Design and Operation of Automated Ice-Tethered Profilers for Real-Time Seawater Observations in the Polar Oceans



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June 2006

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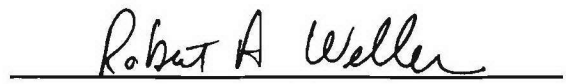
Technical Report

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Robert A. Weller, Chair

Department of Physical Oceanography

Cover photo: An Ice Based Observatory (IBO) consisting of the surface package of Ice-Tethered Profiler (ITP) number 1 in front of Ice Mass Balance (IMB) buoy 7949 after installation at 79.8° N, 150° W in August 2005 with *CCGS Louis S. St. Laurent* in the background (photo by Chris Linder).

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Design and Operation of Automated Ice-Tethered Profilers for Real-time Seawater Observations in the Polar Oceans.

ABSTRACT

An automated, easily-deployed Ice-Tethered Profiler (ITP) has been developed for deployment on perennial sea ice in polar oceans to measure changes in upper ocean temperature and salinity in all seasons. The ITP system consists of three components: a surface instrument that sits atop an ice floe, a weighted, plastic-jacketed wire-rope tether of arbitrary length (up to 800 m) suspended from the surface instrument, and an instrumented underwater unit that profiles up and down the wire tether. The profiling underwater unit is similar in shape and dimension to an ARGO float except that the float's variable-buoyancy system is replaced with a traction drive unit. Deployment of ITPs may be conducted either from ice camps or icebreakers, utilizing a self contained tripod/winch system that requires no power. Careful selection of an appropriate multiyear ice floe is needed to prolong the lifetime of the system (up to 3 years depending on the profiling schedule). Shortly after deployment, each ITP begins profiling the water column at its programmed sampling interval. After each acquired temperature and salinity profile, the underwater unit (PROCON) transfers the data and engineering files using an inductive modem to the surface controller (SURFCON). SURFCON also accumulates battery voltages, buoy temperature, and locations from GPS at specified intervals in status files, and queues that information for transmission at the start of each new day. At frequent intervals, an Iridium satellite transceiver in the surface package calls and transmits queued status and CTD data files onto a WHOI logger computer, which are subsequently processed and displayed in near-real time at http://www.whoi.edu/itp. In 2004 and 2005, three ITP prototypes were deployed in the Arctic Ocean. Each system was programmed with accelerated sampling schedules of multiple one-way traverses per day between 10 and 750-760 m depth in order to quickly evaluate endurance and component fatigue. Two of the ITPs are continuing to function after more than 10 months and 1200 profiles. Larger motor currents are observed at times of fast ice floe motion when larger wire angles develop and drag forces on the profiler are increased. The CTD profile data so far obtained document interesting spatial variations in the major water masses of the Beaufort Gyre, show the double-diffusive thermohaline staircase that lies above the warm, salty Atlantic Layer, and many mesoscale eddys. Deployed together with CRREL Ice Mass Balance (IMB) buoys, these ITP systems also operate as part of an Ice Based Observatory (IBO). Data returned from an array of IBOs within an Arctic Observing Network will provide valuable real time observations, support studies of ocean processes, and facilitate numerical model initialization and validation.

BACKGROUND

The need for broad-scale, frequent ocean sampling is being addressed outside the polar latitudes by the JASON (http://sealevel.jpl.nasa.gov/mission/jason-1.html) and Argo (http://www.argo.ucsd.edu/) projects that are returning satellite altimeter measurements of sea level anomalies and drifting profiling float measurements of the upper ocean temperature and salinity fields, all feeding a global data assimilation effort (GODAE; http://www.usgodae.org/). Since perennial sea ice makes it difficult to use many modern automated observational instruments, the Arctic represents an observational gap in the "global" ocean observing system. Consequently, there are not sufficient observations to accurately quantify change in environmental conditions and to validate or disprove hypotheses about Arctic climate variability.

Those observations that have been made hint that the Arctic has been undergoing large changes recently, motivating broad, interdisciplinary, multi-scale research (SEARCH SSC, 2001). For instance, changes in the Atlantic water, and in the overlying cold halocline layer have been observed over the previous decades (e.g. Morison et al., 2000). At the same time, an ensemble of global climate models predicts the decline and eventual disappearance of the perennial sea ice cover in the Arctic within this century (ACIA, 2004). These concerns have led to enhanced international research in the Arctic, including organization of an International Polar Year (IPY) in 2007-2008.

