DEVELOPMENTS IN SATELLITE COMMUNICATION SYSTEMS
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1. INTRODUCTION

Mobile satellite systems (MSS) may be classified according to orbit altitude as follows:

- GEO - geostationary earth orbit, approx altitude: 35 000 km
- MEO - mid-altitude earth orbit, approx altitude: 10 000 km
- LEO - low earth orbit, approx altitude: <1 000 km

LEOs can be further sub-divided into Big LEO and Little LEO categories. Big LEOs will offer voice, fax, telex, paging and data capability, whereas little LEOs will offer data capability only, either on a real-time direct readout ('bent pipe') basis, or as a store-and-forward service.

Since the satellite footprint decreases in size as the orbit gets lower, LEO and MEO systems require larger constellations than GEO satellites in order to achieve global coverage and avoid data delays. Less energy is, however, generally required for LEO and MEO satellite communication because of the shorter average distance between transmitter and satellite. Some systems implement several high-gain antennas to generate ‘spot beams’ and so reduce the requirement of the mobile to have a complex antenna and/or high output power. A key feature of several MSS currently under development will be their inter-operability with existing public switched telephone and cellular networks, using a dual-mode handset, for example.

Because of the commercial forces which are driving the implementation of the new systems, many will primarily focus on land masses and centres of population, and will not offer truly global or polar coverage. These systems will not in general be acceptable for global ocean monitoring. Furthermore, while the technical capabilities for the new MSS do currently exist, delays are inevitable due to problems with spectrum allocation, licensing (in each country where the service will be offered), company financing, and availability of launch vehicles and ground stations.

It is unlikely that all of the planned systems will overcome all of these hurdles. Indeed, major financial difficulties have hit a number of systems, with Starsys having been cancelled, Iridium having collapsed (and been relaunched), and both Orbcomm and New ICO having been in and out of Chapter 11 bankruptcy protection in the US. Mergers are becoming increasingly common, as market reality forces system planners to cut their losses and pool resources: CCI, Teledesic, Ellipso and New ICO have all recently signed buy-out or collaboration agreements with cellphone entrepreneur Craig McCaw.

From a technical point of view, some systems do offer significantly enhanced capabilities compared with existing methods. Potential advantages include two-way communication, more timely observations, and greater data rates and volumes. Some systems may also prove to be considerably less expensive than existing channels, although this is as yet unclear. However, dangers will exist for data buoy users of most MSS, in that they will generally be small minority users of the system, with consequent lack of influence in regard to pricing. The arrangements for data distribution are also unlikely to be tailored towards data buoy applications, in particular those that require data insertion on the GTS.

2. DESCRIPTION OF CANDIDATE SATELLITE SYSTEMS

The following paragraphs describe the salient features of those systems that might have a data buoy application. In many cases systems are at an early planning stage, and reliable technical information on which to base an evaluation is unavailable. This section is summarised in tabular form in at the end of the document.

2.1 Little LEOs

2.1.1 Argos

Argos has been used by the oceanographic community for more than two decades, and is a dependable, true polar, operational data collection and platform location system. Communication is one-way only, at 400 baud, with practicable data rates of the order of 1 kbyte per day. Transmissions by the mobile are unacknowledged by the system and therefore have to incorporate some form of redundancy if data transfer is to be assured. The system enjoys a particularly clean part of the spectrum (401.65 MHz), with minimal interference from other users. Traditionally, Argos has flown as an attached payload on the NOAA ‘TIROS’ weather satellites, but future launches will also use the Japanese ADEOS and European METOPS platforms

Enhancements to the Argos on board equipment (‘Argos-2’) include increased receiver bandwidth and sensitivity, with two-way communication (‘downlink messaging’) to be piloted aboard ADEOS-II in 2002. Next generation Argos equipment (‘Argos 3’) will fly from 2004 onwards, and will offer order of magnitude increases in data rates, as well as two-way communications. The system is one of the few that offers true global coverage, and currently has no commercial requirement to recover the cost of the launch or space segment equipment. Proposed changes to the rules within the US regarding fair competition by fully commercial satellite systems may impact the service that Argos will ultimately be able to offer.

