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REVIEW OF SATELLITE DATA TELECOMMUNICATION FACILITIES

(Submitted by David Meldrum, DBCP Chairperson)

Summary and purpose of the document

This document provides an overview of the current status of mobile satellite systems relevant to SOT operations and data collection activities.

ACTION PROPOSED

The Team will review the information contained in this report, and comment and make decisions or recommendations regarding the evaluation and use of mobile satellite systems for SOT applications.

Appendices: A. Review of other satellite data telecommunication systems

- A - DRAFT TEXT FOR INCLUSION IN THE FINAL REPORT

I-5.2.5 Review of commercial satellite systems

I-5.2.5.1 David Meldrum, chairperson of the Data Buoy Cooperation Panel (DBCP) presented an overview of the current status of mobile satellite systems relevant to SOT operations and data collection activities. The review included description of candidate satellite systems sorted out by (i) geostationary earth orbit (GEO) satellites such as Inmarsat D+, Inmarsat Broadband Global Area Network (BGAN), Data Collection Platforms (DBCP e.g. GEOS, METEOSAT), and Inmarsat Mini-M, Inmarsat C & Mini-C, (ii) mid-altitude earth orbit (MEO) satellites such as New ICO, and (iii) low earth orbit (LEO) satellites such as Argos, Orbcomm, Iridium, and Globalstar.

I-5.2.5.2 Mr Meldrum also provided a comparison of message-based systems outlining characteristics such as message size, airtime cost, monthly price, terminal power consumption, availability of two-way communication, polar coverage beyond the reach of geostationary satellites, data rate, time to send one message, and delivery time.

Appendices: 1

APPENDIX A

REVIEW OF OTHER SATELLITE DATA TELECOMMUNICATION SYSTEMS

1. INTRODUCTION and BACKGROUND

1.1 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

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

1.3 Since both satellite footprint and orbital period 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 (e.g. Iridium, Inmarsat) 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. Another trend is towards much smaller cheaper satellites.

1.4 Because of the commercial forces, which are driving the implementation of the new systems, many will primarily focus on landmasses 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.

1.5 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, Iridium having collapsed (and been re-launched), and Orbcomm, Globalstar 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.

1.6 From a technical point of view, some systems do offer significantly enhanced capabilities compared to 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. However, dangers will exist for marine users of most MSS, in that they will generally be small minority users of the system, with consequent lack of influence concerning 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

2.1 Little LEOs

2.1.1 Argos

2.1.1.1 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. Traditionally, communication is one-way only, at 400 baud, with practicable data rates in the order of one Kbyte per day. Transmissions by the mobile in this mode are unacknowledged by the system and therefore have to incorporate 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. Until now, Argos has flown as an attached payload on the NOAA 'TIROS' weather satellites, but also flew on board the short-lived Japanese ADEOS-II vehicle. Projected launches on board the European METOP and future US NPOESS platforms mark an important diversification of service provision.

2.1.1.2 Current enhancements to the Argos on board equipment ('Argos-2') include increased receiver bandwidth and sensitivity, allowing low power transmitter frequencies to be segregated from higher power transmissions. Next generation Argos equipment ('Argos 3') will fly on the three MetOp satellites, with MetOp-1 already launched. Its Argos-3 equipment is now available for evaluation. Future launches are planned for 2010 and 2014. Argos-3 features two-way communication with Platform Messaging Transceivers (PMTs), and offers uplink data rates of up to 4.8 Kbits/ s. The downlink feature allows the Argos-3 instrument to send an acknowledgement signal to the PMT once the data are received error-free, thus permitting the PMT to avoid unnecessary repetition of the same message. Platform remote control and programming is also possible as users have the opportunity to send short messages (up to 128 bits) to their platforms via the Downlink Message Management Centre (DMMC).

2.1.1.3 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. The first of the Argos-2 satellites was launched in May 1998, and has been followed in September 2000 by NOAA-L (NOAA-16), NOAA-M (NOAA17) in June 2002, and NOAA-N (NOAA-18) in May 2005. NOAA-N' followed in February 2009. The current operational constellation consists of NOAA-17 and NOAA-18, although data from up to three other satellites continues to be collected. New direct readout stations continue to be commissioned bringing the current total to more than 50. This continues the programme of improving data timeliness by exploiting use of Argos in 'bent-pipe' mode.

