TECHNICAL WORKSHOP

APPLICATION OF IRIDIUM TELECOMMUNICATIONS TO OCEANOGRAPHIC AND POLAR RESEARCH

Executive Summary

The Technical Workshop on Applications of Iridium Telecommunications to Oceanographic and Polar Research resulted in an unprecedented exchange of information related to the use of Iridium telecommunications in support of myriad applications. Attendees outlined the successes, shortfalls, frustrations and lessons learned in implementing Iridium data communications, and participated in Working Groups to analyze information provided and to develop recommendations concerning future actions.

Details relating to "lessons learned" and findings regarding the effectiveness of Iridium data communications in support of specific applications provided during the briefings are included in this document. While the general consensus was that Iridium provides a much needed global data communications capability, findings related to the ease of integration and the success in establishing and maintaining data communications differed widely. One user of a multi-channel Iridium modem reported 39% partial failure rates, while another user reported that the integrated 8-channel system worked "out of the box" and performed better than other data modems. These differences are due, in large part, to dissimilarities in hardware, firmware and supporting software used by Workshop attendees. Many utilized the prototype 9500 data modem. Others used the 9500 or 9505 phones, while some used the enhanced 9505 modem. In addition, a number of users modified the Iridium hardware which may have had an adverse impact on its effectiveness.

The 9505 Iridium phone and data modem incorporates hardware and software upgrades that corrected many of the problems identified during the Workshop. For example, problems associated with the self-initiated internal power-down and Universal Asynchronous Receiver Transmitter (UART) lock have been identified and corrected. The Data-After-Voice (DAV) capability reduced latency but also contained a bug which has been corrected, in the firmware.   Another issue addressed was signal strength fluctuation that could cause the modem to lock up if operating in a continuous mode. This problem was corrected in the 9505 modem, which provides for significant enhancements in both hardware and software over the 9500 prototype version. Newer versions of the NAL Research software allows the user to accurately profile signal strength, addressed as a much needed capability by Workshop participants.

In addition, certain software programs proved to be more difficult than others to utilize effectively. Several attendees commented that significant problems exist with Kermit that probably contribute to poor transmission success rates. Another attendee noted that a bug in the Linux Point-to-Point protocol daemon (pppd) software caused calls to drop.

While attendees clearly benefited from the exchange of information, it became apparent soon after Workshop discussions began that a more formalized means to capture, compile, document and make available information concerning Iridium data communications is needed. This concept was strongly supported by the Working Groups. Questions include, "What works? What doesn't work? What problems exist with particular variants and what 'work-arounds' have been identified? Who do we contact?"   Issues addressed include the level of support required, how to structure it, who will provide it and who will fund it. Development of a training program was also identified as a critical requirement.

The Workshop was successful in identifying and articulating critical issues related to Iridium telecommunications in support of oceanographic and polar research and in developing recommendations for consideration. The next steps are to analyze and prioritize requirements, and determine what future course(s) of action can be initiated.

The goals of the Workshop included:
- Outlining findings related to the use and effectiveness of Iridium data communication in support of oceanographic and polar applications
  - Share hands-on successes and failures, lessons learned, problems and solutions;
  - Share findings related to the integration of Iridium data communication hardware/software on specific platforms and systems; and
  - Bring together the expertise needed to effectively address issues raised.
- Conduct Working Groups to analyze information provided and issues addressed to develop findings and recommendations concerning future actions to assist users in effectively implementing Iridium data communication.

Briefings provided during the Workshop, a list of participants and the Technical Workshop agenda can be viewed at http://www.ocean.us/documents/iridium.jsp.

WORKSHOP AND ITS GOALS

The Technical Workshop on Applications of Iridium Telecommunications to Oceanographic and Polar Research was conducted at the University of Washington's Applied Physics Laboratory, Seattle, Washington on 19 - 21 May 2004. Sponsored by the National Office for Integrated and Sustained Ocean Observations (Ocean.US) and the Office of Naval Research (ONR), the Workshop brought together over 40 leading organizations in oceanographic and polar research and Iridium data communications, including universities, federal laboratories, research institutes and other organizations worldwide.

During 1998, the National Science Foundation (NSF) sponsored a Small Business Innovative Research Program (SBIR) initiative, the low-Earth Orbit (LEO) Satellite Communications System for NSF Polar Programs, to review satellite data communication options and to develop a breadboard data modem. The study noted Argos "has many disadvantages including one-way communications, non-continuous temporal coverage, low data transmission rate, long message latency and high cost due to low volume market." During Phase II of the SBIR, data modem breadboards were developed based on the Iridium and Orbcomm satellite systems. The study recommended further development of a data modem based on the Iridium constellation. During 2002, ONR continued the effort by supporting a SBIR initiative to develop an Iridium data modem prototype based on the 9500 series Iridium RF board. Ninety-six modems were distributed under Phase II of the SBIR, and a number of participants in the Workshop was provided with the 9500 Iridium data modems through the SBIR program for implementation in various applications. In addition, some Workshop participants used the 9500 or 9505 Iridium phone to relay data. How to effectively implement and support the use of the Iridium data communications capability was a focal issue of the Workshop.

BACKGROUND

Argos Satellite Data Relay System
The most widely used satellite data relay system for scientific research remains Argos. Traditionally, communication is one-way only, at 400 baud, with practicable data rates on the order of 1 Kbyte per day. Transmissions in this mode are unacknowledged by the system and therefore must 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 Television and Infrared Observation Satellite (TIROS) weather satellites, but the recent launch on board the Japanese Advanced Earth Orbiting Satellite (ADEOS-II) vehicle and projected launches on board the European Meteorological Operational Satellite (METOP) platforms mark an important diversification of service provision.

Enhancements to the Argos on board equipment ('Argos-2') include increased receiver bandwidth and sensitivity, with a highly significant move to two-way communication ('downlink messaging') which was piloted aboard the short-lived ADEOS-II, launched in December 2002. It was equipped with two Japan Aerospace Exploration Agency (JAXA) sensors: Advanced Microwave Scanning Radiometer (AMSR) for quantitatively observing various geophysical data concerning the water cycle, and Global Imager (GLI) for observing oceans, land and clouds with high accuracy. Next generation Argos equipment ('Argos 3') will fly from 2006 onwards on board METOP-1, and will offer order of magnitude increases in data rates, as well as two-way communications.

Argos is one of the few systems that offers true global coverage. The first of the Argos-2 satellites was launched in May 1998 and has been followed in September 2000

by NOAA-L (NOAA-16), and by NOAA-M (NOAA17) in June 2002. New direct readout stations continue to be commissioned, bringing the current total to more than 40. Recent additions included stations in the Antarctic Peninsula (Chile, Meteo Chile), Athens (Greece, CLS), Fiji (Fiji, FMS), Punta Arenas (Chile), Riyadh (Saudi Arabia, CACST), Söndre Stromfjord (Greenland, DMI) and Tromsö (Norway, NMI). These additions continue the programme of improving data timeliness by exploiting use of Argos in 'bent-pipe' mode.
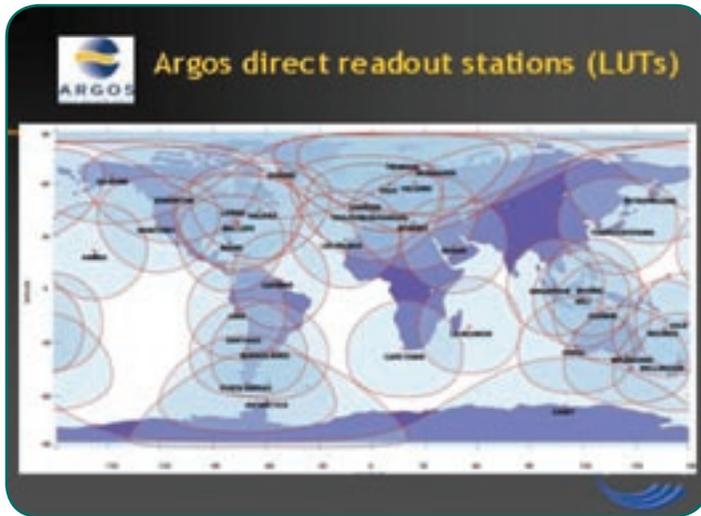

Figure 1: ARGOS Direct Readout Stations (LUTs)

Data collection platforms that utilize the Argos system for meteorological and oceanographic purposes include drifting buoys, ice buoys, moored buoys, sub-surface floats, ships, containers, balloons, Automatic Weather Stations (AWSs) and animals. The Argos system is comprised of Platform Transmitter Terminals (PTTs), the space segment and the ground segment. A PTT includes an antenna, a Radio Frequency (RF) modulator, a power amplifier, a sensor interface unit, an ultra-stable oscillator and a power supply. PTTs are attached to sensor equipment, platforms and even on migratory birds from which data are collected. They are configured by size, weight, power consumption and housing according to the application. An Argos PTT uplinks messages to the satellite at a nominal frequency of 401.65MHz that may contain up to 225 bits (out of 256 bits) of sensor data per message. During a satellite overpass, each PTT can normally transmit at an Argos assigned repetitive period ranging from 40 to 240 seconds. The average duration of PTT visibility by the satellite or the "window" during which the satellite can receive messages from the PTT is about 10 minutes for each satellite pass, assuming that the satellite must be at least 5° above the horizon. Up to four simultaneous PTT messages can be acquired by an Argos satellite provided that they are separated in frequency.

The satellites pass the poles at greater frequency than at the equator. Regardless, for successful transmission of data messages, the schedule of satellite overpass must be accurately provided to the PTT. Figure 2 presents, a contour plots of cumulative visibility time of the NOAA-12 and NOAA-14 over a 24-hour period assuming that the line-of-sight to the satellites is 5° above the horizon. NOAA-12 and NOAA-14 satellites provide slightly less than five hours of coverage over the polar regions and approximately 1.5 hours around equatorial regions each day. Since PTTs are required to uplink at an assigned repetitive period, less than 2% of the total satellite visibility time can be used for transmission.
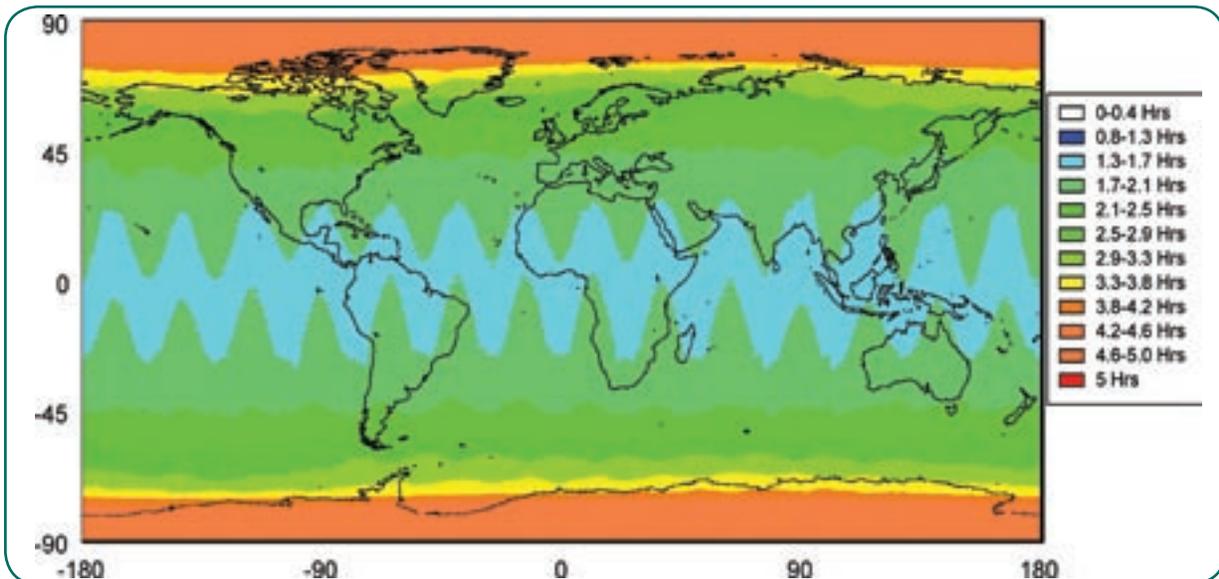
Figure 2: ARGOS Data Latency

Data are retransmitted multiple times for each satellite overpass to improve position prediction and to ensure data integrity. This reduces the overall system capability. Data are down-linked in real-time if the satellite is in view of a ground station at the same time or stored on tape for later down-link. For the latter case, data recorded on tape are read out and transmitted to the ground each time the satellite passes over one of the telemetry stations. Argos data are then rebroadcast from the telemetry ground stations through telecommunication satellites to the National Environmental Satellite, Data, and Information Service (NESDIS)/NOAA computer facility. The data are demodulated and forwarded to Argos Data Processing Centers. At the Argos Data Processing Centers, PTT transmitter locations and sensor data are interpreted and the results are made available to the users. Data may be obtained by users from tapes, floppy disks, computer printouts or computer files accessible by the Internet, telephone, telex or other communication networks. Most data are available within four hours (Figure 3) after the receipt of data rebroadcast from the satellites. The Argos Data Processing Centers receive PTT messages in near real-time when both a regional ground station and a PTT are simultaneously in view of a satellite during transmission.
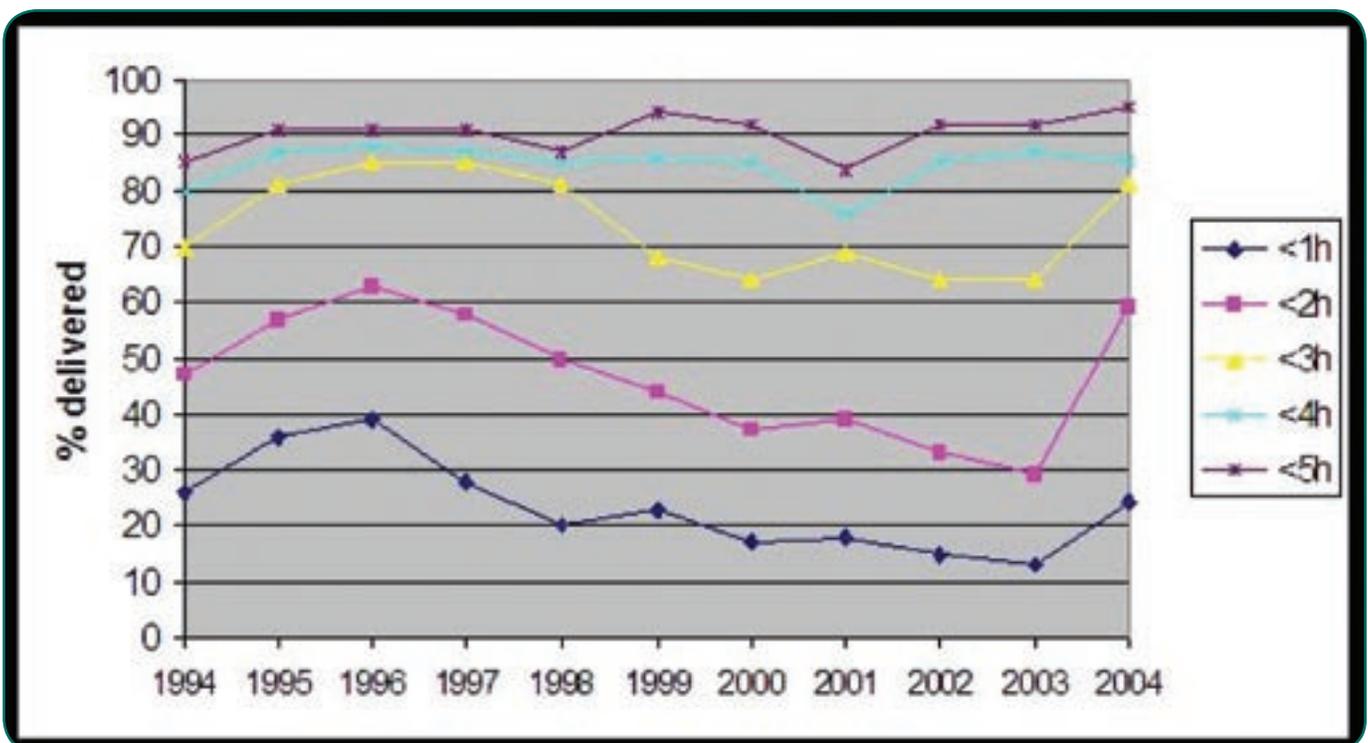