The first of the Argos-2 satellites, NOAA-K (NOAA-15) was launched in May 1998 and is now operational, replacing NOAA-D (NOAA-12) as the morning satellite. This was followed in September 2000 by NOAA-L (NOAA-16). The launch of NOAA-M (NOAA-17) is scheduled for March 2002. Several new direct readout stations have been commissioned recently, including Murmansk, Petropavlosk, Halifax, Edmonton, Monterey, Réunion, Cape Town, Lima, Tokyo, Largo, Cayenne, Hawaii and Toulouse. This continues the programme of improving data timeliness by exploiting use of Argos in 'bent-pipe' mode. Further enhancements to the on board equipment (Argos-3), to the ground processing centres and software are at the planning stage.

2.1.2 Orbcomm

This company was awarded the first FCC Little-LEO licence in late 1994. Satellites consist of discs about one metre in diameter prior to deployment of solar panels and antenna. Two satellites were launched into polar orbit during 1995, using a Pegasus rocket piggy-backed on to a Lockheed L-1011 aircraft. After a prolonged period of launcher problems, 35 satellites are now in orbit, making up the complete constellation – although Orbcomm have been awarded a licence for an expansion to a 48 satellite constellation. Of these satellites, 30 are currently operational. The A, B, C and D planes are at 45° inclination and therefore have poor coverage at high latitudes: only two satellites, in the F and G planes (70°), offer a near-polar service. No further launches have been announced.

The system offers both bent-pipe and store-and-forward two-way messaging capabilities, operating in the VHF (138-148 MHz) band. User terminals are known as ‘Subscriber Communicators’ (SCs). Although there have been significant problems with interference close to urban areas, this is not expected to impact offshore operations, and trials of the system have been encouraging. Operational experience of the system is growing rapidly, although it remains difficult to obtain detailed technical information from Orbcomm.

The message structure currently consists of packets transmitted at 2400 bps (scheduled to rise to 4800 bps), and coverage is now global and near-continuous between the polar circles. Messages are acknowledged by the system when correctly received and delivered to a user-nominated mailbox. The platform position is determined, if required, using propagation delay data and doppler shift, or by an on-board GPS receiver. Position accuracy without GPS is similar to that offered by Argos, i.e. km-scale.

The limitations on the store-and-forward mode messages (known as globalgrams) have become apparent, with SC originated messages limited to 229 bytes and SC terminated messages limited to 182 bytes. Each SC can theoretically have a maximum of 16 globalgrams stored on each satellite. Currently, satellites will not accept or process globalgrams when in view of a ground ('gateway') station. As messages have to be designated as globalgrams or bent-pipe by the SC at the moment of origination, this presently limits the flexibility of the system to adapt to different coverage situations. Work-arounds do, however, exist, and it is expected that the next generation of SCs will be able to adapt more readily to changes in satellite communications mode.

Authorised transceiver manufacturers include Panasonic, Elisra (Stellar), Torrey Science, Magellan and Scientific Atlanta. Elisra were the first to offer a transceiver with a fully integrated GPS engine, although Panasonic now also have one available. Scientific Atlanta have made a chip-set available to third-party integrators. Prices of most units are between $600 - $1000.

The ground segment has started to expand, and there are now active stations in Italy, Argentina, Brazil, Japan and Korea in addition to the four in the US. However the Japanese and Korean stations are not available for international registrations. Further stations are under construction in Malaysia, Morocco, and Brazil, and potential sites have been identified in Russia, Ukraine, Philippines, Botswana, Australia and Oman. 16 international service distribution partners have been licensed. Non-US customers have faced considerable difficulties because of the absence of ground stations, lack of spectrum licensing and the presence of other in-band users. However the situation is improving rapidly. Currently subscription costs within Europe are on a fixed cost per unit with two bands of usage (above and below 4kbytes per month with a typical monthly rate for the higher band being $70). A fully metered billing system based on users' actual data throughput was to be implemented in July 2000 but was postponed, officially due to technical problems. If this billing system is implemented with the planned charges ($6/kbyte) then it will result in a massive increase in airtime costs for any user with data rates over 0.5 kbytes/day. Metered billing is apparently implemented outside Europe.

Orbcomm have been suffering financial difficulties, and filed for 'Chapter 11' bankruptcy protection in September 2000. The outstanding debts are believed to stem largely from the system rollout phase, with net running costs being of much smaller concern. Industry opinion is that Orbcomm will prevail, largely because of the commitment of many third-party equipment and system manufacturers to the success of the system, and evidence of increasing service take-up by a diverse range of customers.

2.1.3 Starsys

This system was to have been broadly similar to Orbcomm, except that it offered bent pipe mode only, thus limiting its usefulness to coastal areas. Further work on the system, in which the operators of the Argos system were closely involved, has been suspended because of difficulties in securing financial backing. The FCC licence was returned in late 1997.

