THE ELLIPSO™ MOBILE SATELLITE SYSTEM

An Optimum Approach for Efficient and Flexible Global Mobile Satellite Communications Service

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Abstract

Mobile Communications Holdings, Inc is in the process of developing and fielding a new, innovative, satellite-based mobile communications system which will offer global service. This system features broadband code division multiple access, simple satellites, and a constellation design that features elliptical orbits, partitionable subconstellations, and medium earth orbit altitudes. This design permits it to efficiently place satellite capability where and when it is most needed and minimize deployment of capability where and when it is little needed. This design offers a unique opportunity to deploy and operate a commercial mobile satellite system with the least and the most effective use of funds.

The Ellipso™ Opportunity and Concept

Ellipso™ was conceived as an innovative, satellite-based solution to extend and complement existing commercial terrestrial mobile communications services. Present mobile services, such as cellular telephone, have in practice only a very short radio propagation range, only a few kilometers, within which good service is available. Many expensive ground cell sites are needed for wide area coverage. Terrestrial mobile system operators are reluctant to expand coverage over areas that cannot themselves yield an economic return on the necessary investment. As a consequence, many rural areas are not served by cellular telephone. Furthermore, it is simply infeasible to offer terrestrial mobile services to some remote areas or areas where infrastructure is nonexistent, many of which have significant populations.

The Ellipso™ System is conceived to extend telecommunications services throughout the world to users that are not well, or not at all served by existing mobile or fixed telephone systems. Unlike cellular telephone, Ellipso™ offers fully nationwide service to every served country, thereby providing service to users located anywhere within the national boundaries, no matter how isolated or remote. With Ellipso™, a user in the middle of a wilderness area will have the same mobile telecommunications service available to him as a user in a major metropolitan area. The subscriber only requires a clear view of a serving satellite to achieve a connection and to connect to anyone else served by the national telecommunications system. Subscribers within view of two or more satellites will benefit from an automatic improvement in service quality, benefiting from Ellipso™'s unique satellite diversity.
processing, using all available satellites simultaneously to optimize circuit quality.

Ellipso™ uses low earth orbiting (LEO) satellites and an efficient system design to reach its subscribers directly and at a price that is competitive with terrestrial cellular telephone service, that is, around $US 0.50 per minute. Ellipso™ will not only offer the user mobile telephone services, but can also offer other digital services as well, such as data transfer, facsimile, paging, voice mail, and messaging. Ellipso™ will also offer geopositioning service to users upon request. Ellipso™ will not bypass existing telephone systems in offering these services, rather Ellipso™ will extend them. Figure 1 illustrates the Ellipso™ System.

**The Ellipso™ Business Plan**

Building to a viable and flexible business plan remains the most important aspect of the Ellipso™ system design. The market potential for mobile satellite services remains tentative.

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**Figure 1**

The Ellipso System
Therefore, Ellipso™ is intentionally designed to be capable of offering a profitable, economical service to a conservatively sized market, in order to succeed and grow while hedging market risks. Furthermore, the Ellipso™ design contains built-in flexibility for tailoring best its geographic coverage to market success.

The Ellipso™ System will profitably operate serving a conservative initial market size of less than 600,000 subscribers throughout the world. Ellipso™’s unique and proprietary LEO constellation of satellites assures not only an even Ellipso™ coverage around the earth for each latitude, but coverage over the entire populated earth tailored in capacity to the earth’s population by latitude. Ellipso™ is initially targeting 250,000 subscribers in the United States and 350,000 subscribers in other areas of the globe.

**The Ellipso™ Constellation**

The Ellipso™ system is unique in that it divides its global coverage into two zones, each served primarily by its own constellation of satellites. The earth’s distribution of land and population by latitude serves as the basis for the overall Ellipso™ constellation design.

Most noteworthy regarding the distribution of the world’s landmasses is that the northern hemisphere contains many times more land mass north of 40°N than the southern hemisphere has south of 40°S. Virtually all of Europe is north of 40°N, almost one half of the United States and all of Canada lie north of 40°N, and all the CIS and part of Japan lie north of 40°N. Among these are some of the largest countries on earth.

In contrast, the southern hemisphere contains much less land mass at high latitudes than the Northern hemisphere. For example, continental Australia reaches south only to 39°S, Tasmania to 43°S, New Zealand to 47° S, South Africa to 35°S, and continental South America to 52 °S. Moreover the amount of land south of 40° is very small in global terms, comprising only southern New Zealand, Tasmania, and the southern half of Argentina and Chile south of areas containing most of the populations. All areas south of 40°S are relatively sparsely populated. In short, almost all the earth’s populated land mass lies north of 40°S.

