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TELECOMMUNICATION SATELLITE SYSTEMS

THE ODYSSEY SATELLITE SYSTEM AND DISASTER/EMERGENCY COMMUNICATIONS

Presentation
by
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Introduction

There is an old saying that the first victim of a disaster is communications. With the advent of global mobile personal communications satellite (GMPCS) services, this need no longer be true. GMPCS service seems like the answer to a prayer for persons engaged in the fields of emergency and disaster management. This paper briefly examines the role one such proposed satellite system, Odyssey, could play and why such satellite-based systems offer a number of advantages over conventional communications.

Satellite Communications - Past and Future

In the past, communications satellites have typically been located in geostationary (GEO) orbit. This orbit, some 36,000 km over the equator, is unique in that satellites maintain a constant position relative to the earth's surface. This tends to simplify system operations and the ground station infrastructure, and only three or four GEO satellites are needed to provide single-satellite coverage of the entire world. Unfortunately, due to the GEO altitude, transmissions through a GEO satellite introduce propagation time delays that are confusing and inefficient for interactive communications. In addition, terminals for GEO systems tend to be bulky and require some setup time. Because of the stationary position of GEO systems relative to the earth's surface, a user may encounter obstacles in the line of sight to the satellites which hinder link completion.

The solution to these GEO problems is to place the satellites in lower orbits, either in Low-Earth Orbit (LEO), about 800-1400 km, or Medium-Earth Orbit (MEO), about 10,000 km. Figure 1 shows the relative orbits of GEO, MEO and LEO satellites.

LEO systems require large numbers of satellites to provide uninterrupted service for global coverage. Because of their low altitude, the coverage area of a single satellite in LEO is very small. As well, the satellites pass overhead rapidly, typically staying in view of a user for about 10 minutes. In order to maintain continuity throughout a call, LEO satellites must either employ complex satellite crosslinks, or utilize hundreds of ground stations spanning the globe.

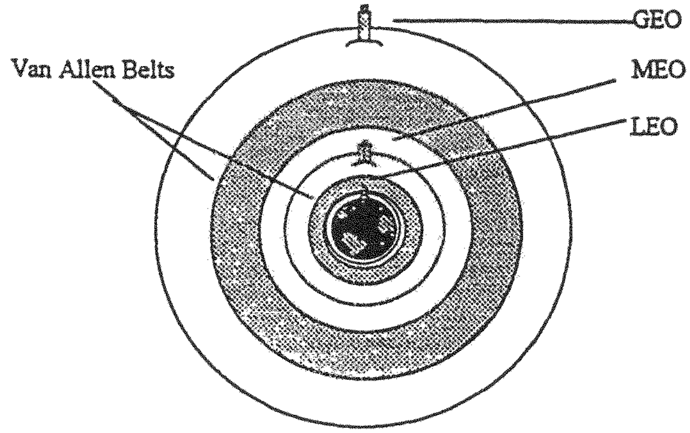


Figure 1. Relative orbits of LEO, MEO and GEO

Table 1 gives a comparison of some of the characteristics of LEO, MEO and GEO satellite systems.

	LEO	MEO	GEO
Per Circuit Cost	Medium to High	Low	Medium
Ground Segment Cost	Medium to High	Medium	Low
Satellite Lifetime (Years	5-7.5	10-15	10-15
Operational Complexity	High	Medium	Low
Global Roaming	Requires interconnection of many ground stations or satellites	Requires interconnection of a few ground stations	Not available
Typical Voice Delay	Imperceptible	Imperceptible	Noticeable to user
Call Handoff	Frequent	Infrequent	None

Table 1. Comparisons of satellite systems

The Odyssey MEO Satellite System

The Odyssey system is designed to provide economical, high-quality, personal communication services from Medium-Earth Orbit (MEO) satellites. Services will include voice, data, fax, short message services and value-added services. The system will provide a link between mobile or fixed subscribers and the public switched telephone network (PSTN) via dedicated earth stations and local gateways (Figure 2). For intercontinental calls, the Odyssey system will route calls through the Odyssey ground network established between the Odyssey ground stations. The gateways are the interface between the Odyssey system and the PSTN in each local area.