2.1.4 Iris/LLMS

This European-led system appears to be similar to Argos, using two polar-orbiting satellites with store-and-forward capability. However, terminals are alerted by the satellite downlink signal, and two-way communications and message acknowledgement are supported. Location is by doppler and ranging, and message lengths of up to a few kilobytes are permitted. Some provision is planned for terminal-terminal communication within the satellite footprint. A single satellite was in orbit for system tests, but nothing further has been heard, and the parent company's website (www.saitrh.com) no longer makes any mention of the system.

2.1.5 Vitasat/Gemnet

This was a 36 + 2 satellite constellation proposed by CTA Commercial systems. Their experimental satellite was the failed Vitasat launch in 1995. CTA is reported to have been taken over by Orbital Science Corporation, the parent organisation of Orbcomm, and the 36-satellite Gemnet component has been cancelled. However, the volunteer VITA organisation still exists and currently has one satellite in orbit, with plans to rent bandwidth on two other existing satellites, HealthSat-2 and UoSat-12. This proposal received FCC clearance in December 2000, and the company have now brought HealthSat-2 on line. The main mission is to offer low-cost messaging services to developing countries.

2.1.6 Faisat

The Final Analysis company have planned this 32 (+ 6 spare) satellite constellation to provide data messaging services, principally aimed at small messages (~ 100 bytes), but with support for larger messages as well. It will operate in both bent-pipe and store-and-forward modes. The first satellite launch, on the Russian Cosmos vehicle, was scheduled for early 2000, but nothing has been reported. Further launches are expected to occur roughly twice a year. The system received FCC authorisation in April 1998. A test satellite (also part of the Vitasat system) was launched in 1997.

2.1.7 Leo One

This US-designed system consists of a planned 48 satellite constellation offering store-and-forward two-way messaging at up to 9600 bps. An FCC license was granted in February 1998, and a spectrum sharing agreement signed with the operators of the Russian maritime satellite system, TSYKADA. Commercial operation is expected to start in 2003, although no details are known regarding the launch schedule. Orbit inclination will be 50°, giving useful coverage up to latitudes of about 65°.

2.1.8 Gonets

Two GONETS LEO messaging systems have been proposed by the former Soviet Union, using both UHF and L/S-band communications channels. Both will offer true global coverage from high inclination 1400 km orbits. One system, GONETS-D already has 8 satellites in orbit with a further 36 planned. No operational experience has been reported to date.

2.1.9 Other Systems

Six E-Sat satellites are planned. Launches were to have started in 2001, but nothing has so far been announced. The system is aimed principally at the US utility industry for remote metering. The Italian based Temisat is another planned system which is intended to offer global coverage. Little further has been heard of the European SAFIR store-and-forward messaging system, which has two satellites in orbit, but has yet to relaunch a service after major technical problems with its first satellite.

2.2 Big and Broadband LEOs

2.2.1 Iridium

Iridium filed for Chapter 11 bankruptcy protection in August 1999, and underwent financial restructuring. Financial difficulties continued and the system ceased operation in April 2000. At that time, Iridium had its complete constellation of 66 satellites plus spares in orbit, and offered a true global service through a network of ground stations backed up by inter-satellite links. The system has since been rescued from planned de-orbiting and resurrected by the US Department of Defense. A commercial service has also been relaunched. Of particular interest to data buoy operators in the early days of Iridium was the Motorola L-band transceiver module, which was designed to be easily integrated with sensor electronics via a standard serial interface, but this product is not now likely to appear. Most Iridium phones are, however, data capable and will interface with a standard modem. Throughput is claimed to be 2400bps. The component parts of some older phones are now being repackaged as stand-alone modems to allow connection to a dedicated data service at the DoD secure gateway in Hawaii. This service will be available to subscribers from the US, Canada, Australia and the UK. Subscribers from other countries may be admitted at a later date. A short message service (1500 bytes max per message) is also to be introduced through this gateway, as well as a dropout-tolerant direct Internet connection at up to 10kbps.

2.2.2 Teledesic

This ‘Internet in the Sky’ system plans a 288 (originally 840) LEO constellation to carry global broadband services such as video conferencing, the Internet, etc. It recently merged with Celestri, another proposed broadband LEO system. Since then there has been some doubt over the actual makeup of the combined constellation. Teledesic has suffered because of the financial difficulties of Iridium, as Motorola, one of Teledesic’s primary investors and head of the industrial partnership developing the system, transferred engineering effort and funding to prop up Iridium. Teledesic has received FCC licensing for operations in the USA. Teledesic, which has now joined forces with Craig McCaw’s New ICO, recently announced that it is ‘nearly ready’ to name its prime contractor for system build.