In light of this asymmetry in populated landmasses, any satellite system offering worldwide coverage of populated landmasses must provide extensive coverage to northern latitudes. To do so requires inclined orbits for all low and medium earth orbit satellite systems. But if circular orbits are used, the inclined orbits mean that equal coverage is also given to the far southern latitudes, where it is largely wasted.

The Ellipso™ system is designed to match its capacity and resources more closely to the distribution of populated landmasses than would be possible using any constellation of satellites in circular orbits. It does so using two complementary and coordinated constellations of
The Ellipso™-Borealis™ Constellation primarily serves areas in the northern temperate latitudes, while the Ellipso™-Concordia™ Constellation serves areas in the tropical and southern latitudes. Each constellation has been carefully conceived to complement the other, so as together to offer the most effective and efficient solution to worldwide coverage possible. The Tropic of Cancer roughly divides the service areas of the two constellations, although there is a wide band of latitudes that can be served by either or both constellations. Ellipso™ can adjust the deployment schedule and capacity of each of these two zones to optimize global coverage to investment and demand as necessary.

Ellipso™-Borealis™

The Ellipso™-Borealis™ Constellation provides coverage of the northern temperate latitudes. This constellation uses up to 15 satellites in elliptical orbits in several planes. All orbits are inclined at 116.5 degrees in order to prevent movement of the apogee around the orbital path. Ellipso™-Borealis orbits have apogees of 7,800 kilometers, perigees of around 520 kilometers, and a three-hour orbital period. The apogees are at the northern extremity of the orbits.

These elliptical orbits act to concentrate most of the deployed satellites to the north of the equator at any one time. Consequently, they can furnish northern service for a greater percentage of their orbits than if the orbits were circular. The elliptical orbits also require less launch energy than a circular orbit of similar northern coverage. Finally, these satellites are mostly quiescent when below the equator, when batteries are recharged. These factors translate into a requirement for fewer, smaller satellites having lower launch costs than would be needed using circular orbits.

Furthermore, the Borealis™ orbits are carefully configured to be sun-synchronous. That is, the orientation of the orbital plane remains fixed relative to the direction to the sun throughout the year. Being sun-synchronous, each orbital plane can be adjusted to optimize the time of day at which the greatest satellite coverage occurs. This is achieved by carefully choosing the orientation of the orbital plane relative to the sun and by tilting the line of apsides (the line connecting the apogee and perigee) of the orbit so that the apogee is placed over the desired northern region at the desired time of day. For example, orbital planes that are edge-on to the sun can have their apogee tilted toward the sun in order to increase system capacity in daylight hours over that at night. This favoring of one time of day over another will be true at all longitudes around the earth. Ellipso™ will exploit design flexibility like this, which are only possible with elliptical orbits.

1 Since satellite angular velocity is dependent on satellite altitude, satellites in elliptical orbits pass rapidly through their perigees and travel more slowly through their apogees.
Ellipso™-Concordia™

The Ellipso™-Concordia™ Constellation provides corresponding coverage to the tropical and southern latitudes. Note that these satellites need not provide high capacity at high latitudes, since there is very little land in the southern hemisphere at high latitudes, and northern high latitudes are already covered by Ellipso™-Borealis™. This permits tailoring an economical orbital configuration for Ellipso™-Concordia™ coverage that focuses greater capacity at tropical and near-tropical latitudes than does Ellipso™-Borealis™.

Present planning calls for an initial complement of six Concordia™ satellites to be deployed in an equatorial orbit at altitudes at around 7,800 kilometers. This constellation configuration will provide continuous initial coverage of all tropical latitudes plus all temperate latitudes between 40 degrees north and 40 south. An additional complement of four satellites in a complementary elliptical Concordia™ orbit dramatically increases daytime capacity.

Refinement of Ellipso™'s orbits and satellites to achieve optimum coverage at least cost continues. One Ellipso™ objective is to maximize design and construction similarities between Borealis™ and Concordia™ satellites. Another Ellipso™ system design objective is to offer at least dual satellite coverage to every served point on the earth above around 40 degrees south latitude, with single satellite coverage to 50 degrees south latitude. This redundant coverage will permit Ellipso™ to exploit path diversity to reduce dramatically the effects of shadowing, blockage, and multipath fading on otherwise marginal links.

Figure 2 illustrates the overall appearance of the Ellipso™ constellation using two planes of satellites in inclined Borealis™ orbits and a third equatorial orbital plane for the Concordia™ satellites. This will be the form taken by the initial Ellipso™ deployment.

