

# Satellite communications systems buyers' guide

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## Executive summary

A large number of competing satellite communications systems are currently on the market. This document evaluates them in terms of their suitability for use in environmental science monitoring projects. We conclude that for small amounts of data, Iridium Short Burst Data (SBD) and ARGOS can be recommended – SBD where data volume is important, and ARGOS for size, power consumption and startup time.

For battery-powered systems requiring larger amounts of data, consider Iridium (dialup or RUDICS) or Thuraya GmPRS if operating in Europe/Middle East/SE Asia. For high-volume applications on land with access to a power supply, look at ThurayaIP or Inmarsat BGAN. On ships, consider using Iridium OpenPort or Inmarsat FleetBroadband. OpenPort is unique in providing high data rate communications at all latitudes, and may prove cost-effective for polar research work in some circumstances.

## Iridium

### **Coverage:**

Pole-to-pole, using 66 low earth orbiting satellites. Satellites are typically overhead for ten minutes at a time, but the system will hand-off calls automatically between satellites. A restricted view of the sky may prevent this hand-off from working properly.

### **Network services:**

Full-duplex, real-time calls for voice and data, plus SMS and Short Burst Data services with maximum of 20 second latency. There's a full technical explanation of the different Iridium data services here:

[http://www.stratosglobal.com/documents/factSheets/irid\\_whitePaper\\_satelliteDataServices.pdf](http://www.stratosglobal.com/documents/factSheets/irid_whitePaper_satelliteDataServices.pdf)

## Dialup

Iridium terminals can make or receive dial-up data calls just like a conventional landline modem. The data rate is 2400bits/s. Calls are routed via a modem at the Iridium gateway station, and can take up to 40 seconds to connect. Dialup costs in the region of \$1/min.

If you dial another Iridium phone (rather than a landline modem), you can take advantage of the DAV<sup>1</sup> feature to reduce the latency on the connection. With DAV enabled, your call passes only via the satellites and not via Iridium's gateway. Some airtime providers will give a discount for Iridium-to-Iridium calls, so for some applications it may be cost-effective to install an Iridium terminal at your lab and use DAV.

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<sup>1</sup> DAV stands for Data After Voice

## **PPP**

If your device is running a TCP/IP stack (for example, if it's a PC or a microcontroller running an embedded Linux), you can use Iridium to make a PPP<sup>2</sup> dialup connection to the internet. This avoids the long call-setup time of the standard dialup service, but reduces the data throughput due to the TCP/IP overhead.

## **RUDICS**

RUDICS<sup>3</sup> is similar to dial-up, but delivers a connection via the Internet rather than via a dial-up modem. Call charges for RUDICS are a bit cheaper than for dialup (\$0.65/min) and the long call setup time is avoided, but Iridium demand a \$2,500 one-off setup fee. If you're monitoring multiple devices, RUDICS may be cost-effective.

## **SBD**

Short Burst Data is a message-based service (as opposed to the call-based services above) aimed at terminals that make frequent short connections. The network supports SBD messages of up to 1960 bytes<sup>4</sup>, but the lightweight SBD-only modem only supports 340 bytes per message. SBD data costs \$13/month, with messages costing \$0.04 for 30 bytes and subsequent bytes costing \$0.0015. It's also possible to pay a slightly higher monthly fee (\$16) and get your first 12,000 bytes included.

## **SMS**

Iridium also supports GSM-style text messaging, carrying 160-character messages for around \$0.45 per message.

## **OpenPort**

The latest Iridium service is designed to compete with Inmarsat's BGAN and FleetBroadband products. OpenPort offers an always-on data service at 32, 64 and 128kbit/s at a much lower price per megabyte than traditional Iridium data. The service is only available on the specialised OpenPort terminal (costing £2700), which is designed to be mounted on a ship. OpenPort data costs vary depending on how much monthly subscription you pay, but expect to pay between \$5 and \$17 per megabyte.

## ***Terminals:***

The standard Iridium module is the "9522", which supports dial-up, PPP, RUDICS, SMS and SBD. It runs on 4.4V DC and consumes 250mW in standby and 2500mW during a transmission. Each transmission burst (which is 8.2ms out of every 90ms) will draw a peak current of around 2.5A (=11W).