2.2.3 Globalstar

Globalstar was Iridium’s main competitor in the mobile satellite telephony market. After a bad start in September 1998 when 12 satellites were lost in a single launch failure, Globalstar now has its complete 48 satellite constellation in space, and commenced a limited commercial service in the US in October 1999. Service has since been expanding to other regions and was available in the UK in mid 2000. Globalstar differs significantly from Iridium in that for a call to be made the user must be in the same satellite footprint as a gateway station. There is no inter-satellite relay capability as in Iridium. This means that coverage will not be truly global, especially in the short term as far fewer gateways have been built than originally planned. Although Globalstar was currently in a much stronger financial position than any of its competitors, only 55,000 subscribers have been signed and the company laid off half of its work force in August 2001.

Data services at 9600 bps are planned to be commercially available sometime in the near future. As with Iridium this is likely to be very dependent on the initial success of the basic voice service. Globalstar also has a second generation system planned, said to involve 64 LEO satellites and 4 GEO satellites. Little else is known about the planned enhancements of this system.

2.2.4 Other Systems

Other planned big LEOs include Ecco (by the owners of Orbcomm), Ellipso (a hybrid elliptical LEO/MEO system, now merged with Teledesic and New ICO), LEO SAT Courier (a German led system which was originally a much smaller little LEO system), Signal and SkyBridge.

2.3 MEOs

2.3.1 New ICO

New ICO (formerly ICO Global Communications) is the third of the three main players in the global satellite telephony market. However it also has suffered severe financial difficulties and filed for Chapter 11 bankruptcy protection in August 1999, just two weeks after Iridium. The system, formerly known as Inmarsat-P but now fully autonomous, will use a constellation of 12 MEO satellites backed by a 12-station ground segment to provide a truly global voice, fax, data and messaging service. The aim is to complement and be inter-operable with existing digital cellular telephone networks. Prior to filing for bankruptcy protection, the first launch was planned for late 1999 with commercial service roll out scheduled for the third quarter of 2000. The company emerged from Chapter 11 protection in May 2000, and the first satellite was launched in June 2001, with service scheduled to start in 2003.

When the complete constellation is in service two satellites will always be visible from any point on the earth's surface. The space segment is being built by Boeing Satellite Systems. Data rate will be 9600 bps. Many large manufacturers are engaged in developing dual mode ICO/cellphone handsets. An ICO ‘engine’, is to be defined for the benefit of third-party equipment manufacturers (OEMs).

New ICO have joined forces with Teledesic (both owned by ICO-Teledesic Global), with major revisions to the scope of both systems. In particular New ICO is now putting a far greater emphasis on data services, rather than voice services which are now widely recognised as holding smaller potential.

2.3.2 West

Little is known about this system, being designed by Matra Marconi Space, except that 9 MEO and GEO satellites were planned, with multimedia-like services scheduled to begin in Europe via West early Bird in 2003. A follow-on vehicle supporting a fully fledged ATM switch is planned for 2004.

2.4 GEOS

2.4.1 Inmarsat D+.

This is an extension of the Inmarsat D service using the new (spot-beam) Inmarsat Phase 3 satellites and small, low-power user terminals. The system was initially designed as a global pager or data broadcast service, with the return path from the mobile used only as an acknowledgement. D+ permits greater flexibility, but the uplink packets are still limited to 128 bits. The first ground station has been implemented in the Netherlands by the existing Inmarsat service provider (Station 12), but useful technical information has been difficult to obtain.

D+ transceiver manufacturers include JRC, Calian, STK-Atlas and Skywave. The JRC unit features an integral GPS receiver and combined GPS/Inmarsat antenna, and is the first to receive type approval. The Skywave unit includes an integral antenna and is specifically designed for low power applications.

The service may prove particularly attractive to national meteorological services as protocols already exist with Inmarsat service providers for the free transmission of observational data to meteorological centres for quality control and insertion on to the GTS. Inmarsat, given its assured multinational backing and established infrastructure, is also extremely unlikely to disappear.