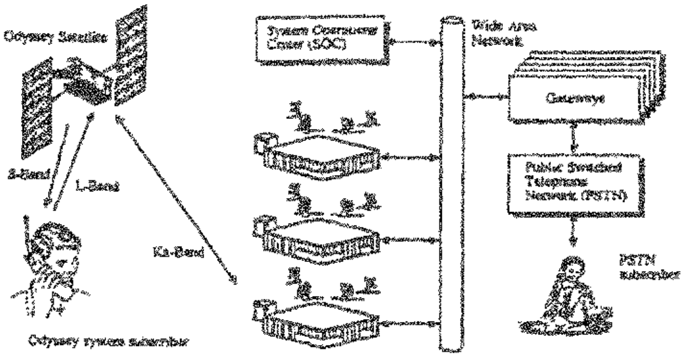


Figure 2. Odyssey System overview

The Odyssey system has been designed to work with national telecommunications networks, and to a great extent will complement existing terrestrial systems.

Odyssey Space Segment

The Odyssey constellation consists of 12 satellites at an altitude of 10,354 km, with four satellites in each of 3 orbital planes inclined at 50° to the equator. The satellites, which will be built by TRW Inc. in the United States, were designed to reduce technical complexity and risks, and minimize costs.

The Odyssey satellites, thanks to their Medium-Earth Orbit, rotate around the earth in about six hours; typically, a satellite is in view of a user for 90-120 minutes.

The Odyssey spacecraft is illustrated in Figure 3. The satellite can be launched singly on the Delta, Soyuz and Long March, or two at a time on Proton and Ariane-5 vehicles. The satellites are designed for a mission life of 15 years, which will significantly reduce the life-cycle cost of the Odyssey system.

Odyssey Ground Segment

The main components of the ground segment are the earth stations, primary and backup System Operations Centers (SOCs), local Gateways, and the Odyssey Ground Network. The ground segment interconnects Odyssey subscribers to the PSTN through the Odyssey earth stations and local gateways. It will also provide the interconnections and database operations necessary to offer subscribers global roaming capability which is user-transparent.

Seven Odyssey earth stations around the world provide the RF links to the satellite constellation. The constellation is controlled from a centralized SOC. Commands and telemetry to/from the satellite are routed through the earth station links. System planning and management is provided from the SOC, which also manages all service operations and the overall Odyssey Ground Network.

Gateways will provide the connectivity between the Odyssey system and the country-/area-specific PSTNs.

The Odyssey Ground Network will be a redundant private fiber-optic network interconnecting the SOCs, all earth stations, and the gateways.

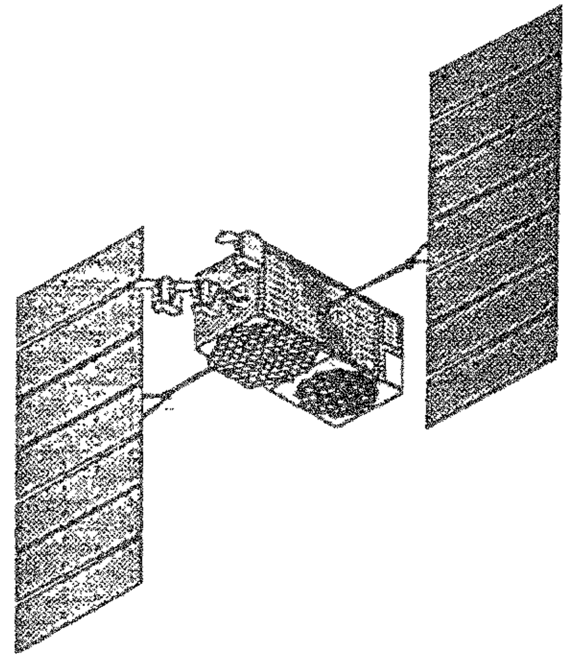


Figure 3. Odyssey satellite in deployed configuration

Odyssey User Segment

The Odyssey User Segment consists of mobile handsets and fixed wireless terminals. The fixed wireless terminal is basically the same as a handset; however it will utilize a larger antenna and be able to transmit more power.