Figure 3: ARGOS Data Timelines

Iridium Satellite System Overview

The Iridium system is the only satellite system that provides true global coverage, including all ocean areas and Polar Regions, at all times. It provides a two-way, near-real time data communications capability, as all areas of the Earth are covered with at least one satellite. The Iridium system is a low-Earth Orbit (LEO) satellite network developed by Motorola® to provide personal mobile services. The original concept was visualized as far back as 1987 and was granted a full Federal Communications Commission (FCC) license in January of 1995 for construction and operation in the United States. The Iridium satellite network is now owned and operated by Iridium Satellite LLC (ISLLC). There are four components to the network: (1) a constellation of 66 satellites and 13 spares, (2) three terrestrial gateways, (3) a Satellite Network Operations Center (SNOC) and (4) Iridium Subscriber Units (ISU).
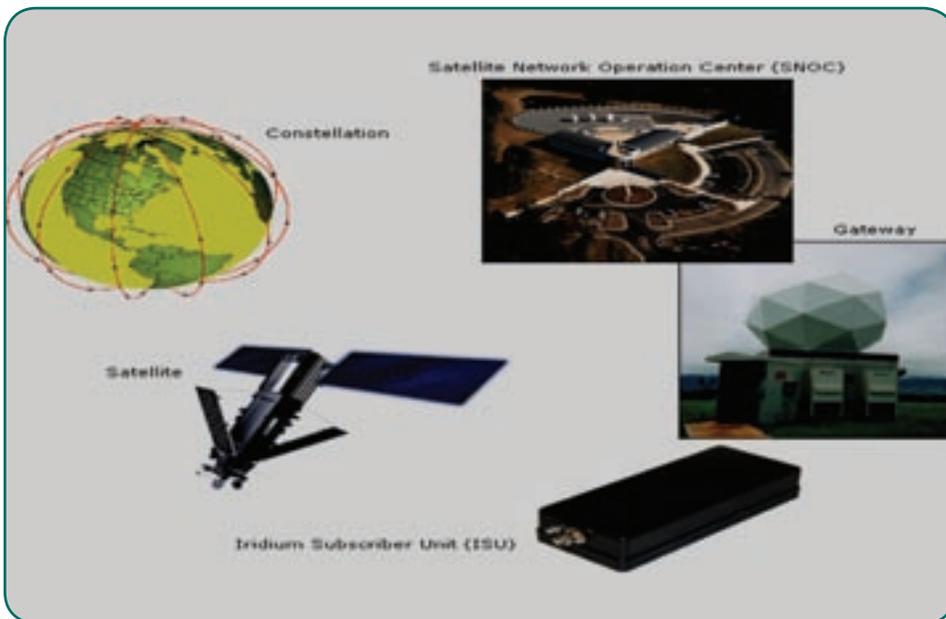

Figure 5: Iridium Satellite

The satellites are in six orbital planes separated by 31.6° at an altitude of 780 km and 86.4° inclination. The Iridium network is designed to operate in the L-band of 1616 to 1626.5 MHz for ground user links; in the Ka-band of 19.4 to 19.6 GHz and 29.1 to 29.3 GHz for gateway down- and up-links; and in the Ka-band of 23.18 to 23.38 GHz for Inter-Satellite Links (ISL). The exact L-band frequencies used depend on local regulating authorities and issued licenses in any particular region.

Each satellite projects 48 spot beams (which may be viewed as providing coverage cells on the ground similar to terrestrial cellular systems) on the surface of the Earth. Each beam is approximately 600 km in diameter. The 66-satellite constellation has the potential to support a total of 3,168 spot beams; however, as the satellite orbits converge at the poles, overlapping beams are shut down to prevent interferences. The satellite footprint is ~4,700 km in diameter. Under each footprint, a satellite's power is limited to ~1,100 simultaneous circuits. A user is in view of a satellite for approximately nine minutes, with about one minute under each beam, before being handed-off to the next satellite.

Figure 4: Iridium Satellite System

Please see http://www.nalresearch.com/QuickRef NetworkDescription.html for a video showing the orbit of the Iridium satellites.

Each Iridium satellite is ~4 meters high and weighs ~667 kg fully fueled. Each satellite has three L-band antenna panels providing the 48 beams of footprint. The satellite has four 23 GHz cross-links antennas. These antennas point to the nearest spacecraft in the same plane (fore and aft) and in the two adjacent co-rotating planes. The "feeder link" antennas relay information to the terrestrial gateways. The spacecraft payload is the dominant component with high-speed digital switching to handle complex telephony routing.
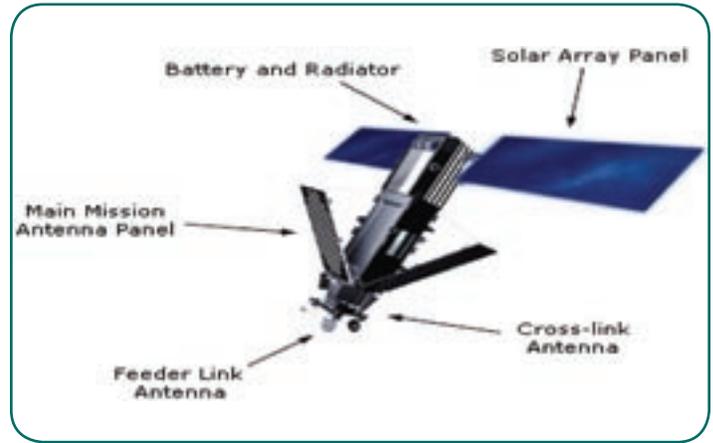
Inter-satellite link or ISL is the network architecture employed by Iridium (versus bent-pipe employed by Globalstar and Orbcomm). A unique feature of the Iridium ISL capability is that the satellites not only can talk to ISU and gateways, but they can also talk to each other, forming a network aloft. When a signal is up-linked to a satellite by an ISU, it is down-linked immediately to a gateway located within the satellite's footprint and then gets distributed to the final destination. However, when a gateway is not

visible to the satellite, information is passed through the network of satellites to the one that is immediately over a gateway. Iridium ISL also allows ISUs to talk to each other without ever referencing to any ground stations at all, thereby reducing signal latency that can adversely affect time-sensitive protocols such as TCP/IP.

ISL provides benefits such as enhanced system reliability and capacity and reduces the number of gateways required. The greatest advantage of using ISL is essentially the capability of truly worldwide coverage without signal latency in either voice or data mode. By eliminating the dependency on ground infrastructure for traffic links, an ISL-based system such as Iridium becomes more autonomous. Moreover, ISL can make communications virtually impervious to terrestrial service disruptions that may be caused by earthquakes, hurricanes, floods and other natural and man-made causes.

There are currently two commercial Iridium gateways located in Tempe, Arizona, United States and Fucino, Italy. The U.S. Government/Department of Defense (DoD) selected Iridium for voice and data communications due, in large part, to its global coverage and secure systems architecture. The U.S. Government owns and operates a secure Iridium gateway, located in Hawaii. Each gateway generates and controls all user information pertaining to its registered users, such as user identity, geo-location and billing items. Gateways also provide connectivity from the Iridium system to the terrestrial-based networks such as the PSTN (Public Switched Telephone Network), DSN (Defense Switched Network), Internet, Misprint, etc. Although there are multiple gateways, a user is registered to a single gateway that will handle his data and voice communications.

An ISU can be either an Iridium satellite phone or any of Iridium's CDM and 9500/9505 series modems. It is capable of operating from 1616.0 to 1626.5 MHz; however, the actual frequencies used are in accordance with regional spectral licenses and international frequency coordination. An ISU (as well as Iridium satellites) uses Right Hand Circular Polarization (RHCP) and provides a maximum gain of 3.5 dBic from 8.2° to 90° elevation and a maximum gain of 0 dBic at 0° elevation. The average and peak RF transmitted powers are 0.6W and 7W, respectively.

The L-band interface between an ISU and an Iridium satellite is based on hybrid FDMA/TDMA (Frequency Division Multiple Access/Time Division Multiple Access) architecture using a 90 milli-second frame TDD (Time Division Duplex). The fundamental unit of the TDMA channel is a time-slot, which is organized into frames. A frame consists of a 20.32 milli-second downlink simplex time-slot, followed by four 8.2 milli-second uplink time-slots and four downlink time-slots with various guard times interspersed. Each frame is composed of 2250 symbols at the channel burst modulation rate of 25 kilo symbols per second (ksps).
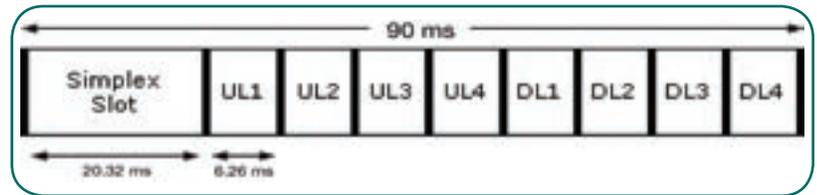

Figure 6: Iridium L-Band Interface Structure

Frequency accesses are divided into the duplex channel band and the simplex channel band. The duplex channel band is further divided into sub-bands, each occupying 333.333 kHz. In duplex operation, the Iridium network is capable of operating up to 30 sub-bands, containing a total of 240 frequency accesses. The Iridium system re-uses duplex channels from beam to beam when sufficient spatial isolation exists to avoid interference. A 12-frequency access band is reserved for the simplex channels. These channels are allocated in a globally allocated 500 kHz band between 1626.0 to 1626.5 MHz. The L-band downlink channels use DE-QPSK (Differentially Encoded Quaternary Phase Shift Keying) for traffic, broadcast, synchronization, ring alert and messaging. Power Spectral Flux Density (PSFD) provided to ISU ensures adequate service link margins. The uplink traffic channels use DE-QPSK modulation. The uplink acquisition and synchronization channels both use DE-BPSK (Differential Encoded Binary Phase Shift Keying). BPSK is used since it provides a 3 decibel (dB) link advantage, which improves the burst acquisition probability. Traffic channels operate with adaptive power control, which acts to limit power transmissions beyond what is required for a robust connection.

The L-band link between an ISU and Iridium satellite is designed for a threshold channel bit error of 0.02. The system operates with an average link margin of 13.1 dB above this level. Under good channel conditions, this level is reduced by adaptive power control. Even under adaptive power control, link margin is maintained to mitigate fades that are too short in duration to be compensated for by the power control loop. Adaptive power control uses a closed loop algorithm to adjust its transmitted power to the minimum value necessary to maintain high link quality. When the entire available link margin is not required to mitigate channel conditions, adaptive power control has the effect of reducing system power consumption.

The Iridium network makes calculations of the geographical location (geo-location) of an ISU each time a call is placed. This is done for billing purposes only. The technique employed to determine the geo-location of an ISU is based on measurements of the ISU, satellite propagation delay and Doppler frequency shift. These measurements are used to estimate cosines of spherical angles that identify the ISU's location relative to the satellite by the gateway. In the Iridium geo-location process, the ISU sends the satellite an uplink geo-location burst, saving the delay and Doppler corrections needed to send the message. When the satellite receives the uplink geo-location burst from the ISU, it measures the time and frequency offsets of the burst relative to its time and frequency standards. The satellite then responds with a downlink burst, which the ISU uses as an acknowledgement that the satellite has received the previous uplink geo-location burst. When the downlink burst arrives, the ISU checks to see if it is satisfied with its estimates for the timing and Doppler. If so, it then transmits an uplink Associated Control Channel, L-Band (ACCHL) message to the satellite that includes the propagation time and Doppler frequency offsets that were used by the ISU during the last geo-location uplink burst. If the ISU did not receive a response, or if the ISU is not satisfied with the accuracy of the exchange, the ISU will repeat the process again.

The Iridium network can locate an ISU to within 10 km only about 78% of the time. The location accuracy can be much higher; however, the information is not available to commercial users. Geo-location errors in the east-west dimension, therefore, are sometimes more than 100 times greater than in the north-south dimension. However, DoD sponsored the development of the Iridium modem with an integrated GPS module to provide accurate location data independent of geo-positioning.

The Iridium network supports Global System for Mobile Communications (GSM)-based algorithms for authentication and encryption to safeguard critical data to the satellites.

