a gateway satellite facility. Applications will include LAN-to-LAN connections, electronic commerce, remote manufacturing, video conferencing and high-speed Internet access.

GEO Mobile Satellites

Despite an apparent worldwide boom in the market for wireless mobile communications, there is no question about there being big winners and losers in the satellite vs. terrestrial and satellite vs satellite competitions.

The fate of a pioneering firm American Mobile Satellite Corp. seems in doubt. In 1989 the FCC granted AMSC (whose shareholders include McCaw Cellular Hughes and Singapore Telecomm) a license to provide a full range of mobile services in the US. Their GEO satellite AMSC-1 has been in operation since late 1995 with services including satellite/cellular phone service, fleet communications and private networking. But AMSC is apparently having financial problems. In its filings with the SEC the company states it “does not believe it can obtain, on commercially reasonable terms, adequate liquidity to support its operations in the near term without substantial credit support from its principal stockholders.”

Further evidence of this comes from another early adopters, TMI the Ottawa-based company, which provides phone, fax and data services over its MSAT-1 satellite to the country’s most remote regions.

TMI recently laid off 60 of its 180 employees, as the satellite communications firm readjusted for lower-than-expected subscriber rates. TMI’s satellite-based data services gained only 3000 subscribers in 1996, far less than the 20,000 for which the company had hoped, and analysts suggest that increasing competition from PCS and cellular services will make it difficult for TMI to compete in the future.

TMI’s MSAT-1 satellite was deployed two years later than planned, a delay that cost the company market share to rival cellular service firms that it has yet to recover. The delay forced TMI in late 1995 to offer its services over a sister ‘bird’ (AMSC-1) owned by U.S. counterpart American Mobile Satellite Corp. When MSAT-1 was eventually launched, it was soon realized that a valuable window of opportunity had been lost. In the period from May 1994 the cellular carriers rapidly extended their coverage.

One point of view comes from Mark Fabbi, research director at Mississauga, Ont.-based consultant Gartner Group Canada, said “Alberta is one key area where cellular coverage, over the Telus Mobility network, has significantly improved. Coverage in Alberta is just exceptional from a cellular perspective and that was probably one of TMI’s biggest markets — the resource industry,” said Fabbi.

Without a doubt competition for TMI and other GEO system operators will at some point come in the form of low-earth and medium-earth orbit satellite systems offering voice service, such as Odyssey (MEO), Iridium (LEO), and Teledesic (LEO) systems. However the Big LEOs are at least two to four years away and will undoubtedly have their own problems to work out.

There are however, optimistic projections such as those published by London, England-based Ovum Ltd., which claim the number of subscribers to mobile satellite services (MSS) is expected to increase from 130,000 in 1998 to eight million in 2002, generating in that year $8.5 billion (U.S.) in revenues. They claim that while regional Geostationary (GEO) satellite services such as Ottawa-based TMI Communications Inc.'s MSAT system and the American Mobile Satellite Corporation systems have a headstart in the mobile communications market, the new breed of LEO satellites is expected to spur interest and, in effect, generate an increase in market demand.

"The development of MSS has been driven by the satellite industry's need to find a continuing role in telecommunications as terrestrial bandwidth becomes cheaper and more plentiful," states a summary of the report.

The high-cost of providing satellite communications might sap some start-up firms' revenue, leaving more established cable companies and cable modems as the long-term winners for Internet service. While on-line use is growing it is still very low in terms of building up a business around a huge cost like satellites. Such costs will inhibit the acceptance of satellite data delivery for mainstream consumers. Charges such as the best rate DirectPC has for unlimited access is about $130 a month which is about 6 times the price of a 56 Kb connection to a local ISP.