The Ellipso™ Satellites

Ellipso™ uses relatively simple transponder satellites. Proven, space-qualified components and spacecraft designs are used to the maximum extent possible. These satellites will interconnect the Ellipso™ subscriber with Ellipso™ Ground Control Stations, from where the subscriber will connect with the existing national telecommunications network or to another Ellipso™ subscriber via satellite. Electronic processing functions are performed in the earth stations to reduce satellite costs and to permit the flexibility in processing approach by region discussed above.

Important advantages of the transponder approach to satellite design are the smaller size, weight, and cost of the satellites, and system flexibility to accommodate changes in modulation or multiple access techniques. Such changes may be necessary to implement future system improvements or to tailor Ellipso™ better to the specific
technical characteristics of each region's infrastructure.

The Ellipso™ satellite will be a 3-axis stabilized design using solar wings and body-fixed antennas. The satellite antennas used for serving the mobile users will divide the visible earth into 19 adjoining areas, each served by its own beam. These beams are arranged in a circularly symmetric manner. Each beam illuminates approximately the same earth area. Beams whose signals must traverse a greater distance have more gain to compensate for the added distance. Figure 3 illustrates the layout of the 19 satellite mobile service beams.

Each beam will carry the entire 16.5 megahertz Mobile Satellite Service (MSS) band. This eliminates the need for users to switch frequencies as the beam or satellite serving them changes, in contrast to present cellular service practice as a user transitions from cell to cell. The signals in each mobile user beam are translated to a separate band for transmission between the satellite and the Ground Control Station over the feeder links. The satellite transmits and receives from the Ground Control Stations using single area coverage beam antennas in the corresponding feeder link bands.

The satellite will use momentum wheels and thrusters for attitude control and station keeping. The satellites will contain enough battery reserve to allow full eclipse operation. The satellite is specified to have a five year mean life.
Figure 3
The Ellipso™ Mobile Service Beam Array

Ellipso™ Satellite Deployment

Here too the Ellipso™ design offers flexibility. Ellipso™ will introduce marketable services in phases, corresponding to its level of deployment. The Ellipso™ satellites will begin deployment in the latter half of 1996.

Ellipso™ satellites may be launched up to six at a time while building the constellation, depending on the booster used. Constellation replenishment will use smaller boosters to launch one or two at a time. Eight satellites in two inclined planes will initiate full northern hemisphere Borealis™ service above the Tropic of Cancer. Six Concordia™ satellites will provide complete and continuous coverage of the tropical and southern latitudes. Therefore complete service can be deployed to the region with the earliest demand with only a partial deployment of Ellipso™ satellites.

Additional Ellipso™ satellites will add capacity to those regions of the globe having additional demand, and can be deployed in any of
several combinations between Borealis™ and Concordia™, depending on the distribution of demand. Indeed, Ellipso™ is free to adjust the timing of the introduction of northern versus southern capacity depending on the demand in each region.

**Ellipso™ User Terminals**

The Ellipso™ user terminal will be very similar in form and operation to those used for cellular telephony. Ellipso™ signal parameters have been selected to correspond closely to anticipated terrestrial CDMA cellular designs of the future. Necessary upgrades to add Ellipso™ service capabilities to terrestrial cellular terminals of any type will be held to a minimum.

There will be two primary types of Ellipso™ user terminals, mobile or portable and handheld. Mobile terminals are designed for vehicular use and may be capable of 5 watts or more of RF power (note that actual emitted power from any terminal is controlled during the call to the momentary levels adequate for good quality service; the nominal power level will be significantly less than full power). Handheld terminals will have a lower maximum power level. In both terminals, the antennas will provide hemispheric coverage. In many cases, Ellipso™ terminals will be dual mode terminals, capable of operating in the Ellipso™ system or in the local terrestrial cellular system.

Other terminal designs are also possible. Indeed, variations on user terminal design and packaging are only limited by the design ingenuity of terminal suppliers. For example, very small units can effectively support low rate data service or paging across the Ellipso™ operating area. Ellipso™ services will also lend themselves well to integration with the new personal communications services proposed by some as the next generation in public telecommunications.

It is expected that Ellipso™ user mobile terminals should cost around one thousand US dollars within one to two years of service initiation.