INMARSAT Satellite System Overview
The Inmarsat Satellite System is supported by a constellation of geostationary satellites that extend mobile phone, fax and data communications to every part of the world, except the poles and selected ocean areas. The satellites are controlled from Inmarsat's headquarters in London, which is also home to Inmarsat Group Holdings Ltd, Inmarsat's parent company, as well as a small Inter-Governmental Organization (IGO), the International Mobile Satellite Organization (IMSO), created to supervise the company's public-service duties to support the Global Maritime Distress and Safety System (GMDSS) and satellite-aided air traffic control for the aviation community. Inmarsat came into being to provide global safety and other communications for the maritime community. Starting with a customer base of 900 ships in the early 1980s, it then grew rapidly to offer similar services to other users on land and in the air until, in 1999, it became the first IGO to be transformed into a private company. It now supports links for phone, fax and data communications to ship, vehicle, aircraft and other mobile users. Inmarsat's primary satellite constellation consists of four Inmarsat (I-3) satellites in geostationary orbit. These are currently backed up by a fifth spacecraft that can be brought in to provide additional capacity. Between

Figure 7: INMARSAT COVERAGE
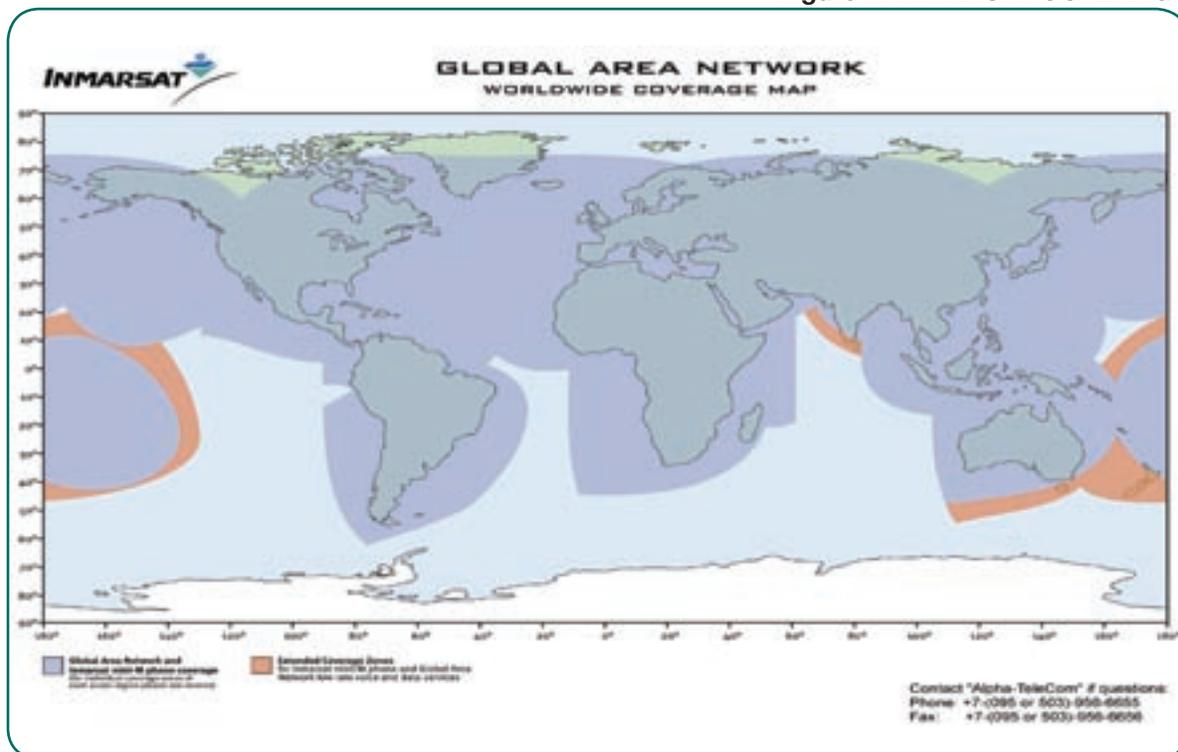
them, the main "global" beams of the satellites provide overlapping coverage of the surface of the Earth apart from the Polar Regions and selected ocean areas.

A geostationary satellite follows a circular orbit in the plane of the Equator at a height of 35,600 km, so that it appears to hover over a chosen point on the Earth's surface. Three such satellites are enough to cover much of the Earth's surface.

The control teams at the Satellite Control Center (SSC) in London are responsible for keeping the satellites in position above the Equator and for ensuring that the onboard systems are fully functional at all times. Data on the status of the nine Inmarsat satellites is supplied to the SCC by four tracking, telemetry and control (TT&C) stations located at Fucino, Italy; Beijing, China; Lake Cowichan, western Canada; and Pennant Point, eastern Canada. There is also a back-up station at Eik in Norway. A call from an Inmarsat mobile terminal goes directly to the satellite overhead, which routes it back down to a gateway on the ground called a Land Earth Station (LES). From there the call is passed into the public phone network. The Inmarsat I-3 satellites are supported by four previous-generation Inmarsat-2s, also in geostationary orbit. A key advantage of the Inmarsat I-3s over their predecessors is their ability to generate a number of spot beams as well as single large global beams. Spot beams concentrate extra power in areas of high demand, as well as make possible the supply of standard services to smaller, simpler terminals.

Launched in the early 1990s, the four second-generation Inmarsat I-2 satellites were built to Inmarsat specification by an international group headed by British Aerospace (now BAE Systems). The three-axis-stabilized Inmarsat I-2s were designed for a 10-year life. Inmarsat-2 F1 was launched in 1990 and is now located over the Pacific, providing lease capacity. F2, launched in 1991, is over the western Atlantic, providing leased capacity and backing up Inmarsat I-3 F4. Also orbited in 1991, F3 is stationed over the Pacific Ocean, providing lease capacity and backing up Inmarsat I-3 F3. The fourth Inmarsat-2 was launched in 1992 and is used to provide leased capacity over the Indian Ocean and backing up Inmarsat I-3 F1 and Inmarsat I-3 F3.

Launched in 1996-8, the Inmarsat I-3s were built by Lockheed Martin Astro Space (now Lockheed Martin Missiles & Space) of the USA, responsible for the basic spacecraft, and the European Matra Marconi Space (now Astrium), which developed the communications payload. The Inmarsat I-3 communications payload can generate a global beam and a maximum of seven spot beams. The spot beams are directed as required to make extra communications capacity available in areas where demand from users is high. Inmarsat I-3 F1 was launched in 1996 to cover the Indian Ocean Region. Over the next two years F2 entered service over Atlantic Ocean Region-East, followed by F3 (Pacific Ocean Region), F4 (Atlantic Ocean

Region-West) and F5 (limited services on a single spot beam, back-up and leased capacity).

Responding to the growing demand from corporate mobile satellite users for high-speed Internet access and multimedia connectivity, Inmarsat has been building its fourth generation of satellites. The company awarded European spacecraft manufacturer Astrium the contract to build the three Inmarsat I-4 satellites. The job of the satellites will be to support the new Broadband Global Area Network (BGAN), currently scheduled to enter service in 2005 to deliver Internet and intranet content and solutions, video-on-demand, videoconferencing, fax, e-mail, phone and LAN access at speeds up to 432kbit/s almost anywhere in the world. BGAN will also be compatible with third-generation (3G) cellular systems. The satellites, the world's largest commercial communications satellites, will be 100 times more powerful than the present generation and BGAN will provide at least 10 times as much communications capacity as today's Inmarsat network.

IRIDIUM AND OCEAN OBSERVATIONS

Why did ONR choose to develop the Iridium data modem?

The Iridium Satellite System is the only provider of truly global, truly mobile satellite voice and data solutions with complete coverage of the Earth (including oceans, airways and Polar regions). Iridium provides benefits such as enhanced system reliability and capacity; it eliminates the need for multiple regional gateways, reducing associated costs and eliminating a potential regional "single point of failure." In addition, ISL allows the capability of global coverage without signal latency in either voice or data mode.

Figure 8: Iridium Satellite Constellation

The Iridium constellation consists of 66 operational satellites and 13 spares orbiting in a constellation of six polar planes. Each satellite is cross-linked to four other satellites: two satellites in the same orbital plane and two in an adjacent plane.

Iridium provides a greater data throughput capacity than Argos without the associated latency. As previously addressed, in the Argos system, data is often stored on tape for later downlink with latency timeframes. Iridium covers areas not serviced by Globalstar or Orbcomm. In addition, as Iridium satellites orbit at 780km above earth, considerably less power is required to relay data as compared to the GEO Inmarsat system, positioned 33,600km above the earth. For many of these reasons, the DoD entered into a series of telecommunications service contracts with Iridium through 2008 and developed a DoD owned and operated gateway in Hawaii.

In addition, there are now a variety of Iridium data communications capabilities to support the user specific requirements. Information on dial-up, direct internet, Router-based Unstructured Digital Inter-Working Connectivity Solution (RUDICS), Short Burst Data (SBD) and Short Messaging Service (SMS) were addressed by Iridium Satellite LLC during the workshop. Please see the brief by Scott Scheimreif and Kent Keeter (Iridium Satellite LLC) at http://www.ocean.us/documents/iridium.jsp for additional information.

The silver 9500 Iridium data modem was the first version modem developed under the ONR SBIR initiative and was distributed to many workshop participants. The 9505 modem followed, with significantly enhanced hardware and firmware. Finally, the Iridium data modem with integrated GPS module and micro-controller was developed.
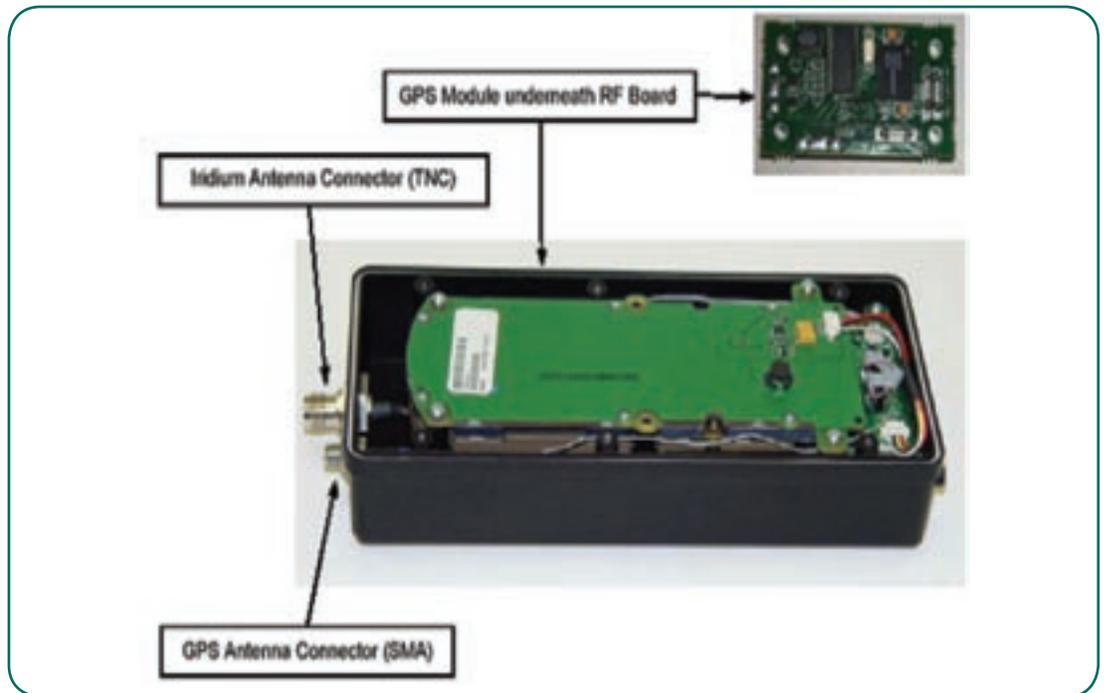
Figure 9: Iridium Data Modems and Modem with GPS

9500 Iridium Data Modem

9505 Iridium Data Modem

9505 Iridium Data Modem with GPS

WORKSHOP REPORT

WORKSHOP REPORT
Iridium Applications and Field Results
Mobile Applications, High Latitude Applications and Fixed Platform Working Group Findings

The following briefings, summarized below, are available on the Ocean.US website, http://www.ocean.us/documents/iridium.jsp, were presented:

Supplemental Contribution: Overview, Performance and Reliability from Summer 2004 SUMMIT, Greenland Field Experiments July 14-July 25, 2004 - Victor Frost, (University of Kansas)

A 24x7 9600 baud Continuous Mobile to Mobile Connection for Network to Network Connectivity - Gary L. Ferentchak (Raytheon Polar Services)

Using Iridium to Transmit Geodetic GPS Data from Remote Antarctic Installations - Paul Tregoning (Australian National University)

Experiences with an Iridium Based Communications System in Polar Regions - Victor Frost (University of Kansas)

Polar Experience with Iridium: Dial-up and SBD - David Meldrum and Duncan Mercer (Scottish Association of Marine Sciences)

Experiences with Real-time Data Retrieval from Remote Observatories using Iridium Communications Links - Dan Detrick (University of Maryland)

Iridium Data Transfer from North Pole Deployed Ocean Flux Buoys - Tim Stanton (U.S. Naval Postgraduate School)

Communications in Rapid Environmental Assessment - Alex Trangeled (NATO SACLANT Center)

Experiences with Real-Time Data Retrieval from Remote Stations using Iridium; and Data Distribution: GTS and IOOS - Steve Collins (U.S. National Data Buoy Center)

Seaglider Communications Performance: Results from Two Years of Open Ocean Operations - Neil Bogue and James Bennett (University of Washington)

ARGO, Profiling Floats, and Iridium - Stephen C. Riser and Dana Swift (University of Washington)

First Experiences with an Iridium Telemetry System on the DOLAN Buoy in the Atlantic - Eberhard Kopiske (University of Bremen)

An Overview of PMEL Iridium Ocean Observatories - Christian Meining (Pacific Marine Environmental Laboratory)

Real-time Over-the-horizon Communications for MBARI's Ocean Observing System AOSN II - AOSN II Video - Lance McBride (Monterey Bay Aquarium Research Institute)

Gulf of Maine Ocean Observing System (GoMOOS) - Robert Stessel (University of Maine)

Experiences with a Small Moored Surface Telemetry Buoy Including the Subsurface Inductive Data Link - Andreas Pinck (Institute für Meereskunde, Universität Kiel)

Use of Iridium in a Small Moored Buoy, and on a Large Commercial Vessel - Jonathan Campbell (Southampton Oceanography Center)

Iridium Enabled TCP/IP for Coastal Ocean Observing Systems - Christopher Calloway (University of North Carolina)

Iridium Satellite LLC, System Update - Scott Scheimreif and Kent Keeter (Iridium Satellite LLC)

Workshop participants are identified below.

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Following the briefings, attendees were divided into Working Groups, to focus on issues related to mobile, fixed and high latitude applications. Working Group findings are addressed later in the proceedings.