2.1.1.4 Planning is now underway for 'Argos-4' and the operators are anxious to engage in immediate debate with potential users to ensure that their wishes are fully considered.

2.1.2 Orbcomm

2.1.2.1 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 piggybacked 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, and these have proved to be unreliable. In Mar 2005, the company announced a new launch programme that would carry an Automatic Identification System (AIS) payload, transmitting ship identification and position for use by the US Coast Guard. In July 2006, Orbcomm ordered six satellites from OHB System AG. The satellite buses and launch procedures are to be handled by Omsk, Russia, with Orbital Sciences Corporation (OSC) providing the communication payloads and AIS processing.

2.1.2.2 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). Early results with the system were quite encouraging, although data buoy implementations seem to have decreased in favour of increased usage of Iridium for higher bandwidth applications.

2.1.2.3 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.

2.1.2.4 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 however, do exist, and it is expected that the next generation of SCs will be able to adapt more readily to changes in satellite communications mode.

2.1.2.5 Authorised transceiver manufacturers include Elisra (Stellar), Quake and MobiApps. All manufacturers offer units with integral GPS. Quake sells a fully integrated unit, which features a built-in antenna as well as GPS. Prices of most units are falling, with models now available for around \$500 and less.

2.1.2.6 The ground segment has continued to expand, and there are now active stations in Italy, Morocco, Argentina, Brazil, Curacao, Japan, Malaysia and Korea in addition to the four in the US. However, the Japanese station is not available for international registrations. Further potential sites have been identified in Russia, Ukraine, Philippines, Botswana, Australia and Oman, though these have yet to be implemented. Sixteen 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.

2.1.2.7 Orbcomm has suffered financial difficulties, and filed for 'Chapter 11' bankruptcy protection in September 2000. The parent company, Orbital Sciences Corporation, has put together a new consortium to run Orbcomm. The outstanding debts are believed to stem largely from the system rollout phase, with net running costs being of much smaller concern. Industry confidence in Orbcomm continues to grow, 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. Lately, the USCG has awarded Orbcomm a contract within their automatic ship identification (AIS) programme.

2.2 *Big and Broadband LEOs*

2.2.1 *Iridium*

2.2.1.1 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 Defence. A commercial service has also been re-launched. Most Iridium phones are data capable, and do

communicate with a standard modem. Throughput is about 2400bps. The component parts of some phones are now being repackaged as stand-alone modems. A short burst data (SBD) service (~1900 bytes max per message) was introduced in late 2002, as well as a dropout-tolerant direct Internet connection at up to 10kbps.

2.2.1.2 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. This product has now reappeared as the Motorola 9522 modem, and is capable of both dial-up and data-only modes of operation.

2.2.1.3 The SBD service offers an easily implemented solution for the transfer of a few Kbytes of data per day, transactions taking place as conventional e-mails and attachments. The system is bi-directional and messages may be queued for the mobile. The cost is currently ~\$1.50/kbyte, plus a monthly fee. The new 9601 SBD modem offers simple interfacing, compact size and modest prices (about \$400), and has a recently upgraded maximum message size of 340 bytes. Dial-up remains the better option for larger volumes of data, with costs capable of falling below \$0.1/kbyte. Energy costs are also low for both modes of access (~20J/kbyte), largely because of continuous satellite availability and the implementation of spot beams to reduce the mobile transmitter power requirement.

2.2.1.4 A new 'near broadband' product has also been announced, expected to offer transfer rates of about 100kbps at an undisclosed cost. Discussions are also underway regarding special tariffs for scientific and environmental users, and CLS have entered the arena as potential service providers (Value Added Resellers) for this category of use.