The handset will transmit approximately 0.2 Watt average - adequate for both voice and digital data transmission. Although Odyssey's orbital altitude is greater than LEO, satellite antenna gain compensates for the greater path loss. The transmit power level provides an appropriate margin against loss due to fading effects. It should be noted that since the Odyssey system operates with high elevation angles (greater than 20°), less margin is required for path loss parameters than with very low orbiting systems which must operate at shallow elevation angles.

Odyssey dual-mode handsets will be compatible with terrestrial cellular signal formats. This will be achieved by the addition of microelectronic chips to existing handset designs to produce inter-operability with both cellular systems and Odyssey. The Odyssey handset will meet all of the communication system design requirements, most importantly - low cost, small size and reliability.

Odyssey handsets are expected to cost about $500-700; fixed wireless terminals will cost about $750-1000.

Odyssey and Disaster/Emergency Communications

Although not designed solely as a tool for disaster and emergency telecommunications, there is no doubt that satellite-based systems such as Odyssey have an important role to play in this area, and offer a number of advantages over conventional telecommunications solutions such as radio, cellular systems and the PSTN.

Satellite-based systems offer the prospect of survivable communications. Since the Odyssey system does not rely on local ground segment for call completion, calls can still be completed even if local facilities are knocked out by a disaster. In the event of earthquakes and tropical storms, for example, local cellular and radio facilities are often disrupted at the height of the disaster - just when they are most needed.

Most of the proposed GMPCS systems have also established a call hierarchy; in the case of Odyssey, 14 levels of access prioritization will ensure that disaster and emergency communications can get through, and that the system will not be congested by less urgent calls.

Odyssey also offers geo-location capability, so that users can report their position with accuracy up to 2 km (or less, if a GPS-type handset is used). This functionality is useful, for example, in the event of marine or light aircraft emergencies, or for locating persons lost in remote areas.

As well, satellite-based services are not affected by local weather conditions, and are not subject to sun-induced interference as are most conventional radio services.

Systems such as Odyssey lend themselves readily to closed user groups, such as emergency networks, police, search and rescue units, etc., where security of communications is an important consideration. Call encryption is an integral aspect of the Odyssey system design.

Global roaming capability means that mobile handsets can readily be taken into a disaster zone, providing reliable, no-hassle communications before, *during* and after an emergency situation.

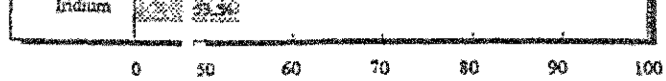
Service pricing is also an important consideration. While satellite-based services can be expected to cost more than cellular service, Odyssey has been optimized as a system to offer the lowest possible wholesale price and the highest possible service quality. Typical rates for end-users are expected to be about $0.65/min. for fixed wireless terminals, and $0.95 for mobile units. Dual-mode hand-held terminals, compatible with local cellular systems, will default to a cellular service if it exists (or if it is still functioning during the disaster), or to the satellite if cellular is not an option, thus ensuring the lowest possible per-minute costs.

Satellite systems such as Odyssey should be seen as tools for disaster/emergency telecommunications. They are only one of many such tools at the disposal of safety, rescue and relief organizations, but there can be little doubt they are one of the most flexible and cost-effective.

Odyssey Advantages

There are great differences in the proposed global mobile satellite systems. Odyssey, thanks to its patented technology and Medium-Earth Orbit, offers a number of significant advantages over other systems.

Perhaps the most important advantage of the Odyssey MEO orbit is high viewing (or elevation) angles. Two Odyssey satellites will be visible almost anywhere in the world at all times, a factor which leads to high line-of-sight elevation angles, thus minimizing blockage by terrain, trees and buildings. GEO satellites provide attractive viewing angles at latitudes near the equator, but very low angles at high latitudes. With LEO constellations, a large number of satellites is required to provide global coverage even at low elevation angles. Odyssey has elevation angles averaging 45°-55° at all latitudes, better than both LEO and GEO systems on a worldwide average. With the full constellation, a minimum line-of-sight elevation angle of 20° can be guaranteed to at least one satellite 100% of the time. Figure 4 shows the percentage of time at least one satellite is visible above 25°.