Overview of briefings presented:

United States Antarctic Program, Supervisory Control of Iridium LBTs for Continuous Multi-Channel ML-PPP Applications, Gary Ferentchak, Raytheon Polar Services

- NSF tasking to utilize multi-channel (four) modems to provide continuous network to network link between the South Pole and Denver
  - Modems (ISU to ISU) were used with a Cisco 2651 Router with ASYNC card
  - DoD and commercial SIM cards used
  - Using Data-After-Voice Mode (to reduce latency)
- Information on the frequency of dropped calls
  - Average drop for Denver to Denver calls ranged from 2 hours and 2 minutes during night and weekends to 30 to 40 minutes during prime business hours
  - Average drop for Denver to South Pole ranged from 20 to 25 minutes on good days to 10 - 20 minutes on bad ones, although it did "clear up some" later on
  - Help provided by Iridium and Boeing in moving the RTAD from McMurdo Station to South Pole
  - Early testing showed 13.8 drops per channel per 24 hours
  - Noted non-responsive units
- Issues/Problems
  - Self-initiated Internal Power-Down (DAV) (95%)
  - UART Lock-up (4%)
  - Occasional Failure to present DSR (less than 1%)
  - Continuously working with Boeing and NAL Research
  - CISCO router successfully recovers responsive LBTs and reestablishes the recovered channel into the ML-PPP session - all the while managing data flow through the remaining channels - if the LBTs are responsive!
  - Noted a requirement to be able to profile signal strength and to correct self-initiated power-down
- Post Conference Testing and Information
  - John Rice from Iridium stated that the problem causing power-down and UART lock had been determined and corrected.
  - Subsequent LBT testing with the SIM reader hardware upgrade and firmware upgraded to SAC0309 has shown the incidences of non-responsive LBT behavior has been reduced from occurring on an average of once per 7.25 hours per channel to more than 140 hours per channel.
  - NAL Research now offers a commercially available LBT with auto detection and recovery from non-responsive behavior.

- Dr. Hoang from NAL Research noted software is now available to profile signal strength
- The 9505 modem and modem with GPS provides a more robust and consistent capability than the 9500 modems

Transmitting GPS data from Remote Installations in Antarctica Using the Iridium System, Paul Tregoning, Research School of Earth Sciences, The Australian National University Canberra, ACT Australia

- The goal was to measure the rate of present-day rebound of the Antarctic continent
  - Amount and timing of melting of ice sheet
  - Implications for present-day global sea-level change
  - 4 sites installed - visited once a year - solar powered
    - fully automated
    - 2 with Inmarsat-B
    - 2 with Iridium
  - Inmarsat is expensive, difficult to install, high power consumption, 9600 baud, high success rate of transmission
  - Iridium is less expensive, small and easy to install, low-power requirement, 2400 baud, variable success rate of data transmission
- Transfer process
  - TP400 computer running Linux
  - Data transfer using the program "Kermit"
  - Dialup system to connect to a computer in Canberra running Unix
  - Transfer of files
  - End connection
- Satellite modem can send calls but could not receive them (problem?)
- Transmission success rate
  - 37% total failure
  - 39% partial failure
  - 24% completed
  - Good weeks and bad weeks
  - How do we fix the data dropout rate
- Several attendees commented that significant problems exist with Kermit that probably contributes to poor transmission success rates
- General impressions of Iridium
  - Hardware simple to incorporate and transport
  - Low power consumption is very attractive
  - Provides comms in locations where Inmarsat is too difficult
  - Disappointing success rate of GPS data transfers
  - Why do the data transmissions drop out?

- Polar Radar for Ice Sheet Measurement (PRISM)
- Previous work included a 4-channel Iridium system
  - Conclusions from 2003 field experiments
    - Developed a reliable multi-channel Iridium
    - Data communication system based on Iridium satellites that provide round the clock, pole to pole coverage
    - Developed console based link management software that ensures fully autonomous and reliable operations
    - End-to-end network providing Internet access to science expeditions in Polar Regions was demonstrated
    - System efficiency greater than 90% achieved
- Several attendees commented that significant problems exist with Kermit that probably contributes to poor transmission success rates
- 8-channel Iridium System
  - Design Elements
    - Integrated 8 modems and components in an 19" rack mount unit
    - Single board EBX format system
    - PC104 type multi-port serial card
    - Integrated LCD screen
    - Developed GUI based management/control software that configures the unit in all the data modes; a) ISU-ISU DAV mode, b) ISU-ISU data mode, c) ISU-PSTN mode
    - XML database registers all call drops and retrials

  - Results
    - Average throughput efficiency was observed to be 95% from test cases where no call drops were experienced
    - Average throughput during the FTP upload of large files was 15.38 Kbps
    - Call drops reduced efficiency to ~ 80%
    - 14 July test (12 hours)
      - Call drop pattern during 8 ISU - 8 ISU DAV mode test
      - 89% uptime with full capacity (8 channels); 98% uptime with at least one modem
      - Total number of primary call drops during 12 hours = 4
      - Average time interval between drops is 180 minutes
    - Results of 19 and 22 July tests presented
      - Call drop pattern during 8 ISU-8 ISU DAV mode test
      - 85% uptime with full capacity (8 channels); 96% uptime with at least one modem
      - Total number of primary call drops during 32 hours = 24
      - Average time interval between drops is 72 minutes
    - Mobile testing conducted with success
- Conclusions
  - Integrated 8-channel system works "out of the box"
    - Reliable and fully autonomous operation
    - The throughput and delay performance of the system using the ISU-ISU DAV mode is better than other data modes
  - Newly develop GUI-based control software reduced field setup time, increased the ease of operation and is suitable for use by non-technical users
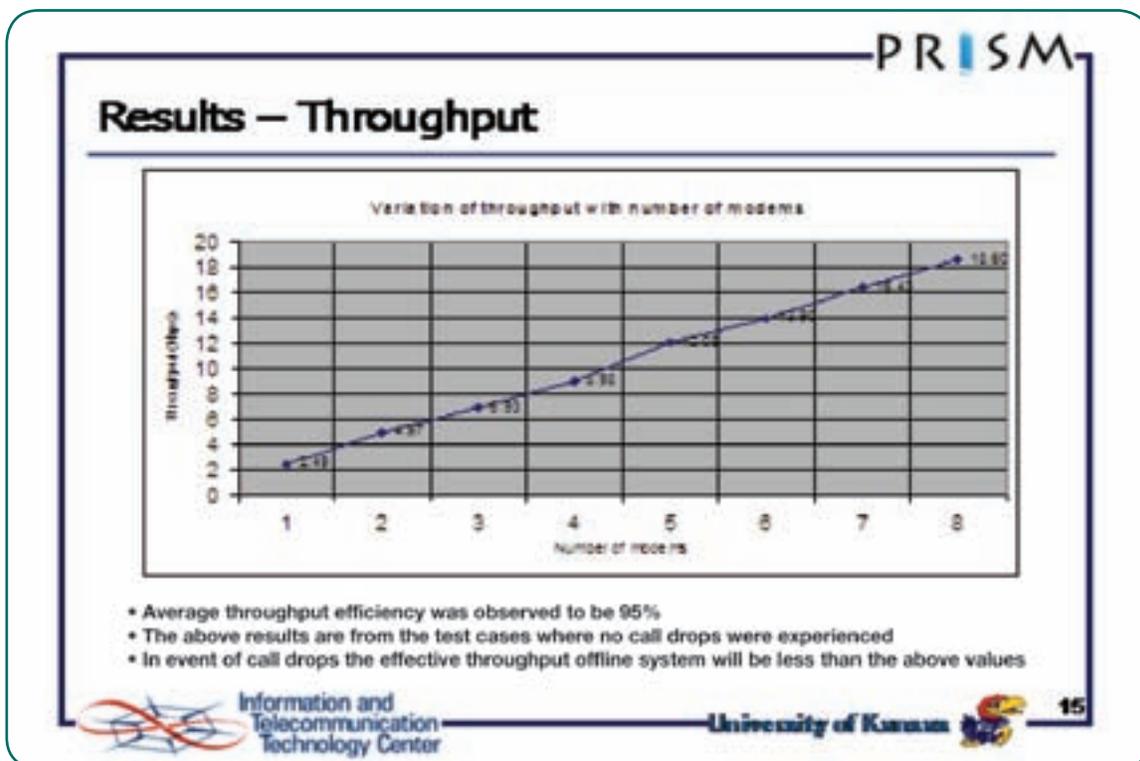
- System performance based on field experiments
  - Average throughput with 8 channels is 18.6 Kbps, efficiency >90%
  - Average uptime with full capacity using DAV was 85%
- Average time interval between call drops is 60 minutes and varies a lot
- Better performance using ISU-ISU DAV modem than other modes
- System worked well on the move with GPS

■ Lessons learned
- Modem firmware failures were experienced - modem locks up randomly and needs power cycling. Problem is not severe and occurred less than 5 times during the experiment.
- Due to a bug in Linux pppd software, a call drop on the primary modem still causes the entire bundle to drop

■ Recommended future work is outlined to understand and enhance the MLPPP Iridium System
- Call drops need to be categorized and studied
  - Due to poor signal strength
  - Handovers
  - Other reasons
- Upgrade modem firmware
- Develop user-friendly GUI based server software
- Research and correct pppd bug

Polar Experience with Iridium: Dial-up and SBD, David Meldrum and Duncan Mercer, Scottish Association of Marine Sciences (SAMS)

■ SAMs active use of Argos (1980) and Orbcomm (1999)
■ Iridium for polar applications
■ History repeats itself (Iridium)
- Early problems with Argos
  - Does it work?
  - Whom do you contact?
    • DBCP (1985)
    • Technical coordinator (1987)
- Based at Argos Toulouse
    • Successful
■ CASES Deployment
- Three "pancake ice" buoys deployed (between 70 and 72 degrees North and 120 degrees West)
- SBD packets of 892 bytes - 8 messages per day
- 2000 messages in total
- Transmission rate of up to 740 Baud
- 10% lost messages
- 100% of messages correctly acknowledged
- Problems with mail server: data lost!
- The question was asked if SBD can be sent to more than one site. SBD can now be sent to a maximum of 5 sites.
■ GreenIce Dial Up
- COMMS cost $115K for 6 months
- Dial up problems with "no connect"
- Transfer files of 37 Kbytes
- First 2 weeks the average transfer time was 120 seconds

- 3100 Baud!
■ Iridium conclusions
- Excellent potential for higher data rates
- Real-time interaction with mobile
- 1 or 2 orders of magnitude more energy efficient than Argos or Orbcomm
- 10 cents/Kbytes for dial-up
- SBD costs
  - $1/kbyte
  - Easier to implement
  - Expensive for large datasets
- Still lots to learn
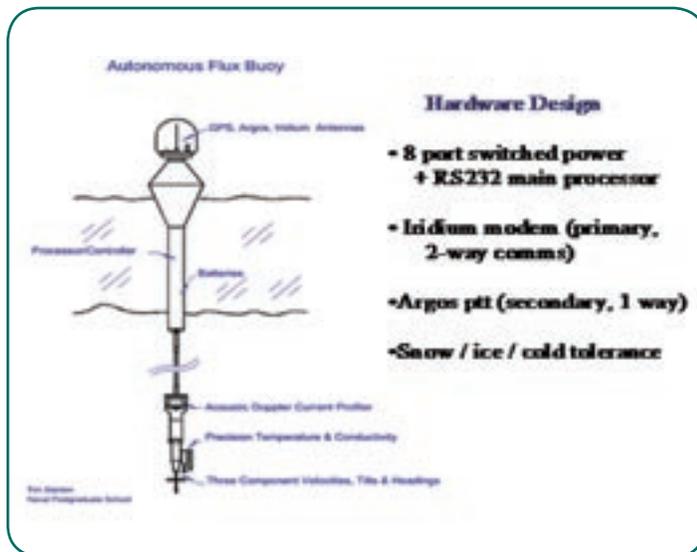 - **Much better technical information/support needed!**

Experiences with Real-time Data Retrieval from Remote Observatories using Iridium Communications Links, Dan Detrick, T.J. Rosenburg, J.E. Etter, and L.F. Lutz, University of Maryland, Rick Sterling, Stephen Mende, University of California, Berkeley and Noel Petit, Augsburg College

■ **P**olar **E**xperiment **N**etwork for **G**eophysical **U**pper-Atmosphere **In**vestigations (PENGUIn)
- System originally deployed with the AGOs - recorded data to on-site hardware which was retrieved during annual servicing visits
- New data system using Iridium installed in December 2002; linked to CONUS computer allowing real-time data retrieval and distribution
  - Capable of autonomous action to remedy anticipated faults at data acquisition unit or Iridium modem
- Data made available to researchers in real time via FTP server
- 2-MB dual-port memory buffer inserted between the data acquisition unit and the Iridium modem with data throughput managed by microcontroller
- CONUS PC and data acquisition unit programmed to recognize anticipated communication interruptions and perform corrective action
- 20-MB/day throughput
- Iridium data system integrated and tested for instrumentation on three AGO systems
- December to March 2002, 1.5 GB of data was sent from the three AGOs with sustained data throughput of about 20 MB per day
  - Although frequent losses of signal between paired Iridium modems, connections are capable of transferring 98% of the data
  - Data availability achieved by cycling the data acquisition from the VLF Snapshot channel and by commanding the unit to run the channel on/off
■ Summary of Iridium Experiences
- Very happy with Iridium
- Iridium link
  - AT modem command language (modem-to-modem connection)
  - Layer 2 networking protocol (data line: CONUS

DAS<->DAW firmware)
- Fixed-length data frame (2053 bytes)
- Verified frame reception
- No data loss due to transmission errors
o Iridium disconnections
- LOS ~4-5/hour, 2002/2003; ~15-20day, 2003/2004
- Autonomous re-dial
o Data throughput
- 20-MB/day (per Iridium channel)
- Achieved 98% of channel capacity, even with interruptions

[Iridium Data Transfer from North Pole Deployed Ocean Flux Buoys](#), Tim Stanton, Oceanographic Department, U.S. Naval Postgraduate School

■ Autonomous Flux Buoy
o 2-way communications
o 20 to 200 Kbytes/day data transmission (buoy status, position, ice velocity, mean fluxes) and selected raw data blocks of (u, v, w, T, S)
o Adaptable sampling
o 9500 Iridium modem; fallback to summary messages via Argos

Autonomous Flux Buoy

Hardware Design
- 8 port switched power + RS232 main processor
- Iridium modem (primary, 2-way comms)
- Argos ptt (secondary, 1 way)
- Snow / ice / cold tolerance

■ Remote selection of data types to output, sample intervals, sample duration, sub-intervals, remote programming of sample-doubling threshold, remote monitoring of buoy performance parameters and settings and monitor values updated with each transmission
■ Data communication solution
o Iridium direct dial-in to NPS workstation
- Quick connect, low overhead protocol
- Relatively simple software design
- Built in tolerance to "no connects, dropped connects"
- Built in hand-shaking block by block data transfer protocol