2.2.2 Globalstar

2.2.2.1 Globalstar was Iridium's main competitor in the mobile satellite telephony market. The company's voice and data products include mobile and fixed satellite units, simplex and duplex satellite data modems and flexible service packages. 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 its competitors were, only 55,000 subscribers had been signed by late 2001 and the company laid off half of its work force in August 2001. Globalstar subsequently filed for Chapter 11 bankruptcy protection in February 2002. The company has now been taken over by Thermo Capital Partners LLC. Recently in March 2006 Globalstar announced to have 200,000 customers using their satellite voice and data services. Moreover, Globalstar has also announced an agreement with Qualcomm to manufacture its current and next generation handset, and it has signed agreements with two prospective launch providers to launch its eight spare satellites, planned for early 2007.

2.2.2.2 Data services at 9600 bps are now available, using a dedicated modem. Moreover, Globalstar announced that it has collaborated with satellite communications ocean software and hardware company, OCENS, to launch a comprehensive suite of data services. This would now improve data compression rates with effective data transfer speeds of up to 56 kbps. Globalstar also has a second-generation system planned, said to involve 56 LEO satellites and 5 GEO satellites. Launch was planned to begin in 2006 but little else is known about the planned enhancements of this system.

2.3 MEOs

2.3.1 New ICO

2.3.1.1 New ICO (formerly ICO Global Communications) was the third of the three main players in the global satellite telephony market. However, it also 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, planned 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 was 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, referred to as 'F2', which currently provides data gathering services. ICO is currently using one gateway ground station equipped with five antennas, located in the United States, to monitor F2. They also own a facility in Itaborai, Brazil, at which certain gateway equipment for the MEO system is located. In addition, they have ten MEO satellites in storage under an agreement with Boeing Satellite Systems International, Inc., most of which were in advanced stages of completion prior to the termination of work under the satellite agreements. No further information about their launch schedule is available at present.

2.3.1.2 More recently, it seems that New ICO is concentrating on the terrestrial market, and recently launched a geostationary satellite 'G1' with coverage of most of the US and adjoining territories.

2.4 GEOS

2.4.1. *Inmarsat D+*

2.4.1.1 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 existing Inmarsat service provider (Station 12) implemented the first ground station in the Netherlands, and a number of equipment and service providers have emerged, e.g. Skywave and Satamatics.

2.4.1.2 Inmarsat D+ is being superseded by IsatM2M, a burst data service like Iridium SBD and Orbcomm. Terminals can send 10 or 25-byte messages, and may receive messages of up to 100 bytes. Messages from terminals take about 30 seconds to be delivered, and the terminal can wake up from low-power "sleep mode" in roughly 45 seconds. Sleep mode consumes 300mW, with receive mode-using 800mW and transmit using 9W.

2.4.1.3 IsatM2M terminals are intended for asset tracking, and thus come in a similar format to Orbcomm units – a programmable box that you can customise to operate as a simple tracker or as a more complex logger. SkyWave and Satamatics manufacture them, and all the ones currently on the market include a GPS receiver. SkyWave also offer a product that combines IsatM2M with GSM/GPRS for use in coastal applications. SkyWave's terminals are between 100mm and 160mm in diameter, and 52 to 100mm high. They weigh between 500g and 1kg.

2.4.1.4 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 *Inmarsat Broadband Global Area Network (BGAN)*

2.4.2.1 Inmarsat Broadband Global Area Network (BGAN) offers a mobile communication service, which provides both voice and broadband data simultaneously through a portable device, on a near-global basis. BGAN service is accessible via a range of small, lightweight satellite terminals with an option of single user or a small team. The terminals may be connected to a laptop through wired or wireless connections including BlueTooth and WiFi. BGAN delivers Internet and intranet content and

solutions, video-on-demand, videoconferencing, fax e-mail, phone and LAN access at speeds of up to 492 kbps. Moreover, it supports both circuit-switched and packet-switched voice and data services. It uses the new (spot-beam) Inmarsat-4 (I-4) satellites which were launched in late 2005. The first two of three I-4 satellites are commercially operational in Inmarsat's Indian and Atlantic ocean regions, with coverage extending across North and South America, Europe, Africa and the Far East. The third launch of the Inmarsat-4 has yet to be determined.