**The Ellipso™ Signal**

**Ellipso™ Services and Signals**

It is anticipated that the primary service Ellipso™ will support will be voice telephony. To support this service, Ellipso™ presently anticipates using a state-of-the-art digital voice encoding technique, known as the Code Excited Linear Predictive (CELP) algorithm, for efficiently replicating high quality voice using a 4.8 kilobits per second digital rate. Testing has shown that this voice algorithm yields natural-sounding, high quality voice reproduction. Ellipso™ will offer even higher grades of voice service during off-peak hours or to subscribers who request it.

Ellipso™ will also use its basic digital transmission capability to support various kinds of digitally-based services, such as data transfer (e.g., computer to computer transfers), facsimile, message forwarding, paging, and geolocation information. These services will be...
available at various data rates from 300 to 9600 bits per second with commensurate adjustments in price.

Before transmission, the user's signal is error control encoded using a relatively powerful convolutional error correcting code. This is followed by bit interleaving for randomizing burst errors, and conditioning for eliminating phase transition ambiguities. Finally, the user signal is multiplied by a high speed digital direct sequence spreading code, a random-like but reproducible digital sequence running at a rate around 3,300 times faster than the user signal to be spread. This has the effect of spreading the signal's energy, which formerly occupied only several kilohertz, over sixteen megahertz of bandwidth. After spreading, the resulting signal is transmitted using a power-efficient modulation technique.

On the feeder links between the Ground Control Station and the satellite, all signals related to a particular beam between the satellite and the subscribers are sent within the 16.5 megahertz band segment of the feeder link band used for that beam. The satellite relates the signals in each such feeder band segment to the respective subscriber beam. In this way the GCS can direct a signal to any beam without the need for any satellite on-board switching. Figure 4 illustrates the relationship between feeder link band segments and subscriber beams.

When active, EllipsotM user terminals monitor one of several packet-based signaling channels for monitoring system status and availability, monitoring for incoming call alerts, and maintaining synchronization. Calls in either direction are handled over the signaling channel through a series

![Figure 4](image)

**Figure 4**
Mapping of service link beams into the feeder link
of information packets exchanged between the user terminal and the Ground Control Station. Once the parameters for the call and the call connection have been established, the GCS assigns a call spreading code key to the user terminal and the user terminal and the GCS transition to this "code channel" for the call itself.

During the course of the call there is occasional need for control information, such as for power control settings, to be passed between user terminal and GCS. This information is inserted among the data bits pertaining to the call itself in a manner that is invisible to the user.

Some functions, such as simple requests for position determination, and some types of short messages, such as for paging, are handled uniquely over the signaling channels.

Ellipso™ will handle advanced signaling and call services available through the public switched telephone network. In all respects Ellipso™ will offer the modern call features that many users have come to expect from a telecommunications service.

Ellipso™'s Approach to Multiple Access: CDMA

Ellipso™ has chosen to use Code Division Multiple Access (CDMA) to permit multiple simultaneous access by many subscribers to Ellipso™ resources. CDMA has shown itself to be ideally suited for the mobile satellite environment, combining superior capacity, robustness, and flexibility when compared to system designs using other multiple access techniques.

Most mobile satellite systems will want to support many users simultaneously (permit "multiple access") in order to serve many subscribers and use system resources efficiently. There are several fundamental approaches for doing this. Each involves dividing up a resource and allocating a portion to each active channel.

The oldest multiple access technique divides up the frequency band to be shared into portions having a differing frequency and allocates a portion to each signal. The AM and FM broadcast bands use this technique to permit many radio stations to operate at once. This technique is known as Frequency Division Multiple Access (FDMA).

A second technique is to assign to each user the same frequency and allocate to each a different time to transmit. This is known as Time Division Multiple Access (TDMA). A conference call or a voice radio network are older examples of this approach. Digital techniques have refined this technique so that turns can be taken so quickly that it appears to each user that he has a full-time channel. The new digital GSM cellular standard is a modern application of TDMA.

The newest multiple access technique to come along is Code Division Multiple Access (CDMA), the technique Ellipso™ has chosen. Here each user is allocated the same band, in its entirety on a continuous basis. Each is assigned a unique spreading code for
spreading his signal to fill the band. The spreading code has a "processing gain" associated with it, which translates into an ability to recover the desired signal in an environment of strong interference. The greater the processing gain, the greater the permissible interference. Since each user's signal accounts for a portion of the total interference present, CDMA can be described as a means for dividing up a total permissible interference budget among simultaneous users.