- Large buffer for outbound blocks to overcome service drops
o Fallback on one way, summary data transfer via Argos
o Iridium data transfer performance
- Statistics for a 6 month period
- Dial-in success rate of 94.9%
- 350 connect attempts
• 325 full data transfer success
• 12 had no successful data transmission
• 13 transmitted at least 1 data block
- 93% of calls were fully successful, 7% had dropped calls
- Effective throughput of 25 KB transfers was 1979 Baud
- Effective Baud rate on 132 KB transfers was 2949 Baud
■ Summary
o Iridium is an excellent solution for the 20-200KB/day data transfer requirement in polar regions
o Two-way data communications is great
o The direct dial-in protocol was quick to develop and effective, but does not scale well to large deployments
o Two-way communication exploited to provide adaptive sampling and diagnostic capabilities
o Care needed with snow/ice covering antenna
o Would be great if there were a slow-charge method for the super capacitor in the 9500 …this is an unnecessary burden on batteries/switchers at turn-on

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Communications in Rapid Environmental Assessment, Alex Trangeled, Daniel C. Conley, NATO Undersea Research Centre, La Spezia, Italy

- Rapid Environmental Assessment definition: "The acquisition, compilation and release of tactically relevant environmental information in a tactically relevant time frame"
  - Wave height, surf zone width, longshore current strength are of critical importance in planning for amphibious operations, mine clearance and special operations
  - Goals include
    - Develop efficient information distribution architecture and communications paths
  - EMACS highlights
    - Configurable for a variety of sensors
    - Remote configuration and control
    - Transmission via LEO satellite and/or wireless network
    - Low-cost COTS = disposable
    - Prototypes built for real time surf monitoring
    - Hardware - Eurotech; CPU-1232; Coastal Environmental Weatherpak; Iridium modem
- VSAT, Globalstar and Iridium used for various applications
  - VSAT provides the greatest throughput, followed by Globalstar
  - Iridium deemed "best choice for sensor/portable Tactical Decision Aids"
    - Notes worldwide coverage, end-to-end encryption and dedicated defense gateway
    - Used 9500 modem

National Data Buoy Center's Experiences with Real-Time Data Retrieval from Remote Stations using Iridium; and Data Distribution: GTS and IOOS, Steve Collins, U.S. National Data Buoy Center

- New requirements are making data streams longer and more frequent
- Data flow for moored buoy system utilizing Argos to include data acquisition and transmission times
- GOES alternative development
  - May 2002 - tasking for non-GOES communication system
    - Iridium selected for best coverage
  - Testing on 3 meter discus buoy conducted in Gulf of Mexico
    - 98% throughput with Iridium compared to 81% for GOES
    - Certified for operational use in December 2003
  - Concept of Operations
    - One "passive" remote modem per station
    - One to several "active" base station modems
    - All calls originated by base stations
    - PC software-controlled base station
      - Remote stations "listen" for incoming calls on programmed schedule for power management
   - Iridium provided real-time data communications

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  - Base Station Issues
    - Antenna cable length limited to less than 3bD loss
    - Satellite visibility
    - Will require additional base stations
    - Security
      - No "firewall" on remote station
      - Security limited to general public not knowing station phone number for incoming calls
      - Cannot make outgoing calls (Note: Iridium does provide the capability for two-way data communication)
    - Anticipated Improvement
      - Multi-channel Iridium modems for base station
        - Reduce equipment cost
          - > Fewer PCs and modems
          - > Will require software change
          - > Benefits - Iridium vs GOES
      - Increase in data availability over GOES
      - Lower power requirement
        - Power available for more frequent observations
        - Potential reduction in power system failures
      - Potential for more data
      - Remote two-way communications
      - Potential cost savings in field service using remote "repair" and diagnostics
      - Shore-side event driven reporting possible
    - Concerns
      - Telecommunications costs (compared to no usage costs for GOES)
      - Unknown future pricing
      - Base station requirements for comms with 150 remote stations
      - Performance in severe environments/weather events
    - Plans
      - Install on 2 new buoys (summer of 2004)
        - Funded by USCG
        - Top of hour GOES transmissions, bottom of hour Iridium transmissions
      - Install on DART buoys
      - Install on prototype USCG Automated Identification System (AIS) equipped buoy
  - Potential to install on all moored buoys and most C-MAN platforms for USCG AIS communications
  - Overview provided for NDBC data assembly center

Seaglider Communications Performance: Results from Two Years of Open Ocean Operations, Neil Bogue and James Bennett, University of Washington

■ Provided overview of Seaglider
  o Used components of Iridium 9500 phone for communications
  o Would have preferred a data modem


Iridium Phone and RF Switch
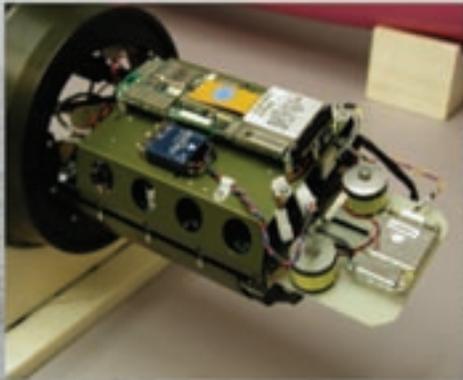
  o Combined GPS-Iridium antenna developed
    - Pressure-tested to 1000m
    - Available for $2,200 (randyf@u.washington.edu)
  o Software goals
    - Maximize ability to locate and control vehicle
    - Minimize time on surface and energy spent transmitting data
    - Permit graceful recovery from missed or incomplete calls
  o Modified xmodem protocol
    - Sent files in fragments
    - Automatic change in buffer sizes during marginal connections
    - Ability to resend whole dives or fragments
  o Next steps
    - Compression using gzip
    - Investigate PPP
      • Unsuccessful to date
      • Balky embedded TCP/IP stack
      • Large code size and protocol overhead
■ Testing conducted in the Washington Coast, Gulf of Alaska, and Labrador Sea
  o 1907 dives
  o Connection statistics range form 75% on first attempt in Washington Coast to 35% for the Labrador Sea (SG008)
    - Labrador Sea (SG004) first attempt success rate was 56%
    - Connection statistics deemed to be marginal

ARGO, Profiling Floats, and Iridium, Stephen C. Riser and Dana Swift, University of Washington

■ Profiling floats…a modern method of observing the state variables of ocean circulation
  o Great interest in expanding the capabilities to include new sensors and communications links
    - Issues: power, weight, unattended
  o Communications: Service Argos (~0.1 baud)
  o ARGO is an international program designed to deploy 3000 profiling floats at 300 km resolution - first real-time situ ocean observing system
    - Present status: 1244 deployed by 14 nations
  o UW float group built and deployed over 400 profiling floats in past 6 years
  o Example float
    - Profile contains 500 bytes of data (3 variables x 2 bytes x 71 sample depths + engineering data)
    - Requires 6-10 hours per profile transmitting using Service Argo system
  o Built several floats that use Iridium; deployed as surface drifters in the Antarctic Circumpolar Current
    - Results show that data can be transferred using real 2-way communication at nearly 2400 bps
    - Mission parameters can be changed in real-time
    - Cost is comparable to…Service Argos
    - Service Argos: 500 byte transfer require ~9 hr; Iridium: 20Kb transfer requires < 10 min!

Drifter with Iridium unit installed
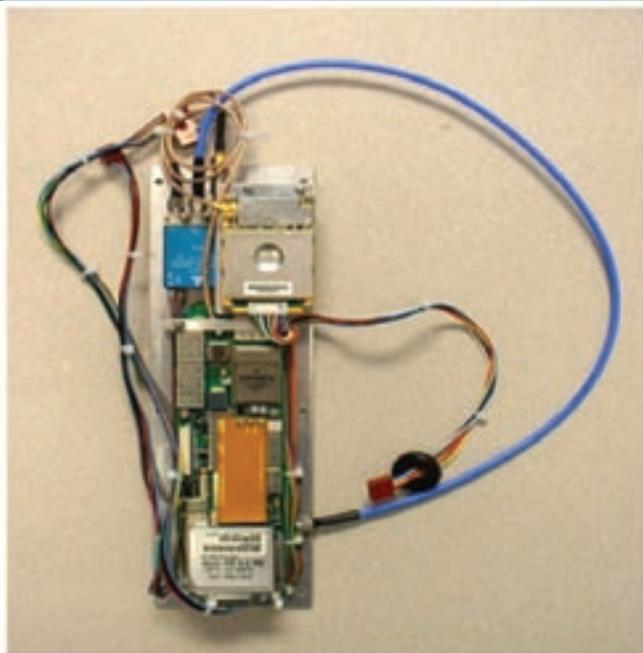
Iridium modem (in this case a 9500 phone unit) and GPS unit

- Used 9500 phone and GPS unit
- Usually a connection is established on the first attempt; in a few cases 2 or 3 attempts are necessary
- In most cases the full 20Kb file can be transferred in one connection
  o Summary
    - Profiling float technology is advancing rapidly - many uses
    - Major improvement in these floats will come if and when Argos is replaced with Iridium
      - Much faster data transfer rates
      - 2-way communications will be possible
    - First deployment of the Argo/Iridium float anticipated summer of 2004

First Experiences with an Iridium Telemetry System on the DOLAN Buoy in the Atlantic, Eberhard Kopiske, University of Bremen

- Overview presented on the DOLAN Sensor/Telemetry
- DOLAN Surface Buoy
  o Tracking: Inmarsat Mini-C
  o Orbcomm communications
  o Satel Packet Radio
  o Wind speed/direction
  o Acoustics Sub-Sea Modem
- Iridium Telemetry on DOLAN buoy
  o NAL Iridium modem
  o Embedded PC (ELAN 520 Processor)
  o GPS Sensor
  o Automatic e-mail (GPS data) generated every two hours

- Experiences with Iridium
  o Satellites accessible from every location on the Atlantic
  o Iridium sessions last for 2 to 60 minutes without break down
  o Log-on to satellite is difficult during two time windows - UTC 7:00 and UTC 10:00 for approx one hour each
  o Much better availability of satellites for high latitudes than for example Orbcomm
  o Problems occurred during development and testing
    - The structure on how Iridium works is not very clear
      - Settings like 'AT+CBST=7,0,1' and prefix number for dialing
      - How can we access the modem (which prefix number) via Iridium?
  o Short Burst Data (SBD) will be very useful but it wasn't available for testing (Note: SBD has been completed and provides a cost effective means to relay packets of data)
- Experience with DoD SIM Cards/NAL Modem
  o Satellite signal strength not available via AT commands (NAL Modem) only one LED indicates a satellite in view (Note: you can now check signal strength using an AT command)
  o 9505 mobile phone more robust than NAL 9500 modem
    - Many situations phone can log on the satellite when modem could not
    - Most of the received modems were not able to log on
  o Computer does not recognize "No Carrier" from Modem (DSR)
- Our "wishes"
  o Standby mode with low power consumption (Note: Standby mode now available)
  o Support of cellular AT commands
  o Higher data rates
  o Compression
  o Comprehensive documentation of hard- and software interfaces
  o Firmware upgrades (Note: Firmware has undergone several upgrades)

An Overview of PMEL Iridium Ocean Observatories, Christian Meining, Pacific Marine Environmental Laboratory

- PMEL Engineering Development Division
  o Mission is to support PMEL research effort with innovations in the fields of digital and analog electronics, mechanics, materials, and software engineering
- FY03 Support
  o 30 cruises on 11 different ships; 260 DAS
  o Over 180 moorings deployed, 48ea 40' container shipped
  o End-to-end support serving NOAA's missions
- Developed a number of PMEL Iridium Systems

PMEL Iridium Systems

PMEL Iridium Linux Server
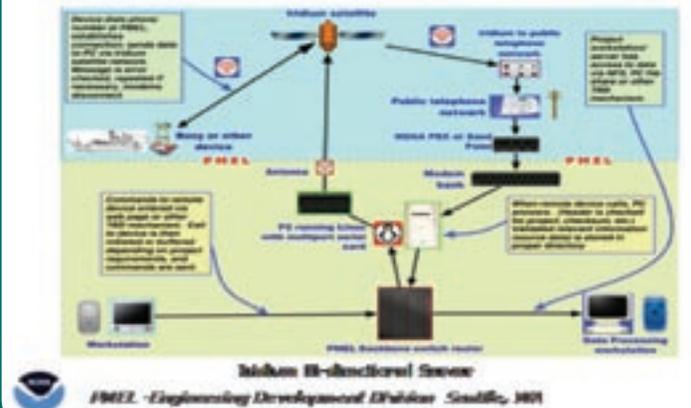
- NemoNet Goals - understand and quantify volcano's impacts on surrounding ocean's…environment
  - Real time bi-directional buoy-based ocean observatory (1yr) w/low bandwidth (10Kb/day) needs
  - Web-based
  - Iridium replacing Orbcomm
- Prototype next-gen "Tsunameter"
  - GOES (Sutron) 80% return (some firmware issues)
    - High power!
    - Not bi-directional
  - Iridium 95% return
    - Protocol based on acoustic modem experience
    - Will Iridium be around?
    - Iridium can contact buoy to send at higher data rates
    - very happy with the data rate provided by Iridium
  - Wants desktop to seafloor in 3 minutes
- PICO (Platform and Instrumentation for Continuous ocean Observations)
  - "Buoy in a box" - internal antenna
    - Costs are high
    - Complex and dangerous operations
    - Large buoys
    - Limited subset capabilities
    - Vandalism problems
    - Design challenges outlined

PICO electronics

- Asset Tracker: Iridium Position System developed along with the PMEL Iridium Linux Server
- Future development: Air Deployable Surface Buoys?
  - Viable alternative compared to UNOLS and NOAA ship costs
  - Worldwide deployment capability
- Future Iridium Development Wish List
  - Data Services Provider
    - Add metadata, calibrations GTS, bi-directional, etc.
  - Higher QC on Iridium modems
  - TCP/IP for embedded systems
  - Reduce dependence on POTS (plain old telephone system)
  - Smaller, cheaper, faster
- Much confusion on architecture - SMS, SBD, dial-up, RUDICS, direct internet
- Need funding for dedicated technical support

Real-time Over-the-horizon Communications for MBARI's Ocean Observing System
AOSN II - AOSN II Video, Lance McBride, Monterey Bay Aquarium Research Institute

- MBARI Ocean Observing System (MOOS)
  - Buoy
  - AUV Dock
  - Benthic Instrument Node (BIN)
  - Stand-alone remotely deployable cabled observatory
  - Delivers OEM cable to seafloor
  - System requirements
    - Readily configurable
    - Real-time interaction
    - Event response
    - Affordable
  - MSE 2005 Benthic Science Instruments
  - Data Requirements - as planned
  - 257Kb/day to 3.3MB/day
  - Telemetry - Data Publishing
    - Buoy dials shore modem periodically
    - Establishes PPP link to portal computer
   • Buoy publishes recently archived data on portal
    - Buoy disconnects