A smaller, lighter modem, the "9601" is available for use with the SBD service only. It runs on 5V DC and consumes 330mW in standby and 1750mW during transmission. Peak current requirement is 1.5A (=7.5W).

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<sup>2</sup> PPP stands for Point-to-Point Protocol. It's the same technique that's used to dial-up to the internet over a landline modem.

<sup>3</sup> RUDICS is short for Router-based Unrestricted Digital Internetworking Connectivity Solution

<sup>4</sup> These figures are for Mobile Originated SBD messages (i.e. messages from an Iridium terminal). Mobile Terminated messages (i.e. messages to the Iridium terminal) are slightly shorter.

The OpenPort terminal is much larger than the other two terminals – the antenna unit is nearly 60cm in diameter and weighs 11kg! This is a new product and details of its power consumption weren't available at the time of writing, but it's likely to be relatively high.

## **Inmarsat services**

Inmarsat operate a fleet of geostationary satellites that cover the earth to around 70 degrees north and south. Originally a non-profit organisation providing distress communications for shipping, Inmarsat is now a commercial outfit with products aimed at land-based users as well as those at sea.

### ***BGAN and FleetBroadband***

Broadband Global Area Network is Inmarsat's "portable broadband" product. The terminals are about the size of a laptop PC, and when pointed at the satellite will provide voice calls and IP data at speeds of up to 492 kbit/s. BGAN is sold as a land-based product only – the marine equivalent (which is physically larger, uses a stabilised antenna and has a top bitrate of 432kbit/s) is called FleetBroadband.

Confusingly, BGAN and FleetBroadband are priced differently. BGAN costs around \$50/month in line rental, and then \$7/megabyte. FleetBroadband has "free" line rental but charges \$12/megabyte, subject to a minimum monthly spend of \$30. BGAN terminals cost between £1500 and £3000 depending on specification.

BGAN terminals use around 0.5W in standby and 20W during transmission. Some can operate from an internal lithium battery. FleetBroadband units require 150W – the extra power is needed to stabilise the antenna. Both BGAN and FleetBroadband terminals are designed to operate from 12V or 24V supplies.

### ***Fleet 33/55/77***

These services are the replacement for the old Inmarsat B system, and operate in much the same way. Only Fleet 77, the most expensive, is fully GMDSS<sup>5</sup> compliant. All the Fleet services offer voice, fax and dial-up data services. The new feature of Fleet over Inmarsat B is MPDS, a packet-based, pay-by-the-bit data service. MPDS operates at 64kbit/s (downlink) and 28kbit/s (uplink) on Fleet 33, at 64kbit/s on Fleet 55 and at 128kbit/s on Fleet 77. MPDS data costs around \$34 per megabyte<sup>6</sup>. Dial-up data (ISDN data) costs \$7/min for 64kbit/s (on F55/F77) or \$13/min for 128kbit/s (on F77 only). F33 offers a 9.6kbit/s service for \$3/min.

Fleet terminals use stabilised antennas and consume up to 150W. Fleet 33 terminals start at around £5000, with Fleet 55 coming in at £8500 and Fleet 77 at £11000.

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<sup>5</sup> GMDSS is the Global Maritime Distress and Safety System – the regulations which govern communications equipment for commercial ships, ensuring that they're equipped to send and receive distress, urgency and safety of navigation messages.

<sup>6</sup> Note that Inmarsat charge for MPDS by the *megabit*, and it's necessary to multiply by 8.4 to get a comparable figure per *megabyte*.

## ***IsatM2M***

This is the service that's replacing Inmarsat D+, and is 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.

IsatM2M terminals are intended for asset tracking, and thus come in a similar format to Orbcomm units – a programmable box which 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.

SkyWave offer an "evaluation kit", priced at \$1440 which includes a terminal, a PalmPilot PDA and the software development kit, plus \$300 in airtime for use in your first three months. You also get \$200 credit for activation fees, a 2-3 day training course for one person and 3 months of unlimited technical support.