2.4.2 ODL

Oceanographic DataLink (ODL)[3] is a US Office of Naval Research sponsored demonstrator system that uses Intelsat C-band transponders to communicate with small oceanographic packages at rates of up to 10 kbps. New signal processing techniques allow such transponders to be used in low energy applications. Both antenna and transceiver size are small (the complete package is expected to be video cassette size), and data costs are expected to be low. Successful bench trials have been completed, and the results of field evaluations are now awaited with interest, but no information has been forthcoming.

2.4.3 Thuraya

This advanced GEO offers voice-band communications with compact cellphone-sized handsets by using steerable spot beams to achieve sufficient link margin. Data services are available using a modem connection on the handset. Coverage is not advertised for oceanic areas, but may be available on request.

3. REFERENCES

1. Hanlon, J (1996). Emerging LEOs telemetry options for use in scientific data buoys - a marine instrument manufacturer's perspective. In: *Proceedings of the DBCP Technical Workshop, Henley on Thames, October 1996*. DBCP Technical Document No 10, WMO, Geneva.

2. Hoang, N (1999). Data relay systems for drifting buoys utilizing low-earth orbit satellites. In: *Proceedings of the DBCP Technical Workshop, Hawk's Cay, October 1998*. DBCP Technical Document No 14, WMO, Geneva.

3. Gamache, K A and Fogel, P E (2000). Oceanographic DataLink. *Sea Technology*, May 2000, pp 23-31.

Many interesting articles and status reports may be found in: *International Space Industry Report*, Launchspace Publications, Washington (see below).

4. USEFUL WEB SITES

4.1 General information

Little LEO status, launch dates	*http://www.ee.surrey.ac.uk/SSC/SSHP/const_list.html*
Constellation overview	*http://www.ee.surrey.ac.uk/Personal/L.Wood/constellations/*
The Satellite Encyclopaedia	*http://www.tbs-satellite.com/tse/online/*
General satellite news/gossip	*http://www.hearsat.org/*
Satellite news	*http://www.spacedaily.com/*
General space news	*http://www.space.com/spacenews/*

4.2 Specific operators

Argos	*http://www.cls.fr/*
	http://www.argosinc.com/
Ellipso	*http://www.ellipso.com/*
E-SAT	*http://www.dbsindustries.com/*
Final Analysis	*http://www.finalanalysis.com/*
Globalstar	*http://www.globalstar.com/*
GOES	*http://www.goes.noaa.gov/*
Inmarsat	*http://www.inmarsat.org/*
Iridium	*http://www.iridium.com/*
LEO One	*http://www.leoone.com/*
LEO SAT Courier	*http://www.satcon-de.com/*
METEOSAT	*http://www.esoc.esa.de/external/mso/meteosat.html*
New ICO	*http://www.ico.com/*
Orbcomm	*http://www.orbcomm.com/*
Ocean DataLink (ODL)	*http://www.viasat.com/government/globalcontrol/index.htm*
SAFIR	*http://www.fuchs-gruppe.com/ohb-system/*
Skybridge	*http://www.skybridgesatellite.com*
Teledesic	*http://www.teledesic.com/*
Thuraya	*http://www.thuraya.com/*
VITA	*http://www.vita.org/*
West	*http://www.matra-marconi-space.com/*

Overview of mobile satellite systems with possible data buoy applications

System	Status[*]	Date (if known)	Orbit type	Buoy position	Message type	Terminal size	Power (watts)	Comments
ARGOS	Operational		Little LEO	Doppler Shift	data: 32 bytes	Handheld	1	Various enhancements, incl 2-way messaging, are scheduled
ECCO (CCI Global)	Planned	2003+	LEO	GPS Required	voice/data	Handheld	TBD	12 equatorial satellites planned by 2003. Status questionable – merged withICO-Teledesic Global
ELLIPSO	Licensed	Service 2003+	Big LEO	GPS required	voice/data	Handheld	TBD	17 satellites in highly elliptical orbits, serving major land masses. Status questionable – merged withICO-Teledesic Global
EYESAT	Experimental		Little LEO	GPS Required	data: 60 bytes	Handheld	5	1 satellite 1995, principally for radio amateurs
E-SAT	Licensed	Launch 2001+	Little LEO	GPS Required	data: TBD	TBD		6 satellites for utility metering (aimed at Continental US only initially)
FAISAT	Licensed	Service 2002+	Little LEO	GPS Required	data: 128 bytes	Handheld	10	38 satellites 2000+ Test satellite launched 1997
GEMNET	Cancelled (pre-op)		Little LEO	GPS Required	data: no maximum	'laptop'	10	1st satellite 1995 - launch failure 36 satellites by ???
Globalstar	Operational	1999	Big LEO	GPS Required	voice/data: no maximum	Handheld	1	48 satellites + spares (constellation complete) Limited coverage due to lack of ground stations. Financial difficulties.
GOES, Meteosat, GMS	Operational		GEO	GPS required	data: various options	'laptop'	10	4 satellites; directional antenna desirable NOAA / ESA / Japanese met satellites.
GONETS-D	Pre-operational		Little LEO	GPS/ Glonass	Data	Handheld	TBD	8 satellites in orbit, 36 more planned
GONETS-R	Planned		Little LEO	GPS/ Glonass	Data	Handheld	TBD	48 satellites planned