- Portal publishes data to shore-side data system through firewall
o Telemetry - Instrument Services
  - Buoy dials shore modem periodically - or RF reset initiated
  - Establishes PPP link to portal computer
    • Portal publishes buoy DNS information
  - Shore computer opens remote console on buoy via ssh
  - Shore computer establishes console to instrument
    • Remote configuration/diagnostics/driver updates
    • Add instrument and remotely start instrument service
o Iridium and Globalstar considered
  - Iridium covered all areas of interest - Globalstar did not
o Globalstar @ 7.4kbps; Iridium @2.4kbps
  - More Iridium airtime needed to send data - higher airtime cost
  - Globalstar testing and integration
    • Qualcomm GSP-1620 utilized
    • Reliable 7.6kbps for IP traffic over PPP line
o Iridium testing
  - 9500 Iridium modem
  - Fixed mast antenna model SAF5350
  - Buoy spends most time between 0 and 20 degrees
  - Signal strength noted as issue
  - Results
    • FTP'd multiple small files of varying formats
      ♦ .zip, .jpg, .gif, .pdf, .txt, .rtf
      ♦ File sized from 1.5 to 15kB
    • Tilted antennas to predefined heading and angle to simulate buoy motion
      ♦ Dial-up only
    • Also transferred large text file (100kB to 1MB)
  - Iridium testing results (small files)
    • "Dial-up data service" (tested in Linux) - AVE 2.04 kbps; MAX 6.0kbps; MIN 1.28kbps
    • "Direct Internet" service (tested in Windows)
      ♦ Compression from Brand Communications
      ♦ AVE 6.76 kbps; MAX 26.24kbps; MIN 1.36kbps
    • Noticed lower bandwidth at low angles than high angles
      ♦ Suspected antenna gain pattern
  - Iridium testing results (large files)
    • "Dial-up"
      ♦ MAX: 2.6kbps
      ♦ AVE 2.5kbps
      ♦ MIN 2.2kbps
    • "Direct Internet"
      ♦ MAX: 15.0kbps
      ♦ AVE 13.9kbps
      ♦ MIN 13.1kbps
    • Dropped link 4 times out of 16 at around 600kB

- Iridium testing (compression)
  • Large files compressed with WinZip
    ♦ 100kB to 1.24kB; 500kB to 3.39kB; 1.02MB to 6.055kB
- Changed components based on previous testing
- Used 9505 Iridium phone with data kit and auto adapter
- Test conclusions
  • Use optimized antenna for application
  • Transfer small files
  • Transfer pre-compressed files
o Data requirements
  - CIMT in Monterey Bay: 4.1MB/day
  - MTM2 in Monterey Bay: 1.1MB/day
  - Airtime cost; Iridium higher than Globalstar
o Future Plans
  - Reduce link overhead
  - Implement shore initiated link establishment
  - Deploy Iridium on buoy in regions outside Globalstar service area

Gulf of Maine Ocean Observing System (GoMOOS), Robert Stessel, University of Maine

■ Moored buoy system utilizing cell phone or Iridium LEO phone
■ GOES satellite transmitter (backup) Design goals
  o Real time data acquisition and display
  o Reliability
  o Serviceability
  o Expandability
  o Low Power Consumption
■ Future Plans
  o Fixes
    - Cell phone - cold WX
    - Met sensor - icing
    - Cable breakage
    - Instrument batteries
    - Solar Panel blowouts
    - Verify Power Budget
  o Additions include wave-3D, humidity, and active radar reflector
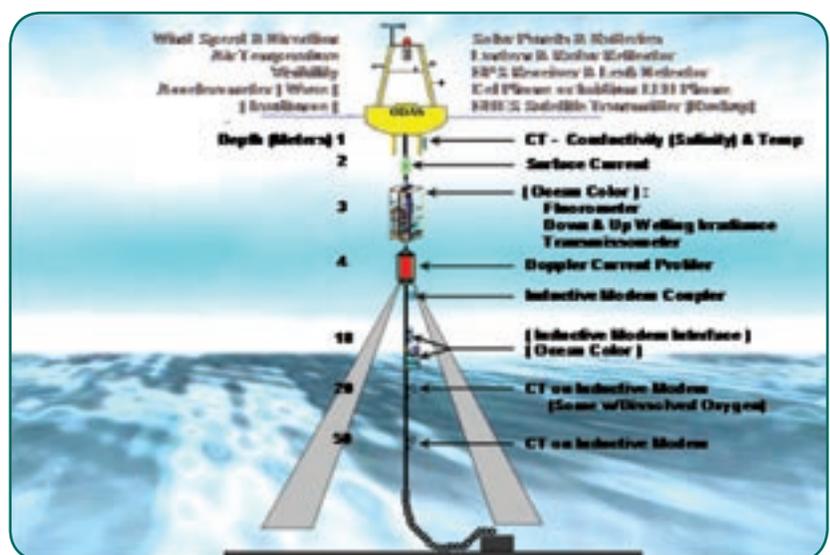
Andreas Pinck, Institute für Meereskunde, Universität Kiel

■ Provided overview of buoy system with subsurface data link

Surface Buoy
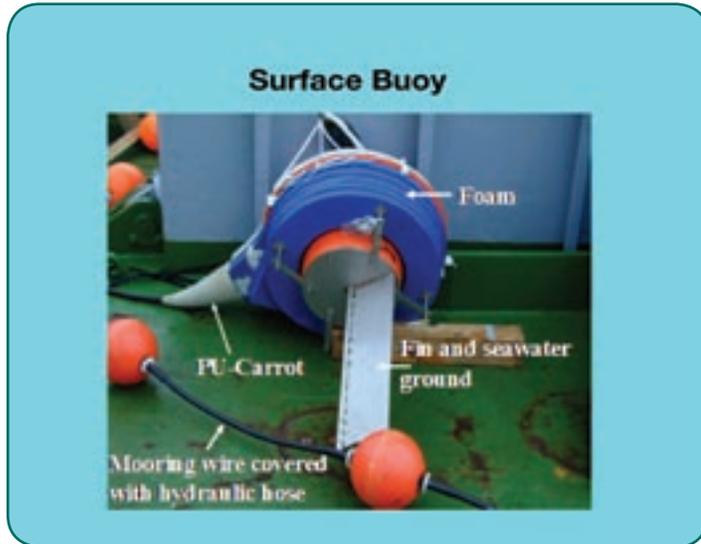
■ System specifications
  o Data sampling rate: 2h
  o Transmit rate: 4h
    - Repetition rate: 20s
    - Transmit duration: 110min
  o Data transmit mode: cycle of 4 blocks at 32 bytes
  o Information/time: 768byte/day
  o Power consumption/msg: 0.25Ah/kBytp
■ Utilized ARGOS transmitter
■ Next step is to utilize Iridium

Jonathan Campbell, Southampton Oceanography Center (SOC)

■ Iridium applications at SOC
■ Telemetry buoys on Inductive Moorings for the RAPID Climate Change Programme
  o 8 inductively coupled SeaBird CTD
  o 7 inductively coupled SonTek ADCP
  o Main underwater buoyancy at 50m
  o Iridium equipped buoy on 250m neutrally buoyant tether
  o 14 months duration
  o Iridium 9522 LBT
  o Seabird Inductive Modem
  o Trimble GPS receiver
  o 8 analogue sensor channels monitoring voltages and temperatures
  o Iridium Scheme
    - All calls initiated by buoy according to preprogrammed schedule
    - 66 byte SBD message sent every 2 hours with position and status parameters
    - Dials up every 8 hours and transfers up to 13kB of data

    - Sends data in 2kB blocks and waits for handshake response
  o Results
    - Buoy deployed 28 February
    - Inductive link damaged during deployment
    - Iridium communications ceased on 30 March
    - Unable to locate buoy on 8 May
    - Mooring will be recovered in Spring 2005
  o Iridium performance of the 31 days
    - All 377 SBD messages received
    - All 93 dial-up messages received
      • 5 of these required a second attempt
    - Due to broken inductive link, all dial-up messages were only 3kB
■ Testing of Combined Iridium/GPS antenna for use on Floats
  o Deployed 29 April
  o Trident systems developed antenna
■ European Ferry Box Project
  o Cost effective platform for measuring short and long term changes in Bay of Biscay
  o Uses Orbcomm since 2002
    - Sends 160byte message every 10 minutes
    - Data displayed on website within 1 hour http://www.soc.soton.ac.uk/ops/
  o Iridium to be installed next month
    - Running parallel with Orbcomm
    - Dial-up every 4 hours
    - Use simple 2kB block transfer protocol

Chris Calloway, University of North Carolina

■ Iridium used in multiple applications

    - Five Iridium efforts:
      • UNC: NCCOOS towers and Slocum Glider
      • USC: Caro-COOPS buoys
      • GA Tech: TriAXYS buoys
      • U of Miami: SWAMP profiler
  o Caro-COOPS buoys
    - ISU to ISU
    - Dedicated data logger (ZModem)
    - Shore dials in to observing platform

- Low throughput (100 bytes/sec)
o NCCOOS towers
- ISU to ISP
- SBC with instrumentation buss
- ISU "calls home"
- High throughput
- 2MB/day
o Utilized Iridium 9500 data modem
- Median burst rate: 7503 bytes/sec
- Average power consumption: 1 watt
- Transfer Rate Statistics (bytes per second)
  • Points: 460
  • Average: 6563
  • Median: 7503
  • 25 Percentile: 4417
  • 75 Percentile: 8334
  • Std Dev: 3047
  • Minimum - 200; Maximum - 13582
■ To do (includes)
o GPL; more statistics (connect rate, connect time); test 9505 modem; Iridium Data Gateway; ISAPI; Linus

Iridium Satellite LLC, System Update, Scott Scheimreif and Kent Keeter, Iridium Satellite LLC

■ Corporate overview provided
o System acquired Dec 2000
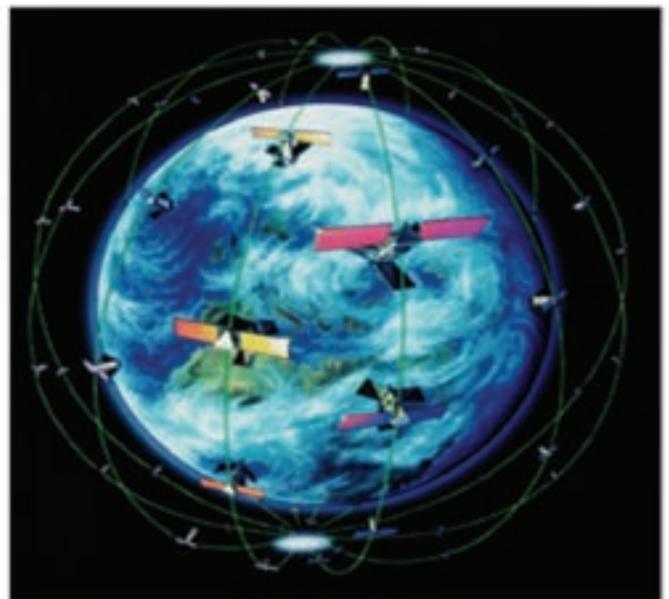o Commercial service re-introduced in March 2001

o Vertical market distribution strategy for voice and data services
o Strategic relationship with Boeing for satellite operations and maintenance
o 2013/2014 constellation life
■ Uniquely satisfies DoD's EMSS requirements
o Global pole to pole coverage
- Polar regions
- Ocean areas (no gaps)
o Uses Cross-Linking Satellites to relay data to secure DoD owned and operated gateway
o Independent from foreign infrastructure
o Seamless DSN Connectivity
o Enhanced DoD Services
o Secure on-the-move global voice/data for DoD's special requirements
■ Iridium Operational Usage includes
o Command and control
o Targeting
o Tracking
o Voice and data
■ Provided overview of Iridium communication capabilities
o Dial-Up
- PSTN or ISU
o Direct Internet/RUDICS (Router based Unstructured Digital Inter-Working Connectivity Solution)
- Faster connection time

Commercial Status
Constellation and Gateway

IRIDIUM

- **One Commercial Gateway Provides Global Connectivity**
  - Tempe, Arizona
- **DoD Gateway in Hawaii Supports US Government Traffic**
- **Satellite Constellation**
  - 66 Fully Operational Satellites
  - 19 In-Orbit Spares
  - Constellation Life to 2019/2014
- **Satellite Operations**
  - Main Facility in Leesburg, VA
  - Back-up Facility in Chandler, AZ
- **All Gateways Support Voice and Data Services**
  - Dial-up
  - Direct Internet Access
  - Short Message Service
  - Short Burst Messaging
  - Paging
  - RUDICS
- **36 Months of Continuous Growth**

- 15 seconds compared to 40 seconds for dial-up PPP
  - Transparent compression seamless connect/disconnect
    - Reduces on-air charges
    - Maximizes ISU battery life
    - No tail-end charges at Gateway
  - Smart connect
  o Short Burst Data (SBD)
    - "Ultra-efficient" way to transmit small accounts of data
      - 70 bytes in ~1 second
      - High reliability
      - Two-way exchanges
      - Limited power source
- Data After Voice (DAV) has shown a 7,400% increase from September 2001 to January 2004
- Attendees asked where they should go to procure SIM cards
  o Value Added Resellers offer airtime
- It was noted during discussions that RUDICS is standard or PPP, but PPP was is not available at the DoD gateway (PPP is now available at the DoD gateway)
  o RUDICS doesn't work with Linux
- A discussion item during the brief was that a DAV code problem had been causing units to "power-down", but that a fix has been implemented
- It was also noted that a PSTN can call an ISU that has a DoD SIM card but that a specific card is required

The second day of the Workshop began with an update from Dr. Ngoc Hoang, President and founder of NAL Research Corporation. Dr. Hoang noted that Iridium hardware had been significantly improved since the initial 9500 modem was developed. Many of the problems addressed during the Workshop had been corrected in the 9505 modem. Of particular interest were two issues. The Data-After-Voice (DAV) capability reduced latency but contained a bug in the firmware. The problem was isolated and corrected. Workshop attendees who have the 9500 modem can return the units to have them re-flashed with updated firmware. The second issue involved signal strength fluctuation that could cause the modem to lock up if operating in a continuous mode. This problem was corrected in the 9505 modem. He noted that the design of the next generation hardware, referred to as the Daytona, is underway and that a few prototypes will be available in the September timeframe. The Daytona should be ready for full scale production in about a year and will replace the DSC bus with a DPL bus. The new phone will be referred to as the Monaco.

Dr. Hoang addressed an ONR effort to develop a "soft SIM" capability that will utilize software contained in the micro-controller, eliminating the need for an actual SIM card. It would then be possible for multiple Iridium units to share a single SIM designator. Units could be programmed to report at varied intervals to ensure they do not interfere with each other. However, the effort is being delayed pending development of the Daytona model,

which will have different interfaces and protocols. Iridium Satellite LLC expressed concern as to how this capability would be managed and controlled.