SkyWave charge \$100 to set up a control station (a computer at your lab), and \$20 to register a new terminal on the network. Discounts are available if you're registering large numbers of terminals. Messages from terminals are priced at \$0.06 for a 10-byte message or \$0.120 for a 25 byte message. There's a minimum monthly spend per terminal of \$5.

## **ARGOS**

ARGOS uses polar orbiting satellites to give global coverage. It's a unidirectional message-based service. Messages are received in real time by receiving stations throughout the world, and are also stored to be forwarded when the satellite passes over one of the three main stations (in Alaska, eastern USA and Svalbard). ARGOS terminals are extremely small and light, and transmit up to 32 bytes of data in less than one second. Because there's no acknowledgement from the satellite, the message is repeated several times to try and maximise the chance of good reception.

ARGOS uses the Doppler effect to estimate the position of each transmitter as the message is transmitted. The accuracy of this technique ranges from 350m to 1km, depending on how many copies of the message were received by the satellite as it passes overhead. Entry-level ARGOS terminals cost in the region of \$2000, but a considerable premium can be paid for the smallest, lightest models.

ARGOS airtime is not charged per message or per byte, but at €2.50 per 6 hour timeslot in which two or more transmissions are received. There's also a €15 monthly fee.

A new version of the system, called ARGOS-3, is just getting going. At present, only one satellite supports it, but it should bring higher data rates (4.8kbit/s) and two-way communications. The terminal will also be able to detect the presence of the satellite

before it transmits, and to receive acknowledgements for messages received correctly, both of which will improve power efficiency.

## DCP

Data Collection Platform is a service provided by a federation of meteorological satellite operators in Europe, the USA, Japan, Russia and China. Unlike the other systems in this report, it's free to use if your system is approved by the satellite operators. DCP allows the transmission of up to 649 data characters per message. These data characters are a subset of the ITA-5 telex alphabet, and include uppercase letters, numbers and some basic punctuation. DCP terminals are allocated a specific 90 second timeslot, and must complete their transmission within 75 seconds (the remaining 15s are a "guard period" in case clocks are not perfectly synchronised). The slot pattern repeats every hour, so units are locked into an hourly reporting cycle. DCP modems can use as much as 100W during transmissions.

## Orbcomm

Orbcomm operate a network of 29 satellites in low Earth orbit, offering a message-based communication service. Unlike the other services described here, Orbcomm operates in the marine VHF band, and hops between frequencies to avoid interference. Orbcomm's coverage is not continuous – holes in the coverage open and close as the satellites move – and they have only one polar-orbiting satellite, making polar coverage somewhat erratic.

Messages are downlinked by regional earth stations ("gateways"). If a satellite is in range, the messages are delivered in close to real-time. Otherwise, the satellite will store the message and attempt to forward it on when it next comes in range. A terminal is normally associated with just one gateway, and additional fees are payable for "roaming" to other gateways elsewhere in the world.

Airtime is fairly cheap, with all-you-can-eat packages available for around \$60/month. Terminals cost between \$200 and \$400, and whilst some are just modems, most incorporate a user-programmable microcontroller that can be used to collect data from peripheral instruments. Terminals have a sleep mode that can reduce power consumption to as little as 600 $\mu$ W, whilst transmit power consumption is around 24W. There is no maximum message size<sup>7</sup>, although experience suggests that shorter messages tend to be more reliable! The uplink data rate is 2.4kbit/s. The system is bidirectional, with downlinks to the terminal at 4.8kbit/s, but users at both NOCS and POL have had issues with establishing reliable two-way communications with Orbcomm terminals.

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<sup>7</sup> There must be a theoretical maximum message size, but exact details are not available. The best information available from Orbcomm's website is that messages may be "several kilobytes" in length.

## **Thuraya**

Thuraya is primarily a satellite phone system which operates from two geostationary satellites covering Europe, the Middle East, most of Africa, central and south-east Asia and Australia. It covers all of European coastal waters and the Atlantic Ocean as far west as Iceland, the Azores and Cape Verde islands.