2.4.2.2 There are many different airtime price plans available with the BGAN service, some of them cost less than a dollar for a low-cost voice call for a minute, combined with high-speed data and Internet connectivity, in a 'go anywhere' satellite terminal. Some of the leading distributors such as BT, UK, France Telecom Mobile Satellite Communications, France, Stratos, USA, Telenor Satellite services, Norway and USA etc, distribute the service.

2.4.3 GOES, METEOSAT, etc

These GEOs exist primarily to collect and disseminate weather imagery, but do also support low-rate data collection systems. Access to the satellites is controlled by pre-allocated time-slots, and the service is largely free. The requirement for significant transmitter powers and/or directional antennae has tended to restrict applications to larger data buoys, although some success has been reported with lower power installations. MTSAT 1R, MTSAT 2 METEOSAT 9, GOES-13 were the satellites launched in the year 2005 & 06 for meteorological studies.

2.4.4 Inmarsat Mini-M,, Inmarsat C & Mini-C, Thuraya, ACes, AMSC, etc

These advanced GEOs offer voice-band communications using compact handsets or laptops by implementing high gain steer-able spot beams to achieve sufficient link margin. Data services may available using a modem connection on the handset. Coverage is generally regional and not advertised for oceanic areas.

3. USEFUL WEB SITES

3.1 General information

Little LEO status, launch dates http://centaur.sstl.co.uk/SSH/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/>

3.2 Specific operators

Argos <http://www.cls.fr/>
<http://www.clsamerica.com/>
Globalstar <http://www.globalstar.com/>
GOES <http://www.goes.noaa.gov/>
Inmarsat <http://www.inmarsat.com/>
Inmarsat BGAN <http://broadband.inmarsat.com/>
Iridium <http://www.iridium.com/>
METEOSAT <http://www.esa.int/specials/ESOC/mso/meteosat.html>
ICO <http://www.ico.com/>
Orbcomm <http://www.orbcomm.com/>

COMPARISON OF MESSAGE-BASED SYSTEMS (COURTESY M PRIOR-JONES, BRITISH ANTARCTIC SURVEY)

System	Message size	Airtime cost	Monthly price, ¹ message/day	Monthly price, ¹ message/hour	Terminal power consumption (during transmission)	Two-way comms?	Polar coverage? ¹	Data rate	Time to send one message	Delivery time
Iridium SBD	<340 bytes	\$13/mo + \$0.0015/byte ²	\$14.24 (30 bytes)	\$31.48 (30 bytes – bulk tariff)	1.8W	Yes	Yes	2400bps?	~1s	<20s
IsatM2M	25 bytes	\$0.06 for 10 bytes or \$0.120 for 25 bytes	\$5 (25 bytes – minimum spend)	\$89.28 (25 bytes)	9W	Yes	No		10s?	30s
ARGOS	32 bytes	\$21/mo + \$3.50/6hr slot ³	\$124	\$437	<1W	No	Yes	480bps	~1s	Up to 2hrs
DCP	650 chars (roughly 400 bytes)	Free	\$0	\$0	50-100W	No	No	100bps	75 seconds	<1 hr
Orbcomm	<2000 bytes?	Unlimited for \$60/mo	\$60	\$60	24W	Yes, in theory!	Sporadic	2400bps	~1 s	Up to 6hrs?
Globalstar simplex	<36 bytes	\$30/mo for 100 9-byte messages	\$30 (9 bytes)	\$165 (36 bytes, bulk tariff)	5W	No	No	100bps	<1s for 9 bytes, ~3s for 36 bytes.	< 30 minutes

1: Polar coverage means coverage beyond the reach of geostationary satellites (i.e. latitudes higher than 75 degrees).

2: There's a minimum fee per message of \$0.04, covering your first 30 bytes. SBD also has a bulk tariff, where for \$16 a month you get 12,000 inclusive bytes, subject to a minimum bill per message of 10 bytes.

3: This is the ARGOS JTA price for scientific applications. Marine animal tracking devices get a further discount – they're only billed for a maximum of 48 timeslots in a given month, regardless of how many they actually use.