* Performance is averaged over the range 0° to 70° latitude, where the vast majority of the Earth's population resides. Figures are based on the Company's coverage analysis on the planned space segment of each system.

Figure 4. Relative elevation angles

Landmass coverage is another important Odyssey advantage. During the period that an Odyssey satellite is assigned to a particular region, the satellite attitude is controlled so that the body-mounted antennas are pointed in the desired direction to optimize coverage. This patented approach is called "directed coverage" and is different from most satellites, which merely keep the antenna beams pointed straight down to the earth (nadir pointing). Figure 5 provides an example of directed coverage. In this example, much of the satellite field of view is over the oceans. By slewing the satellite and aiming the antennas at the coast of China, millions of users are now in the satellite's field of view, thus helping to maximize use of the space assets.

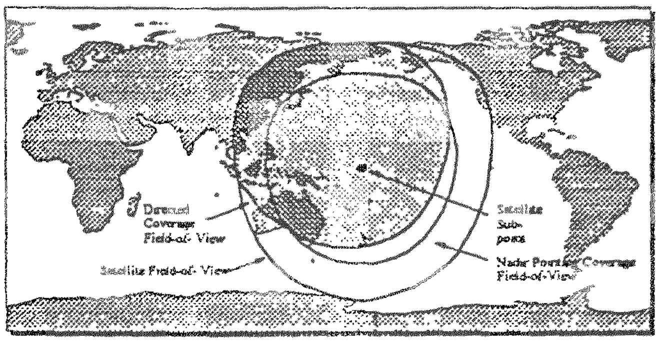


Figure 5. Satellite beam pattern over Asia

As well, thanks to the Medium-Earth Orbit, each Odyssey satellite will remain in view of a caller for well over an hour. Telephone calls are therefore infrequently handed over from satellite to satellite, reducing the probability of a dropped call. This avoids a major communications synchronization problem inherent in LEO systems which must frequently handover telephone calls from satellite to satellite (approximately every 10 minutes).

In addition, Odyssey's orbit configuration reduces propagation time delay to less than 100 milliseconds, imperceptible in human conversations, as compared with 270ms for GEO systems.

Economical design is important so that the subscriber service charges are comparable to terrestrial service charges. Economy is achieved through low investment cost, a major consideration for all satellite programs because the production and launch of reliable satellite networks is a very expensive business.

Odyssey was optimized as a system to offer the lowest-possible wholesale costs, and a number of elements of the system design help to achieve this objective:

- *MEO orbit requires fewer earth stations, satellites, launches and replacements*
- *Longer spacecraft life cycles dramatically reduce overall system costs*
- *Simplified design*
- *Ground segment maximizes use of existing commercial equipment and existing PSTN infrastructure.*

Frequency Plan

Mobile link frequencies for satellite-based personal mobile communications were designated at the 1992 WARC. Uplink transmissions from user to satellite are conducted at L-band (1610-1626.5 MHz), while downlink transmissions are at S-band (2483.5-2500 MHz).

The Odyssey signaling method will be spread spectrum (CDMA), which has been proven in numerous government applications and is an emerging commercial standard. Spread spectrum permits sharing of the spectrum by multiple service operators.

Summary

The Odyssey system in Medium-Earth Orbit has been optimized to meet a variety of market demands, and offers a number of advantages for disaster and emergency telecommunications. While GMPCS service is only one of several means of communications available to disaster relief personnel, such systems are unprecedented in terms of their reliability, effectiveness and overall flexibility.

THE ORBCOMM SATELLITE SYSTEM - A TOOL FOR DISASTER & EMERGENCY COMMUNICATIONS

The ever-increasing miniaturization of electronic circuits, especially those passing digital information, has now made it possible to build very low-cost data communications systems in which battery-powered, handheld transmit/receive units can communicate directly with small satellites orbiting the Earth at low altitude, generally below 1000 km. Such satellite systems are colloquially known as "Little LEOs", where LEO stands for *L*ow-*E*arth *O*rbit, and are quite different from the better-known communication satellites at the geosynchronous altitude of 35,786 km.