Thuraya offers dialup data at 9.6kbit/s, packet data (GmPRS<sup>8</sup>) at 60kbit/s downlink and 15kbit/s uplink, plus SMS messaging. A dialup subscription costs \$35/mo and then \$1-\$2/min. For packet data, the monthly fee rises to \$55, including the first 5MB of data. Additional data is charged at \$5.50/MB.

### ***ThurayaModule***

ThurayaModule is an OEM terminal that includes a GPS receiver. It requires an external antenna, but the module itself is about the size of a pack of cards and weighs 60 grams. It offers the full range of Thuraya services. Power consumption figures aren't available from Thuraya, but one of Thuraya's partner firms produces a module that includes the ThurayaModule with a 3W power consumption during transmit.

### ***ThurayaIP***

ThurayaIP offers internet access at around 450kbit/s, although this is a contended channel shared between multiple Thuraya users. The terminal is A5 size and weighs 1.3kg. The terminal costs \$4000, with airtime being priced at \$550/mo for 138MB (= \$4/MB). There's an all-you-can-eat plan at the eye-watering price of \$5000/mo!

### ***ThurayaMarine***

ThurayaMarine is a marinised Thuraya phone, based on ThurayaModule. It uses around 36W in transmit.

## **Globalstar**

Globalstar is a US-based satellite phone service. It covers North America, the northern part of South America, Europe and north Africa. It fails to cover northern Scandinavia, but does cover most of the North Atlantic.

Globalstar offers conventional dialup data at 9.6kbit/s, and consumes around 5W to do so. Data calls cost €0.70/min in Europe, with a monthly fee of €30. Call prices vary depending on which gateway the terminal is connecting to, so roaming to other gateways may be more expensive.

Globalstar also offer a short burst data service, which they call simplex data. Simplex theoretically supports messages of up to 144 bytes, but the service providers recommend no more than 36 bytes for reliability. Messages can be billed in 9 byte or 36 byte increments. Prices start at \$30/mo for 100 9-byte messages. Simplex terminals run on 5V, and consume 2.5W during transmission. They have a sleep mode that consumes 30µW.

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<sup>8</sup> GmPRS is the name given to Thuraya's packet data service. It's a variant on the GPRS service used on the GSM phone networks.

## Network architecture issues

Most of the systems described here – the exceptions are ARGOS and DCP - offer two-way communications and have an architecture not dissimilar to a mobile phone system. As a consequence, the system expects the terminal to be in standby mode most of the time. For many scientific applications, we want to shut the terminal down completely in order to save on power. When the terminal starts from cold, it then needs to register with the network, which can take anything up to a couple of minutes. What's happening during this time? Is there anything we can do to cut it down?

Most of these systems are proprietary, so the following is informed speculation about what's going on during those frustrating network registration delays.

Firstly, the terminal listens on a beacon frequency for a satellite overhead. The beacon broadcasts the basic information needed to join the network. Having received this information, the terminal will then transmit a message to the satellite on a control channel, giving its identity and requesting network registration. The process up to this point should be pretty quick. However, before the satellite can allow the terminal to join the network, it needs to contact the network control centre. This is the bit that may take some time. The message needs to travel to the NCC – on Iridium, this may involve it bouncing from satellite to satellite until it reaches Iridium's gateway site in the USA – and then the NCC needs to check if the terminal is authorised. This involves checking that your account is active, that you have the necessary credit, and that your terminal isn't being blocked as having been lost or stolen. Once through these checks, the NCC will send a message back to the terminal, giving it permission to join the network. The other function of this registration process is that the NCC now knows where your terminal is, and can start routing any incoming calls or queued data to the correct satellite for onward delivery.

To speed this process up, it would be necessary for the rules to be changed to allow the terminal to send a message immediately on first contact with the satellite, without waiting for the authorisation from the NCC. Because any message sent would pass via the NCC anyway, the authorisation checks could be made before the message is delivered to its destination, rather than whilst the terminal is live.