In response to questions from the audience, Dr. Hoang explained how the 9505 phone is different from the modem. While there are only minor differences in the RF boards, the units utilize different sets of firmware and go through different boot-up processes. There is no difference between the 9505 and 9522 modems from a RF standpoint; both use the same OEM board. However, NAL adds other circuitry and firmware. In addition, NAL Research offers the only Iridium modems that have been HERO (Hazardous Electromagnetic Radiation to Ordnance) and HERF (Hazardous Electromagnetic Radiation to Fuel) certified by the Department of Defense for use around munitions and fuel.

Several issues were raised and discussed:
- There is concern regarding the ownership of data - the architecture should take this into account
- Several attendees addressed the need for a driver specifically in support of ocean platforms
  o It was asked if the source code could be made available for attendees to develop drivers; source code is proprietary and cannot be released
- Documentation for the 9505 is good, but documentation for the 9500 modem is lacking (Note: Documentation can be located on the NAL Research website; http://www.nalresearch.com)
- Training was addressed in depth
  o How to?
  o What works? What doesn't work?
  o Who do we contact?
- List hardware and firmware versions, related bugs and corrections/work arounds
  o Direct internet using Apollo emulator won't work with Linux
  o Can use Linux effectively - PPP to internet
- Inmarsat signal will drown out Iridium
- The Direct Internet with the Apollo emulator will send data from where the connection dropped and not send the whole data file again (spoofing)

Guidance provided on the breakout groups. Areas to be covered include:
- What are the critical issues that need to be addressed?
  o Hardware
  o Software
  o Protocols
- What should the support system/network look like?
  o Level of live support
  o Self-help tools
  o Who should provide support
  o Who should fund it
- How can we control quality and distribution?
  o Standard data and products
  o Real-time vs data base
  o Free access or subscription
  o Who provides the service
  o Who should fund the service

In response to a question, Dr. Piotrowicz stated that Omnet would not play a management role and that a problem in their business plan prevented them from provided services to the oceanographic group. However, a Johns Hopkins wireless project could possibly provide the framework for such support.

Attendees were separated into three Working Groups:
- The Mobile Applications Working Group - Chaired by David Meldrum
- The High Latitude Applications Working Groups - Chaired by Dan Detrick
- The Fixed Platform Working Group - Chaired by Christian Meinig

The final day of the meeting began with a live demonstration of the Emergence Transmission Aerospace Network (E-STRAN) by the King County Sheriffs Office. This demonstration utilized Iridium (ISU to ISU) for data communication and to provide a "chat" capability between an officer in his vehicle and the control station.

Following the demonstration, Working Group debriefs and discussions were conducted.

The Mobile Applications Working Group outlined the following issues

- Hardware/software
  o Remote wakeup capability is needed - incorporate pager feature?
  o More detailed documentation is needed
  o Backwards compatibility - guaranteed!!
- Support
  o Repository of information needed
    - Exchange of info on what does/doesn't work
    - Access, maintenance, structure hosting - needs to be accomplished
    - Who maintains the site?
  o Too many tiers/tears
    - VAMs/SPs are not impartial
  o Iridium education opportunities
    - Community rep/general users
    - Iridium volunteered - who will fund?
  o Circumvent NDAs?
  o Funding
    - Argos/DBCP model? Coordinator in Argos building but funded and reports to users
    - Non-profit entity to support research/operational (non-profit) users
    - Non-profit SP
  o Improved data dissemination/QC needed
  o Different models for different data types

Standardization of modem protocols would be advantageous. Pooling information and running a series of test with various protocols would be a move in the right direction.

The High Latitude Applications Working Groups addressed the following issues

Technical Issues
- Hardware
  o Antennas
    - Placement application notes are needed
      • Manufacturer's/user's recommendations
    - Operational data regarding sky/satellite visibility issues
      • Minimum field-of-view angle for optimal sky coverage? Dr. Hoang suggested minimum elevation angle of 10-degrees (above the horizon) along the satellite path, but an obstruction angle of 45-degrees would likely result in almost-certain LOS (loss of signal)
    - Radiation patterns: manufacturer's information regarding the radiation pattern of an antenna should be provided
      • Assistance should be provided in selecting an antenna for a particular application for optimizing the sky coverage
    - Transparency: antenna manufacturer's/user's recommendations
      • Antenna covering/obstruction material transparency
      • Working group participants suggest that dielectric-type materials (*e.g.,* glass/Plexiglas/fiberglass) have minimal impact on reception, but metal, ice and snow can reduce visibility
      • Under-ice antenna development: information about existing antennas that would enable Iridium reception below sea ice would be useful; otherwise, development of such capability should be explored

- Coaxial cable losses: What 'work-arounds' are available for the Iridium modem 3dB RF signal loss limit? Suggestions include the use of an active antenna and the use of line drivers to extend RS-232 data cable to ~100m
- Minimum antenna separation distance of 1 foot should be sufficient, although the 'hockey puck' antenna appears to tolerate closer positioning.
o Satellite coverage
  - There is up to 10-11 satellite footprint coverage at high latitudes, although only one will be 'active'
  - There is a 10s 'handoff' overlap in satellite coverage, to permit temporary LOS, for example when driving under a bridge or tunnel
  - Satellite coverage has been improved over Antarctica through arrangement with Iridium LLC
o Latency: Characteristics of the signal delays inherent in the modem, satellite, and gateway should be made available; these should include minimum, average, and maximum expected values
o Alert system: a mechanism/system should be established that would alert current Iridium users to hardware/firmware/software upgrades, and should include specific information about the procedures to be followed in getting access to them. For example, an RMA could be provided for the return of a modem for upgrade.
o Modem
  - Better information should be available to the user regarding RF signal/power level, other than the AT+CSQ 0-5 value now available. For example, the 'link margin' should be available through a specified procedure.
  - A 'self-test' mode should be incorporated into future modems and specific access procedures should be detailed
  - Detailed information about new features, such as the Soft-SIM capability, and SBD operating characteristics should be made available to users
  - Current users should be made aware that most problems are being experienced by users of the 9500 series modems, and these 'disappear' in the 9505 and later models
  - There should be a resource available for information regarding known problems with current hardware, as well as established procedures for mitigating them
  - Information should be made available regarding avenues for getting 'customer support' for modem/ Iridium problems; since most users in the Ocean/NSF group are application developers ('experts') established self-help procedures would allow them to solve most problems on their own. No avenue currently exists for getting hardware support from Iridium LLC.
o Iridium service improvements
  - The link margin in SBD mode is 22 dB, but only 12.5 dB in 'dialup' mode

- In order to improve Iridium access to a specific unit, for example for SAR missions or other safety-related purposes, the priority rating for a specific unit could be increased; however, it would be extremely difficult to increase the link margin for a specific unit
- With SBD, a valuable capability would be to request the Iridium registration information, by e-mail, to include the date/time and location. This would allow tracking of the unit, without the need for sophisticated protocols.
■ Software
  o Modem
    - Specific initialization procedures should be made available. Procedures should be made available for modem conditioning, such as 'burn-in' periods. (Dr. Hoang related that NAL Research performs a 30-minute burn-in for all modems).
    - Operational procedures should be specified/ published for making Iridium connections in modem-modem, modem-landline, and modem-internet usage, and should include examples/details about what not to do.
    - Existing 'success stories' should be available to current and new users, and should include software code and documentation
    - All application/testing software should be made available for the Linux operating system, as well as Windows
    - Software application notes should be made available, describing procedures that are known to work, as well as those that don't
■ Protocols
  o Information should be made available that describes which standard protocols work, to include specific details about operating procedures/ characteristics
  o Specific information about needed 'tweaking' should also be available. For example mitigating delay/latency effects inherent in the Iridium system, as well as information about configuring the protocols for operation under various platforms (Windows/Linux)
■ What should a support system/network look like?
  o Level of Live Support
    - Hardware/Service Providers have established support procedures
    - A support Point of Contact would be valuable for the Iridium user community, perhaps similar to the Service ARGOS system
    - Instead of 24/7 on-demand availability, a 24-hour response time would be acceptable
    - Web-based user support links would be valuable, but a better avenue should be available for day-to-day problem resolution
    - Action item: Contact Pat Smith to request icecomms participation by Ocean.US group

- Self-help Tools
  - NAL Research provides signal strength monitoring procedures at ftp://nal-psi.com, user account 'nal_ftp', password 'password'
  - A list of available tools/links should be published, containing for example existing user software application code and procedures
  - A website would be ideal for information and self-help procedures
  - A procedure should be established/published for assisting users to get support
  - A standardized 'form' or procedure should be provided that would help the user 'ask the right question'; for example, this could prevent 'It doesn't work' types of support requests.
- Who Should Provide Support?
- Who Should Fund Support?
- How can we QC and distribute standard data products? This activity was deemed to be application-specific, and no general recommendations are offered.
  - Real-time vs. database?
  - Free access or subscription?
  - Who should provide service?
  - Who should fund service?

The Fixed Platform Working Group addressed the following issues

- Solutions will be general to all satellite systems
- Fixed platforms: buoys/towers
- Technical Issues
  - Hardware
    - Interface specifications
    - Live documents
    - Power consumption
    - Super cap
    - 2000uF cap in parallel
    - UART hang-up
    - Auto-shutdown
    - Antenna
      - Leaky
      - Orientation/gain
      - Availability of marine antenna
      - Cable length vs. active antenna
        - 3dB max
        - Connectors
        - cases/enclosures
    - Vibration - screws loosening in 9500 units - 9505 better
  - SIM card holders
    - Foam to retain
  - RF compatibility between separate RF subsystems
    - Check signal with mobile phone (Note: you can now check signal strength on the modems via AT command)
  - RF shielding of future unit
  - Humidity/temperature operating range spec
    - On NAL website
- Nitrogen purged/vacuum/pressurized case
- Industrial vs. commercial semiconductor temp ranges
- Signal strength
  - At transceiver
    - Signal strength
      - Higher levels
      - Bars vs. dB
  - And at satellite
  - Ability to check while using Windows RAS
    - RAS takes over serial port
- Hardware interface stability
  - Stability of hardware
    - Backward compatibility
      - Serial port will be compatible
    - Connectors
    - Physical size
    - Ruggedized
  - DSC vs. DPL
    - What is it?
- Transceiver Quality Control reports
  - Standard testing methods documented and available
  - Configuration sheet
- IMEI number readily available
- Firmware version
- USB vs. Serial
- Modem type (GPS vs no GPS, etc.)
  - How to get GPS data from dual purpose units without SBD
    - For systems that haven't implemented e-mail data processing
    - Need more details on GPS capabilities
  - MXU
    - 4 LBTs
    - Designed to connect to a PBX
    - Splitter 2 LBT channels per antenna
    - Replace Inmarsat on ship
      - Inmarsat RF lobes incompatible with Iridium
        - 100m separation
  - Software
    - Soft SIM – details please
    - Future availability
  - Firmware
    - Flash
      - How to flash modem
        - Done at NAL
        - Software for configuring GPS on NAL website
    - What's the latest?
    - How to read what we have
    - List of versions with known bugs
  - Standardized libraries for embedded platforms
    - Communications
    - Definition of software interface
  - Security
    - VPN/Tunneling
    - How to secure phone line
      - Dial-in security
        - Call window
        - Buoy calls home & checks for file
        - OOB signal to dial

o Linux
  - PPP fix
  - PPTP fix
    • Likely solved by inserting a computer to provide a constant data stream
o Modem drivers vs. modem applications
  - Optimized for application
    • Saving time by optimizing baud rate
      ♦ Reduces negotiation time
      ♦ 4800 likely
    • Compatibility
      ♦ V.92 vs. v.24
    • Ability to create one
      ♦ Requires information on hardware
  - Platform dependency
    • Unique operating system & hardware
      ♦ Windows CE
      ♦ StrongARM
      ♦ Persistor
      ♦ Onset 8
      ♦ Embedded Linux
      ♦ Campbell Scientific
o Compression
  - Apollo not really useful, since Windows Notebooks not used on ocean platforms
    • Make direct internet Linux compatible
    • 008816000021 – direct internet number for both gateways
      ♦ Spoofing
      ♦ Smart connect
      ♦ Windows dependent
      ♦ 10k with compression
    • PPP vs. FASTPP
      ♦ PPP 8816000022
        > Generic login
      ♦ FASTPPP 8816000023
        > No login
      ♦ Needs to be RFC compliant
      ♦ Linux compatible with RFC compliant PPP
        > Documentation of levels of compression
    • What level/What's done/Where?
      ♦ Built into modem
      ♦ Built into Iridium
        > Turned off on gateway due to Apollo/Gateway ISDN link
    • RUDICS faster than Apollo due to lack of required decompression on RUDICS
o Protocols
o Technical expertise
  - Recommendations for protocols based on experience
  - Simplest vs. bidirectional vs. data quantity matrix
  - Most efficient & cost effective use decision matrix
  - SBD: data < 2k; not "bidirectional" – 1 ½ directional
    • What about published/sent directly to FTP server
  - RUDICS
    • No limit of phones to 1 IP address
    • 5 port increments (commercial)
      ♦ Simultaneous connections

    • Connections
      ♦ T1/E1
      ♦ Frame Relay
      ♦ Ethernet
      ♦ VPN
      ♦ Serial
      ♦ Fiber, etc.
    • Dial-UP/Direct Internet/DAV
o Voice calls/Talk slower
  - Use Jabra headset
o New Services
  - Data published/sent directly to FTP server
    • Talk to NAL
    • A cross between RUDICS & SBD
    • Removes necessity of TCP stack on remote controller
  - Matrix
    • Services available
      ♦ What it does
      ♦ What is needed to use it
      ♦ Size/Time/Costs
        > Activation
        > Monthly vs. minute vs. data quantity
        > Per unit
      ♦ Who to call for more complex services
        > Stratos or
        > SRA International
          ✦ Paul Torick 703-502-1208
        > Tier 1
          ✦ Offer both hardware and services
          ✦ Requires 24hr tech support
        > Tier 2
          ✦ Iridium lets Tier 1 choose

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- What protocols are available
  - Documentation
- o Support
  - What level of support is needed?
  - E-mail support
    - For development
  - Information pushed out to users
    - Critical (i.e. DoD Sims down from xx:xx to xx:xx)
    - Who originates information
      - ♦ Ocean.US?
  - 24/7 live required
    - For operations
    - Different requirements for different application
    - Civil defense/military
    - Search and Rescue
    - Depends on problem
- o One-stop for support
  - Central coordinator/Ocean advocate within Iridium
  - What expertise at Iridium tier levels?
- o Online access to individual SIM call logs
- o User experiences
  - Documented successful results
  - Documented completed systems
  - Problems encountered & solutions
  - Lessons learned & how we'd do it differently
  - 9505
    - Available on NAL FTP site
- o Lack of vs. centralization
- o User review of documentation
- o How to build feedback loop
  - E-mail list