System	Data rate, kbit/s ³	Airtime charges ¹			Monthly airtime cost for... ²				Polar coverage ⁵	Marinised
		Monthly fee	Charged rate	Equivalent cost per megabyte ⁴	1MB	10MB	100MB	1000MB		
Iridium dialup	2.4	\$14	\$1/min	\$58	\$72	\$594	\$5814	\$58014	Yes	Yes
Iridium RUDICS	2.4	\$14	\$0.65/min	\$37	\$51	\$384	\$3714	\$37014	Yes	Yes
Iridium OpenPort	32,64,128	\$35 - \$11206	\$5 to \$17/MB	\$5 to \$17	\$52	\$126 (32kbit/s)	\$700 (32kbit/s) \$805 (64kbit/s)	\$5600 (32kbit/s) \$6300 (64kbit/s) \$7470 (128kbit/s)	Yes	Yes
Fleet MPDS	28,64,1287	\$0	\$34/MB	\$34	\$34	\$340	\$3400	\$34000	No	Yes
Fleet 33 dialup	9.6	\$0	\$3/min	\$43	\$43	\$430	\$4300	\$43000	No	Yes
Fleet 55/77 ISDN	64	\$0	\$5/min	\$15	\$15	\$150	\$1500	\$15000	No	Yes
Fleet 77 ISDN2	128	\$0	\$7/min	\$14	\$14	\$130	\$1300	\$13000	No	Yes
BGAN	4928	\$50	\$7/MB	\$7	\$57	\$120	\$750	\$7050	No	No
FleetBroadband	4329	\$010	\$12/MB	\$12	\$30	\$120	\$1200	\$12000	No	Yes
Thuraya dialup	9.6	\$35	\$1/min	\$15	\$50	\$185	\$1535	\$15035	No	Yes
Thuraya GmPRS	15	\$55	\$5.50/MB	\$5.50	\$55 11	\$82.50	\$578	\$5528	No	Yes
ThurayaIP	444	\$55012	\$4/MB	\$4	\$550	\$550	\$550	\$500013	No	No
Globalstar dialup	9.6	\$40	\$1/min	\$15	\$55	\$190	\$1540	\$15040	No	Yes

1: All prices are in US Dollars and exclude taxes. Iridium airtime was priced from NAL Research. OpenPort prices were quoted by AST. Fleet prices were from KVH. BGAN and FleetBroadband, Globalstar and Thuraya (dialup/GmPRS) prices were from Satphone. ThurayaIP prices were from X Sat.

2: This price is the cost per month for the data used in a given month. It includes monthly subscription charges, but does not include initial setup costs such as activation or SIM card fees. The figure shown in **bold italic** is the lowest price for that quantity of data.

3: Figures quoted here are uplink speeds – some systems have asymmetric uplink and downlink speeds.

4: This price shows the per-minute rates converted to per megabyte, ignoring monthly fees or any overheads like minutes used whilst establishing connections.

5: Polar coverage means coverage beyond the reach of geostationary satellites (i.e. latitudes higher than 75 degrees).

6: OpenPort pricing includes a data allowance as part of the monthly charge. Paying a higher monthly charge results in a lower cost per MB. 64 and 128kbit/s data rates are more expensive than the basic 32kbit/s service.

7: MPDS operates at 28kbit/s on Fleet 33, 64kbit/s on Fleet 55 and 128kbit/s on Fleet 77. Airtime prices are the same for all three systems.

8: Only the larger, more expensive BGAN terminals offer 492kbit/s. Cheaper, smaller ones offer lower speeds, but the airtime price doesn't change.

9: There are currently two FleetBroadband terminals on the market. The smaller, cheaper unit offers 284kbit/s data rate. Airtime pricing is the same for both units.

10: FleetBroadband has no monthly fee, but there's \$30/month minimum spend.

11: GmPRS minimum charge is for 5MB

12: Entry-level ThurayaIP plan is \$550 for 138MB

13: \$5000 buys an unlimited data plan