There are also so-called "Big LEOs" which, while still using satellites at lower altitude, are designed to carry voice traffic; as a result, they are much larger and more expensive. Big LEO systems like Odyssey, Globalstar, Iridium and ICO are not expected to be operational on a global basis until about 1998.

ORBCOMM

The first of the Little LEO systems is known as ORBCOMM and has been in commercial service in the United States since February 1996. ORBCOMM is designed to provide reliable, low-cost, two-way global data and messaging communications through a constellation of 28 satellites and a complement of associated ground infrastructure situated around the world.

ORBCOMM satellites orbit the earth every 100 minutes in circular orbits at an altitude of 785 km. Since the Earth is also rotating beneath the satellites, the satellites effectively overfly the entire world. Hence, the entire constellation of satellites is available for use with ground networks throughout the world. In general, a network will use only one satellite at any given time, and will switch from one satellite which is setting below the horizon to another which is then appearing above the horizon in another direction. Some of the larger networks, such as that in the United States, will use three or even four satellites at a time.

Compared to geosynchronous satellites, Little LEO satellites are of small dimensions and low mass; as a result, they are considerably cheaper to build and launch, although they are nevertheless quite complex. When its antenna boom and solar arrays are stowed for launch, an ORBCOMM satellite is shaped like a disk about 1m in diameter and about 10 cm thick, and weighs only 40 kg. The satellites can be launched eight at a time by the innovative Pegasus rocket, which is air-dropped from a modified L-1011 commercial aircraft.

The ORBCOMM constellation will consist of 28 satellites: three planes of eight satellites each, inclined at 45° to the equator; and two planes of two satellites each, inclined 70° to the equator. There are presently two operational satellites in orbit, launched in April 1995, and inclined at 70°.

Applications

The applications for Little LEO systems are many and varied. They include the whole range of SCADA (*S*upervisory *C*ontrol *A*nd *D*ata *A*cquisition) uses, in which the status and performance of remote, unattended machinery can be monitored at a base station (using the inbound communications capabilities), and commands to turn the machinery off or on, or change its operating configuration can be sent using the outbound capabilities. Typical applications thus include oil wells, pumping stations, and pipelines in the energy industry, or center-pivot irrigation devices in agriculture.

Another class of application is the tracking and monitoring of trucks and, especially, refrigerated containers. The satellite communicator unit, with its self-contained battery, is mounted on or in the wall of the container. An outbound message can be sent to the unit, commanding it to respond with its position and status (*e.g.* the temperature inside the container). Importantly, if the temperature rises above some pre-determined value, for example, if the refrigeration unit is malfunctioning, or if some other parameter exceeds its allowable range, the communicator unit can automatically send an alert to the base station, so that the container can be located and repaired before its contents are ruined.

There are also a wide range of applications in which the remote unit is carried by a person, such as a surveyor working in the field.

In terms of disaster and emergency communications, hand-held mobile units have an important role to play, although necessarily more limited compared to handheld mobile satellite voice terminals. Little LEO units could, for example, be carried by private pilots, boaters, mountain climbers, hikers, and others traveling in remote areas, facilitating rescue operations in the event of a problem. Users could send messages requesting assistance, and could also use their units to specify their position. Such units can thus function as personal locator beacons.

Each communicator unit can determine its location by internally processing the measurements it makes of the frequency shift of the downlinked signals caused by the relative motion between the satellite transmitting the signal and the unit receiving it. The accuracy of this position measurement is about 1 km, sufficient for many applications. In cases where greater accuracy is required, units with built-in GPS functionality can specify position to within a few feet.

Status

ORBCOMM's first two operational satellites have been in orbit since April 1995. The ground infrastructure in the United States, consisting of the Gateway Control Center and four Gateway Earth Stations, is in place. Although with just two satellites, only intermittent service can be offered, ORBCOMM is a commercial reality. Licensees authorized to provide ORBCOMM service are now being signed up, and ORBCOMM expects that by 1999 service will be available on a global basis, once Gateways have been constructed in a number of countries.