To summarise:

<b>Existing system</b>	<b>Fast-registration system</b>
Terminal contacts satellite requesting registration	Terminal sends data message to satellite without waiting for registration
Satellite forwards request to NCC	Satellite forwards message to NCC
NCC checks and replies with authorisation	NCC receives message, performs authorisation checks, then forwards message for onward delivery
Satellite forwards authorisation to terminal	NCC sends authorisation and acknowledgement for data to terminal
Terminal sends data message	Satellite forwards to terminal
Satellite forwards data message to NCC for onward delivery, and replies with acknowledgement	If terminal is still switched on, it receives authorisation ready for next message.



### Comparison of message-based systems

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? <sup>9</sup>	Data rate	Time to send one message	Delivery time
Iridium SBD	<340 bytes	\$13/mo + \$0.0015/byte <sup>10</sup>	\$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 <sup>11</sup>	\$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

<sup>9</sup> Polar coverage means coverage beyond the reach of geostationary satellites (i.e. latitudes higher than 75 degrees).

<sup>10</sup> 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.

<sup>11</sup> 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 <sup>14</sup>	Airtime charges <sup>12</sup>			Monthly airtime cost for... <sup>13</sup>				Polar coverage <sup>16</sup>	Marinised
		Monthly fee	Charged rate	Equivalent cost per megabyte <sup>15</sup>	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 - \$1120 <sup>17</sup>	\$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	28,64,128 <sup>18</sup>	\$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	<b>\$14</b>	\$130	\$1300	\$13000	No	Yes
BGAN	492 <sup>19</sup>	\$50	\$7/MB	\$7	\$57	\$120	\$750	\$7050	No	No
FleetBroadband	432 <sup>20</sup>	\$0 <sup>21</sup>	\$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 <sup>22</sup>	<b>\$82.50</b>	\$578	\$5528	No	Yes
ThurayaIP	444	\$550 <sup>23</sup>	\$4/MB	\$4	\$550	\$550	<b>\$550</b>	<b>\$5000<sup>24</sup></b>	No	No
Globalstar dialup	9.6	\$40	\$1/min	\$15	\$55	\$190	\$1540	\$15040	No	Yes

<sup>12</sup> 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.

<sup>13</sup> This price is the cost per month for the data used in a given month. It includes monthly subscription charges, but doesn't 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.

<sup>14</sup> Figures quoted here are uplink speeds – some systems have asymmetric uplink and downlink speeds.

<sup>15</sup> This price shows the per-minute rates converted to per megabyte, ignoring monthly fees or any overheads like minutes used whilst establishing connections.

<sup>16</sup> Polar coverage means coverage beyond the reach of geostationary satellites (i.e. latitudes higher than 75 degrees).

<sup>17</sup> 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.

<sup>18</sup> 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.

<sup>19</sup> Only the larger, more expensive BGAN terminals offer 492kbit/s. Cheaper, smaller ones offer lower speeds, but the airtime price doesn't change.

<sup>20</sup> 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.

<sup>21</sup> FleetBroadband has no monthly fee, but there's \$30/month minimum spend.

<sup>22</sup> GmPRS minimum charge is for 5MB

<sup>23</sup> Entry-level ThurayaIP plan is \$550 for 138MB

<sup>24</sup> \$5000 buys an unlimited data plan

## Conclusions

### ***Message-based systems:***

Iridium SBD looks attractive for many applications. It's two-way, has global coverage and is relatively cheap. ARGOS still offers the ultimate in low-power performance and short startup times, but can only carry small volumes of data and is simplex. IsatM2M has no monthly fee, and so may be attractive for low-volume applications, assuming that polar coverage is not needed.

### ***Continuous systems:***

#### **For users with access to a power supply:**

ThurayaIP is excellent value for money if you're in its coverage area – particularly if you're handling large volumes of data from a land-based terminal. For best value with global coverage, go for OpenPort. If speed is important and you don't need polar coverage, BGAN or FleetBroadband may be a better option.

#### **Battery-operated systems:**

Here it's a straight fight between Thuraya and Iridium. If you're intending to operate in Thuraya's coverage area, then the GmPRS service offers you a faster, cheaper connection billed by the megabyte. Otherwise, Iridium (dialup or RUDICS) is the only show in town. Even in the Thuraya coverage area, Iridium may be preferable for very low usage, as it has a much lower monthly fee.