How CDMA Works. The signal spreading process, using a high speed digital pattern known to both the transmitter and receiver, is the basis for CDMA. The transmitter spreads its signal using a code assigned to it by a code management function. The receiver multiplies everything received in the desired band (including the desired signal, noise, and other signals in the same band) by a synchronized copy of the spreading code used to spread the desired signal. This process has the very useful effect of causing only that signal that was spread with the same spreading code to collapse to the relatively narrow bandwidth it occupied before it was spread at the transmitter. This re-concentrates the signal's energy into its original narrow band.

But any signal at the receiver that was not originally spread by the same synchronized spreading sequence will be spread across the entire band by the same process that de-spreads the desired signal. This is true regardless of the nature of the interfering signal or noise. Consequently the signal energy from other signals in the band and from noise is made dilute in frequency, while the desired signal is concentrated (by a ratio equal to the ratio of the spreading code symbol rate to the de-spread signal symbol rate, which is the processing gain). Receivers can thereby pick out individual, weak signals that are otherwise lost under interference from a much stronger composite of many other signals and noise in the same band, when the receiver knows the appropriate spreading code, and when the code in use has adequate processing gain.

CDMA's Advantages. CDMA's characteristic of apportioning total aggregate interference confers a number of advantages that in turn translate into remarkable advantages in efficiency, robustness, and flexibility when compared to other techniques.

Frequency Re-use in Every Beam and Every Satellite. FDMA and TDMA signals are prone to catastrophic disruption by interference. Therefore FDMA or TDMA systems must ensure that no such interference occurs by 1) ensuring that no other systems or sources interfere significantly, and 2) ensuring that neighboring cells, beams, or satellites within the same system are isolated from each other by using different times or frequencies for them and commanding user terminals to switch frequencies or time slots when the cell or beam providing service changes. This switching requirement can cause brief disruptions or delays to service and complicates user terminal design.

CDMA systems, on the other hand, can accept interference. They are built to do so. The degrading effect of interference on system performance is more than
compensated for by dropping the requirement for isolating neighboring cells, beams, or satellites. Therefore CDMA permits reusing all available time and frequency resources in every beam and in every satellite. This in turn permits hand-offs from beam to beam and satellite to satellite, even potentially from satellite to terrestrial CDMA systems, that do not require any frequency or time adjustment at the user terminal (known as "soft hand-offs"). All hand-off processing can be handled solely at the Ground Control Station.

_path diversity._ Frequency reuse in every beam also permits a second very important performance advantage, that of path diversity. Every Ellipso™ satellite in view will receive the Ellipso™ subscriber's transmitted signal and relay it to the Ground Control Station. The Ground Control Station will combine all received signals to create a composite signal that is better than that from any single path. In this way, if the signal over one path fades due to shadowing or blockage, the Ground Control Station will automatically adjust by using the signal carried by another path. In this way the incidence and depth of fading is greatly reduced over that encountered in systems that do not use path diversity. This process also automatically compensates for any failures in individual satellites. Observations of signal strengths in the subscriber-to-Ground Control Station direction can be used in turn for selecting the best path for signals to the subscriber. TDMA or FDMA systems cannot use path diversity without complex switching techniques designed to keep interference at a minimum.

TDMA and FDMA system's inability to use path diversity forces such systems to use a brute-force technique for combating fading: ensuring that enough signal power will be available the one link that serves each subscriber to overcome most signal strength losses from fading and shadowing. This dramatically increases total satellite power requirements and consequent cost. It also causes difficulties in meeting regulatory limits.

Soft Capacity Limit. CDMA systems have a "soft" capacity limit that automatically adapts to changes in system characteristics. Specifically, the addition of a user above the nominal capacity limit degrades the signals of all user's sharing the spectrum slightly rather than degrading the signals of a few other's catastrophically. In a pinch (for example, to handle an unforeseen peaking of demand), a slight degradation in everyone's signal quality can be traded for more capacity, if desired.

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2For these reasons, for example, Iridium chose to use the Mobile Satellite Service uplink band for their downlinks, since Iridium's high downlink signal strength requirements exceeded international limits in the Mobile Satellite Service downlink band, and since the uplink band has no downlink limits (downlink service in the MSS uplink band is permissible on a secondary, non-interference basis). (ref: Motorola Inc, "Why the Iridium System Cannot Use the 2483.5 - 2500 Band for its Space-to-Earth Link", Feb 4, 1993, document IWG1-28, MSS above 1 GHz Negotiated Rulemaking Proceedings, United States Federal Communications Commission.)
In contrast, TDMA and FDMA systems have hard capacity limits. It is not possible to exceed the capacity limit as the attempt causes the complete loss of an equal number of existing user channels. Once all the frequency or time slots are occupied, capacity is exhausted.