- Too many e-mails
  - ♦ Perhaps a user configurable forum/list
    - > (i.e. Yahoo forum)
- Iridium.Pioneers
  - ♦ Lack of communications
- USENET newsgroup
  - Messages don't drop off
    - ♦ If our own
  - Community owned
  - Persistent messaging service
    - ♦ Forum (i.e. Yahoo forum)
    - ♦ Newsgroup
- WIKI
  - Set of user modifiable web pages
    - ♦ Growing community maintained website
- Moderator
  - Iridium NSF/Ocean.US advocate
- Serves larger user community
- Company participation
  - Iridium
  - NAL
  - Etc.
- Service provider summarizes comments/lessons learned
  - Into FAQs
- Training
  - Provided by Iridium/NAL
  - How often
  - Once-a-year for oceanographic community?
    - ♦ How many people
    - ♦ Limit groups 10-15 people
    - ♦ Multiple groups
  - Best if just marine oriented
  - Best if co-located with major ocean conference
    - ♦ OCEANS or other
- Who supplies support
  - "Who" vs. "Funding"
  - "Who" = someone from community of users
  - Technically competent
- "Funding"?
  - Which of many governing bodies to decide?
  - Ocean.US to request
- Vendors to provide out of the box product support
  - Specific product support
- Someone to provide info on new Iridium services
  - Systems level documentation
  - Main point of support
    - ♦ Refers to vendor if needed
    - ♦ Predicted level required high
    - ♦ # of instances will grow
  - Getting identified problems out to community in time
  - Website/newsgroup
- Product package
  - Modem
  - Antenna & cables
  - PC/modem antenna
  - CD with drivers / documentation

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- QC
  - What is "standard" data & products?
  - Data not released until QC'd
  - How, who?
- o Data Management and Communications – IOOS plan
  - Documented
  - Covers real-time distributed data
- o Iridium system like Argos?
- o Everyone doing this differently
- o Just tell us where to send it
- o Service provider
  - Will provider use all protocols
    - PPP
    - Z-modem, etc.
  - Bi-directional access
  - Reliability
  - Interface documentation
  - Access to technical support
    - Where is the problem?
    - Open communication
    - Defined flow of support
      - ♦ Iridium tiers of technical ownership
      - ♦ Single point of support
        - > Website monitored by all tiers
    - Funding
      - ♦ Stakeholders
      - ♦ Political issue
        - > Existing data repository ownership
        - > Metadata definition
- o Housekeeping/engineering vs. scientific data
  - Error checking
  - Transmission/data integrity
    - Should there be community QC?
    - What form should it be in?
    - Done where
      - ♦ Gateway?
      - ♦ Final destination?
      - ♦ End user?
    - What exists in Iridium system already?
      - ♦ Documented
      - ♦ Is it possible to use an existing mechanism to report to the buoy/shore that the data arrived fully?

- Forward Error Correction
  - ♦ Maybe, but no documentation available
    - > It looks like it
    - > No official answer
    - > Talk to General Dynamics
      - ◆ Engineers not available for questions
- o Rate structure
  - Where is it going?
  - Free air time critical for further development
    - Allows more time to debug systems
    - Significant systems deployed using Iridium as a direct result
  - Suppliers
  - List of equipment/resellers
- o Communications from suppliers
  - How to get information from them without asking for it
  - "Prototype" aspect of 9500 not communicated
  - Interim designs
- o Uncertainty
- o Daytona vs. next model
- o No difference in serial ports
- o List of items for next year's meeting
  - When would we want to meet again in a similar workshop forum

PROBLEMS/ISSUES/RECOMMENDATIONS

While Workshop participants agreed that Iridium provides a much-needed global and real time data communications capability, a number of problems and issues were identified.

The primary issues addressed relate to establishing a mechanism to support the introduction and use of Iridium data communication and training. The lack of a formalized means to capture, compile, and document and share critical information was identified as a key issue by each Working Group. As noted in other sections of this report, many of the problems addressed during the Workshop briefings had been previously identified and corrected. Improvements in the hardware and software in the 9505 Iridium phone and data modem corrected the self-initiated internal power-down, signal fluctuations, and UART lock problems. The firmware for the Data-After-Voice (DAV) capability was also corrected. Newer software versions allow the user to accurately profile signal strength. It was noted, however, that this information was not readily available to those implementing Iridium data communication. The concept of establishing a mechanism for providing support and disseminating information was strongly supported by Workshop participants. Participants agreed that this support system would include a repository of information that address what works and what doesn't work. For example, it was noted that the Apollo Emulator will not work with Linux and a number of attendees noted significant problems exist with Kermit that probably contributed to poor transmission success rates. The support system should include lessons learned, and list hardware and firmware versions, related bugs and corrections/work-arounds. Information on new Iridium services would be included, along with hardware and protocol documentation. Other information addressed would include:

- o Who do we contact?
- o Information on antenna types, uses, considerations and placement
- o Assistance in selecting an antenna for a particular application
- o Information on antenna covering/obstruction material transparency
- o Radiation patterns
- o Work-arounds for the Iridium modem 3db RF signal loss limit
- o A standardized 'form' or procedure to assist the user in asking the right question
- o An alert system was addressed that would notify current Iridium users concerning hardware/firmware/ software upgrades, and specific information about the procedures to be followed in getting access to them.
- o Web-based user support links
  - On line access to individual SIM call logs
- o Existing success stories
- o Self-help tools

- o Summary by service providers of comment/lessons learned into FAQs
- o USENET newsgroup
- o WIKI
  - Set of user modifiable web pages
    • Growing community maintained website
- o Standardized libraries for embedded platforms

A related issue addressed is how such support should be structured, who will provide it and who will fund it. Attendees noted similar support problems existed with Argos during the mid-eighties, with the Data Buoy Cooperation Panel (DBCP) being initially contacted for support and the later successful introduction of a technical coordinator based at Argos Toulouse. Options addressed included following the Argos model, with a coordinator funded and reporting to the user community. It was suggested that a central coordinator/Ocean advocate be established, possibly within Iridium Satellite LLC or some other office with connectivity to the Global Telecommunications System. The coordinator could come from a non-profit entity that supports research and operational (non-profit) users, or from a non-profit SP (Service Provider), if such an organization was formed. One Working Group suggested the coordinator come from the community of users. Regardless of the source, a high level of technical expertise will be required, much of which resides with the VAMs (Value-Added Manufacturers) and SPs, in widely varying levels. In this regard, vendors should be capable of providing out of the box product support.

It was the consensus that funding be provided by the community of users. The question was poised, which of the governing bodies should decide the funding issue? While no clear answer existed, one suggestion was that Ocean.US lead the coordination issue with the governing bodies.

The Iridium rate structure was also addressed. How will it be structured in the future? How do we determine and compare costs associated with SIM (Subscriber Identity Module) card activation, monthly charges for various services, etc., between various providers? Is there a list of airtime providers and a matrix comparing costs? This is an issue that could fall within the purview of the support structure once established.

Another issue raised is the level of support required. One Working Group stated 24/7 support should be available for Search and Rescue and other safety-related requirements, while another believed that a response within 24 hours would be acceptable. E-mail support should be available in support of developers. It was agreed that information should be pushed to the users, although it not determine who would originate such information.

Several of the issues had legal implications. One was the ownership rights to the existing data repository. In addition, it was suggested on a number of occasions

during Technical Workshop that source code be made available to developers. However, it was also noted that much of this source code is proprietary.

A number of recommendations were made on hardware improvement. It was noted that the VAMs/SPs are not impartial, and that the support system to be established should act as the impartial source of information. Hardware recommendations include:

- Self-test mode in future modems.
- Priority rating for specific units to support SAR missions and other safety-related missions.
- Users of Short-Burst Data (SBD) should be able to request Iridium registration information by e-Mail to include date/time and location to track units without needing sophisticated protocols. (Note: SBD allows the user to register up to 5 e-Mail addresses to receive time/location data for the modem with GPS)
- SIM card holder with a foam type substance that would better secure the card in the SIM holder
- Nitrogen purged/vacuum/pressurized case
- Further ruggidization (industrial vice commercial)
- Multi-channel modem (4 L-Band Transceivers) as a standard product to replace Inmarsat on ships
- Smaller, cheaper, faster modems (Note: The 9600 Short Burst Data-only modem is now being developed. It will be much smaller and significantly cheaper but will not increase throughput)

The self-test features and product modifications/packaging, to include the SIM card holder with foam, industrial ruggidization and nitrogen purged/vacuum/pressurized cases can be accomplished.

Software recommendations included development of a Soft-SIM, enhanced security capabilities and software that will work with Linux. It was recommended that a compression capability be developed independent of the Apollo Emulator.

Development of a training program was also identified as a critical requirement. It was recommended that such training be provided by Iridium and NAL Research, and be tailored for the oceanographic community. How often to schedule training and how large a class should be formed was a topic of discussion. It was unclear what organization will lead the effort to coordinate an Iridium training class.

An issue that was discussed by each of the Working Groups was how to QC and distribute standard data products.   It was noted that this activity is application related. Questions raised include:

- Real-time vs. database?
- Free access or subscription?
- Who should provide service?
- Who should fund service?
- What is "standard" data and products?
- Who QCs data prior to release?

CONCLUSION

The Technical Workshop provided a much-needed forum for our community to share successes, shortfalls, frustrations and lessons learned in implementing Iridium data communications. Significant differences in hardware, firmware and supporting software used by Workshop attendees were evident, and resulted in numerous and valuable lessons learned. Iridium Satellite LLC and NAL Research were available to answer technical questions, and to outline improvements made to the 9505 generation Iridium hardware and software/firmware to correct many of the problems noted. Iridium data communication capabilities, such as SBD and RUDICS, were also addressed.

Users embraced significant improvements in Iridium coverage, latency and data rates as compared to the Argos system. Working Groups were able to articulate problems and issues that require consideration, and formulate suggestions for further evaluation and/or implementation. The primary issues addressed the establishment of a structure to provide support for the introduction and use of Iridium data communication, and the development of a training program. The lack of a formalized means to capture, compile, and document and share critical information was addressed throughout the Workshop. Attendees strongly agree that a repository of Iridium information is needed, and that web-based and live technical support is needed.   The consensus calls for establishment of a central coordinator/Ocean advocate similar to that established in support of the Argo system. As outlined in the Problems/Issues/Recommendation section of this report, how such support should be structured, who will provide it and who will fund it, were discussed at length, with a number of options proposed.

The second major issue involved developing an Iridium training program tailored for the oceanographic community. Ocean.US will take the lead in coordinating with Iridium Satellite LLC and NAL Research to develop and conduct user training.

The Workshop was most successful in providing a means for sharing critical user information related to the use of Iridium telecommunications in support of a myriad of applications. It brought together the technical expertise and community of users to articulate successes and failures, and to collectively document issues and recommendations for the successful implementation of Iridium data communication.   The findings of the Workshop will form the baseline for the evaluation of future requirements and courses of action.

ACRONYMS

Acronym	Meaning
ACCHL	Associated Control Channel, L-Band
ADEOS	Advanced Earth Orbiting Satellite
AIS	Automated Identification System
AMSR	Advanced Microwave Scanning Radiometer
AWSs	Automatic Weather Stations
BIN	Benthic Instrument Node
BGAN	Global Area Network
CONUS	Continental United States
COOS	Coastal Ocean Observing System
COPRI	Coasts, Oceans, Ports and Rivers Institute
COSEE	Center for Ocean Science Education Excellence
DAV	The Data-After-Voice
dB	decibel
DBCP	Data Buoy Co-operation Panel
DE-BPSK	Differential Encoded Binary Phase Shift Keying
DE-QPSK	Differentially Encoded Quaternary Phase Shift Keying
DoD	Department of Defense
DSN	Defense Switched Network
EPA	Environmental Protection Agency
FCC	Federal Communications Commission
FDMA/TDMA	Frequency Division Multiple Access/Time Division Multiple Access
GLI	Global Imager
GOES	Geostationary Operational Environmental Satellite
GoMOOS	Gulf of Maine Ocean Observing System
GMDSS	Global Maritime Distress and Safety System
GSM	Global System for Mobile Communications
HERF	Hazardous Electromagnetic Radiation to Fuel
HERO	Hazardous Electromagnetic Radiation to Ordnance
IGO	InterGovernmental Organization
IMEI	International Mobile Equipment Identity
IMSO	International Mobile Satellite Organization
IOOS	Integrated Ocean Observing System
ISL	Inter-Satellite Links
ISLLC	Iridium Satellite LLC
ISU	Iridium Subscriber Unit
IT	Information Technology
JAXA	Japan Aerospace Exploration Agency
LEO	Low-Earth Orbit
LES	Land Earth Station
MBARI	Monterey Bay Aquarium Research Institute
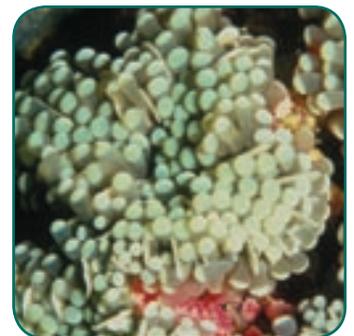
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METOP	Meteorological Operational satellite
MOOS	MBARI Ocean Observing System
MXU	MultipleXer Unit
NASA	National Aeronautics and Space Administration
NC-COOS	North Carolina Coastal Ocean Observing System
NESDIS	National Environmental Satellite Data and Information Service
NOAA	National Oceanic and Atmospheric Administration
NOPP	National Oceanographic Partnership Program
NSF	National Science Foundation
ONR	Office of Naval Research
ORION	Ocean Research Interactive Observatory Networks
PENGUIn	Polar Experiment Network for Geophysical Upper-Atmosphere Investigations
PICO	Platform and Instrumentation for Continuous Ocean Observations
PMEL	Pacific Marine Environmental Laboratory
PPP	Point to Point Protocol
pppd	Point-to-Point Protocol daemon
PPTP	Point-to-Point Tunneling Protocol
PRISM	Polar Radar for Ice Sheet Measurement
PSDK	Spectral Flux Density
PSTN	Public Switched Telephone Network
PTT	Platform Transmitter Terminal
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
RF	Radio Frequency
RUDICS	Router-based Unstructured Digital Inter-Working Connectivity Solution
SBD	Short Burst Data
SBIR	Small Business Innovative Research
SIM	Subscriber Identity Module
SMS	Short Messaging Service
SNCO	Satellite Network Operations Center
SOC	Southampton Oceanography Center
SP	Service Providers
SSC	Satellite Control Center
TCP/IP	Transmission Control Protocol/Internet Protocol
TIROS	Television and Infrared Observation Satellite
TOS	The Oceanography Society
UART	Universal Asynchronous Receiver Transmitter
USCG	United States Coast Guard
USGS	United States Geological Survey
VAMs	Value-Added Manufacturers