INMARSAT-C	Operational		GEO	GPS required	data: no maximum	5.5 kg	15	Steered antenna not required
INMARSAT-D+	Operational		GEO	GPS required	data: 128bytes uplink, 8 bytes downlink	Handheld	1	Global pager using existing Inmarsat-3 satellites Note very oriented to downlink
ICO (New ICO)	Licensed	Service 2003	MEO	GPS required	voice/data: no maximum	Handheld	1	Global voice and packet data services. Recently merged with Teledesic to form ICO Teledesic Global. 12 satellites planned – 1 launched
Iridium	Revived	Service resumed 2001	Big LEO	GPS preferred	voice/data: no maximum	Handheld	1	72 satellites in orbit
IRIS/LLMS	Experimental		Little LEO	Doppler + Ranging	data: up to few kbytes	Handheld	1	1 satellite in orbit. Belgian messaging system part of an ESA research prog.
LEO One	Licensed	Service mid 2003	Little LEO	GPS Required	data uplink 9600bps, downlink 24000bps	Handheld	Max 7	48 satellite constellation, store and forward + 8 spares. No polar sats
LEO SAT Courier	Planned	Service 2003+	Big LEO	GPS required	Data / voice	Handheld	1-5	72 satellites
OCEAN-NET	Experimental		GEO	Moored	no maximum	Large		uses moored buoys + Intelsat
Ocean DataLink (ODL)	Experimental		GEO	GPS	no maximum	Handheld	TBD	uses Intelsat
Odyssey	Cancelled (pre-op)		MEO	GPS required	voice/data: no maximum	Handheld	1	12 satellites were planned
Orbcomm	Operational	1998	Little LEO	Doppler or GPS	data: no maximum	Handheld	5	35 satellites in orbit, 30 operational, expansion to 48 sats licensed
SAFIR	Pre-operational		Little LEO	Doppler or GPS	data: no maximum	"laptop"	5	2 satellites in orbit

Signal	Planned		Big LEO		voice/data			48 satellites planned
SkyBridge	Licensed	Service 2002+	Big LEO	GPS Required	Broadband	Larger than handheld		80 satellites planned. Re-utilising GEO spectrum allocations
Starsys	Cancelled (pre-op)		Little LEO	Doppler + Ranging	data: 27 bytes multiple msgs	Handheld	2	12 satellites 1998+ 24 satellites 2000+
Teledesic	Licensed	Service Late 2004	Big LEO	GPS required	Broadband			288 satellites planned FCC licence granted Merged with new ICO
Temisat	Experimental		Little LEO		Data			7 satellites planned for environmental data relay. 1 satellite launched 1993.
Thuraya	Operational		GEO	Integral GPS	Voice/data			1 multiple spot beam satellite in orbit (over Middle East), 1 planned
Vitasat	Pre-operational		Little LEO	GPS Required	Data			2 satellites in orbit, 2 more planned
WEST	Planned	Service 2003+	MEO	GPS Required	Broadband			9 satellites planned

* Status of systems is categorised into one of six groups:

Planned: Little is known about the system except a name, notional type, and services to be offered. Mostly not licensed, although some may be.

Licensed: System has been licensed by a national or international regulatory agency (in most cases the FCC), but no satellites have been launched.

Experimental: System has one or more satellites in orbit for experimental purposes (not usually part of the final constellation). Includes new systems planning to use existing satellites.

Pre-operational: System is in process of launching, or has launched, its constellation but is not yet offering full services. Some limited evaluation service may be available.

Operational: System has full or nearly full constellation in place and is offering readily available service to external users (not necessarily commercial).

Cancelled: System has been cancelled, either before satellites launched (pre-op) or after (post-op).