**Easier, More Flexible Sharing Among Multiple Systems.** Rather than segmenting the MSS band and assigning a segment to each MSS system, as is normal practice, CDMA MSS systems can all share the same complete band by assigning a maximum interference budget to each. In fact, since thermal noise is an important contributor to total interference, CDMA systems actually lose less capacity by sharing the complete band with each other than by segmenting the band and assigning a segment to each to be used without sharing.

Full-band sharing also facilitates adjustment in the apportionment of band resources if the number of active systems changes (activation of a new system or withdrawal of an existing system). Instead, each system merely readjusts power commensurate with its new interference allocation.

In addition, full band interference sharing requires no wasted guard times or frequencies to ensure that no adverse bleedover of power from one system to another occurs.

**Additional Capacity by Voice Activation.** When a speaker on a voice circuit is listening, his terminal can power down to conserve power and reduce interference to others. This is called voice activation. This action automatically makes additional interference power available to other users. Since the only factor of importance in a CDMA system is the total interference, if the number of users is large, voice activation permits an increase in the total number of simultaneous users. Unlike TDMA systems, which sometimes also dynamically re-assign channels based on user pauses, CDMA systems do not require complex switching capabilities to implement voice activation.

**Resistance to Fading.** Spread signals have better resistance to multipath fading. Multipath reception (a situation where signals from the transmitter arrive at the receiver over more than one path due to signal reflections) causes frequency-selective fading of the received signal (that is, portions of the signal at different frequencies fades at different times). The broad bandwidth of the spread CDMA signal averages much of the frequency-selective fading, resulting in substantially reduced fading levels compared to more conventional narrowband signals, which are not generally wide-band enough to permit useful frequency averaging.

**Precise Relative Time Measurement.** The same spreading code that reduces the effect of multipath fading also gives the signal a much higher resolution in time. This high resolution enables more precise time of arrival measurements, which in turn translate into improved geolocation measurements. The Global Positioning System (GPS) uses spreading codes for this same purpose.
Privacy and Covertness.
CDMA signals also lend themselves to communications security and privacy. The presence or absence of a signal destined for a particular user in the midst of interference from many users is very difficult to detect without knowledge of that user's spreading sequence. Likewise, the range at which a user terminal's CDMA emissions can be detected is smaller than for other types of signals, since the user's signal power is spread so widely (i.e., diluted) in bandwidth. It would be a simple matter to use spreading sequences that are very resistant to defeat or decoding in order to enhance signal security.

Ellipso™ Ground Network Highlights

The Ellipso™ ground segment must successfully accomplish a number of functions in order to offer a coherent, durable, flexible, and broadly capable mobile telecommunications service to its subscribers. These functions include:

- Subscriber record keeping and verification and validation,
- Call connection through the Ellipso™ satellite path from the mobile Ellipso™ subscriber to the GCS,
- Selection and maintenance of the optimum mobile-satellite-ground path for the call,
- Configuration of the mobile-satellite-GCS path to yield optimum signal quality, coordination of call services and features,
- Interconnection of the call to the PSTN as necessary, proper signalling coordination with the PSTN,
- Geo-location of users, derivation, maintenance, and transfer of user location and status information around the network as needed,
- Ellipso™ transaction accounting at national, regional, and global levels,
- Creation and maintenance of an optimum network configuration for efficient Ellipso™ network operation,
- Efficient Ellipso™ resource allocation,
- Maintenance of Ellipso™ system health, and
- Ellipso™ system planning.

In the Ellipso™ System, these functions are distributed among several functional elements of the Ellipso™ ground segment. They include the Ground Control Stations (GCS), the National Network Control Centers (NNCC), Ellipso™ Switching Offices (ESO), the System Coordination Center (SCC), and Tracking, Telemetry, and Command Centers (TTCC).

A primary objective of the Ellipso™ System is to minimize development time and costs of the system. In order to do this Ellipso™ has chosen, insofar as possible, to use as much of the equipment, procedures, and interfaces of existing cellular systems as possible. Indeed, some service
providers may wish to integrate Ellipso™ and cellular facilities and actions as a cost effective and sensible approach to an overall telecommunications package for the consumer.

As a second objective, the Ellipso™ ground network will interoperate with modern switching and trunking facilities and with the CCITT and ANSI Signalling System 7. Ellipso™ is expected to support many of SS7’s advanced features.

The Ellipso™ ground system is designed to offer the same kinds of features subscribers seek in an advanced mobile system. These will include many of the CCITT Signalling System 7 features, such as call forwarding and caller identification. Ellipso™ will automatically support domestic and international subscriber roaming for incoming and outgoing calls, and call handoffs in order to optimize routing and minimize costs for the call.

The Ground Network Elements

These component elements of the Ellipso™ System operate together to enable the placement of a call through the Ellipso™ system between an Ellipso™ subscriber and any other caller, regardless of the callers connection or his location around the world.

The Ground Control Station acts as the ground to satellite interface point for the Ellipso™ ground network. It handles the actual connections to the satellite, including the functions of satellite acquisition, tracking, handoffs, signal modulation and multiplexing. The GCS is essentially a ground entry point for the system. Each GCS typically tracks and uses two satellites while acquiring a third. The GCS exchanges user traffic channels and signalling information with an Ellipso™ Switching Office and control and status information with the NNCC for the area. The GCS also determines the position of subscriber terminals using various techniques over the GCS-satellite-terminal path. The GCS interfaces to the Ellipso™ Switching Office and to the NNCC. Functionally it is analogous to a cellular system cell-site controller. Its interface to a Ellipso™ Switching Office will emulate that of a cell site controller as closely as feasible in order to simplify development and integration. Figures 5, 6, and 7 present block diagrams of the GCS.

The Ellipso™ Switching Office (figure 8) includes a fault-tolerant, redundant switch together with a data processing system and subscriber and network data bases for managing subscriber affiliation, call placement, and network connectivity. The ESOs handle all the real-time switching and routing functions for the Ellipso™ portion of the ground network. ESOs may be collocated with the GCS or with the NNCC, may be collocated with or may be physically a part of the Mobile Switching Center serving a cellular system within an area, or may be remotely sited to serve one or more GCSs, depending on network requirements. The ESO interfaces in turn to the local PSTN in much the same way a cellular Mobile Telephone Switching Office does and uses essentially the same interface standards and protocols. ESOs will accommodate X.25 and
SS7 network interfaces. ESOs will also interconnect with the Ellipso™ NNCC for the served region for control and status purposes and for transfers of call record and subscriber information. Each ESO will interconnect with other ESOs within the region served by the supervising NNCC. ESO interconnections will include dedicated signalling and traffic trunks for accommodating handoffs.

Each Ellipso™ market is controlled by a National Network Control Center (figure 9). The NNCC is the central network planning, management, and accounting facility for the market. It handles subscriber affiliation, record keeping, and validation, transaction accounting, roamer call routing, GCS management, satellite and network resource management for its market, time management, and system performance monitoring and maintenance. The NNCC interfaces to the market's GCSs and ESOs, as described earlier, and to the Ellipso™ SCC for transaction reporting, global roaming management, and system resource management.

The Ellipso™ System Coordination Center (figure 10) handles global level Ellipso™ functions. Overall Ellipso™ global system planning and allocation is handled here. The SCC is the central clearinghouse for Ellipso™ call transactions worldwide. It maintains a consolidated data base of all Ellipso™ subscribers and associated data, together with their present status and market location, and coordinates routing for internationally roaming subscribers. The SCC also manages worldwide Ellipso™ network management and system health and status. The SCC interfaces with the NNCCs for each of the Ellipso™ markets, and with the Ellipso™ TTCC for Ellipso™ satellite segment health, status, and management. Separate SCCs may be established for the Borealis and Concordia subconstellations.

The Ellipso™ Tracking, Telemetry, Command Center (figure 11) is the operational control center for the Ellipso™ satellites. At least two TTCCs will oversee the Ellipso™ satellites; each will be located where together they can see each satellite on every revolution. The TTCC oversees launch, orbital insertion, and satellite commissioning in conjunction with the satellite and launch providers. The TTCC continues to monitor and control the function and integrity of the satellites and their orbits and payloads. The TTCCs will also determine accurate satellite ephemeris information for use in geolocating subscriber terminals and managing satellite allocation and handoffs at the NNCC level.

Ellipso™ Ground Network Deployment

The deployment of Ellipso™ Ground network resources (GCSs, ESOs, and the NNCC) within a market will be very significantly affected by conditions in the market. Significant factors include population and population distribution, demand for Ellipso™ services, the availability, nature, and economics of the existing telecommunications infrastructure, the geographic location of the market, and the Ellipso™ subconstellations used for service.
The Ellipso™ satellites operate at medium earth orbit (MEO) altitudes. As a consequence, each satellite is capable of seeing a much larger area than low earth orbiting (LEO) satellites can see. This significantly reduces the number of ground entry stations the Ellipso™ System requires in order to maintain good joint visibility statistics between the subscriber and the ground entry station, in comparison to a LEO system (conceivably, if territorial interests and the availability and cost of trunking were not factors, Ellipso™ could operate well with only fourteen Ground Entry Stations strategically located around the world). LEO systems must either use a larger number of more closely spaced ground entry stations, more ground entry station handoffs, or intersatellite links in order to prevent poor service (satellite having difficulty seeing both the user and the ground entry station).

As with other satellite systems, Ellipso's requirement for the number and location of GCSs is first and most importantly determined by common visibility requirements from the satellite to both the subscriber and the GCS. In many areas of the world, geographically small markets (less than 1,000 kilometers in extent) with undemanding network requirements may be adequately served by a single Ellipso™ GCS, ESO, and NNCC. A second may be desirable for redundancy purposes. Markets having significant geographic extent like the United States, Canada, Australia, Indonesia, China, and so on will require more than one GCS in order to ensure adequate satellite joint visibility statistics. Generally, GCSs should be located near the extremes of travel of the satellite sub-points as the satellites travel over the market area, with additional intermediate GCS locations if the market extent warrants it. For example, in an area the size of the United States, two GCS locations would satisfy joint visibility requirements for Borealis.

As a market grows, the local Ellipso operator may wish to install more GCSs in order to provide better service at lower cost. For example, siting GCSs near important centers of population may offer favorable trunking economies for completing calls to ground telephone users.

Figure 5 illustrates the interconnections and hierarchy of the various Ellipso™ Ground Network elements.
The United States Negotiated Rule-Making Process for Mobile Satellite Systems

Six companies have applied to the United States Federal Communications Commission (FCC) for licenses to build, launch, and operate a Mobile Satellite System. These include Ellipsat Corporation, Loral-Qualcomm Space Systems, TRW, Constellation, Motorola, and American Mobile Satellite Consortium. The first four companies named proposed systems using CDMA techniques of various kinds. Motorola has proposed a system using time division multiple access (TDMA) and time division duplex (TDD) using the uplink L-band for both uplink and downlink. And AMSC proposed extending its frequency division multiple access system into the MSS bands in order to obtain more capacity.

The FCC wishes to license all applicants in order to ensure a competitive business environment, and seeks to license the applicants as quickly as possible. In order to facilitate this, the FCC established an advisory committee of representatives from each company and from other affected organizations to seek a consensus solution for sharing the MSS bands among the applicants and with other services in the bands, such as Radio Astronomy and GLONASS. This committee completed its work on April 6, 1993.

As a result of negotiations in this committee, all applicants but

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3These applicants included American Mobile Satellite Consortium, Celsat (a declared future applicant), Constellation, Ellipsat, Loral/Qualcomm, and TRW.
Motorola recommended in a report to the committee that all licensees share the entire MSS band by permitting each licensee to use the entire band and allocating to each CDMA system an equitable contribution to the total power spectral density on the ground from the satellite and from users to the satellites. In contrast, Motorola representatives have stated they require a distinct portion of the L-band uniquely for the Iridium system, since the Iridium design cannot tolerate inter-system interference, as can the CDMA systems. Motorola submitted its own recommendation to the FCC to segment the MSS bands among competing multiple access approaches.

In the next few months the FCC will, considering the recommendations of the committee, determine the approach it will designate for best accommodating the interests of the various applicants for license and the interests of the United States and the international community.

Ellipso™ is presently evaluating the impact of the likely national and international sharing rules for permitting multiple systems to provide mobile satellite service. It is possible that these sharing rules could change some aspects of Ellipso™ system design. All applicants have already indicated they will be changing their systems to conform to the final sharing rules.

**Status and Summary**

In summary, Ellipso™ is designed to succeed with a minimum required system financial investment and low cost to the user. It is structured so that it can begin earning revenues early in its deployment phase. Ellipso™ will offer an unprecedented degree of deployment flexibility and is able to tailor its geographic coverage in response to demand and investment. Ellipso™ uses innovative technical features in seeking optimum system efficiency. These features include efficient elliptical orbits for better satellite utilization, and CDMA for maximum spectrum efficiency. Ellipso™ provides an attractive service to the user, one having a low per-minute cost and non-disruptive seamless service transitions and link hand-offs. And Ellipso™'s system characteristics permit adjustment to suit technical and market conditions in each of the regions it serves.

Ellipso™ represents the optimum business and technical approach to introducing new mobile satellite services to users throughout the world. The Ellipso™ project is proceeding rapidly to detailed system engineering and construction.