SEARCH developed a measurement strategy in recognition that a number of long-term, large-scale observing systems have been terminated, or are in danger of disappearing. One of the four major SEARCH themes is thus *long-term observations to detect and monitor environmental change*. This has spurred various recent workshops to devise national and international Arctic observing networks that integrate many types of instruments (such as buoys, under-ice floats, AUVs, moorings and cabled observatories) to achieve broad coverage of the Arctic Ocean (e.g. Proshutinsky et al., 2004). Internationally, an integrated Arctic Ocean Observing System (iAOOS; Dickson et al., 2006) has been endorsed by the Arctic Ocean Science Board. The US Polar Research Board has also recently discussed this concept in the National Academy of Sciences report: "Towards an Integrated Arctic Observing Network" (IAON); (available from http://www.nap.edu/catalog/11607.html).

One of the observational tools recognized as fundamental in observing networks are Ice-Based Observatories (IBOs) which are defined as "automated, drifting, ice-based sensor systems providing comprehensive data from the Arctic environment and incorporating the *multidisciplinary* needs of biological, chemical and physical oceanography, as well as different aspects of atmospheric and sea-ice studies" (Proshutinsky et al., 2004). Ice-tethered drifters with discrete subsurface instrumentation such as the SALARGOS (Morison et al., 1982), IOEB

(Honjo et al., 1995) and J-CAD (Kikuchi et al., 2002) buoys, have been successfully fielded in the Arctic in the past two decades, demonstrating that automated buoys are viable means of acquiring long-term, in situ data from beneath the ice pack. However, the vertical resolution of the temperature and salinity observations from these systems has typically been limited to only a few depths due to the costs associated with outfitting multiple sensors on a single package. In addition, intercalibration of these strings of multiple sensors can be difficult. Moreover, even with a limited number of sensors, total system costs has meant that only a small number of such devices have been fielded at any one time. Another shortcoming of the ocean measurements from those systems is that limited vertical resolution potentially misses some of the small-scale ocean structures of the Arctic Ocean.

Technological and engineering improvements have fostered the development of a number of IBOs consisting of clusters of meteorological, ice mass balance (IMB), and discrete-depth sampling ocean buoys (one example being the North Pole Environmental Observatory, NPEO; http://psc.apl.washington.edu/northpole/). To address the need for automated ocean profiling under sea-ice as part of an IBO, and be both useful and practical to the Arctic scientific community, an instrument with the following specifications was proposed:

- Capable of returning in real time, better than 1-m-vertical-resolution, high-accuracy daily (or semi-daily) temperature and salinity profiles to 750 m depth for 3 years (assuming deployment in robust icefloes).
- Deployable from light aircraft (Twin Otters) and helicopters through a conventional 10.5" ice-augered hole.
- Modestly priced, allowing them to be deployed in large numbers and be considered expendable.
- Capable of supporting plug-in modules for additional surface and/or subsurface instrumentation.

Building on the success of ice drifters, and on the WHOI-developed Moored Profiler instrument (Doherty et al., 1999), an automated easily-deployed Ice-Tethered Profiler (ITP) has been developed to economically measure changes in upper ocean temperature and salinity throughout large expanses of the Arctic Ocean in all seasons (Figure 1). The nominal tether length is 800 m, sufficient to profile through the temperature maximum layer characterizing the Atlantic waters that enter the Arctic through the Fram Strait.

DESCRIPTION

The ITP system consists of three components: a surface instrument package that sits atop an ice floe, a weighted, wire-rope tether of arbitrary length (up to 800 m) suspended from the surface package, and an instrumented underwater unit that travels up and down the wire tether.

The surface unit houses a controller, inductive modem, GPS receiver and an Iridium satellite phone with associated antennae and batteries within a water tight aluminum housing capped by an ultra high molecular weight (UHMW) polyethylene dome. The electronics case sits within a cylinder of Surlyn ionomer foam designed to provide buoyancy for the plastic-jacketed wire rope tether with ballast termination weight, and provide modest protection in the event of ice ridging, and flotation should the ice fracture.

The upper 5-m of the wire tether is cast within a thick protective urethane jacket that also houses an electrical ground lead for the inductive modem. A custom termination is used to mechanically join the tether to the surface unit and preserve the electrical isolation of the wire tether from the sea water.

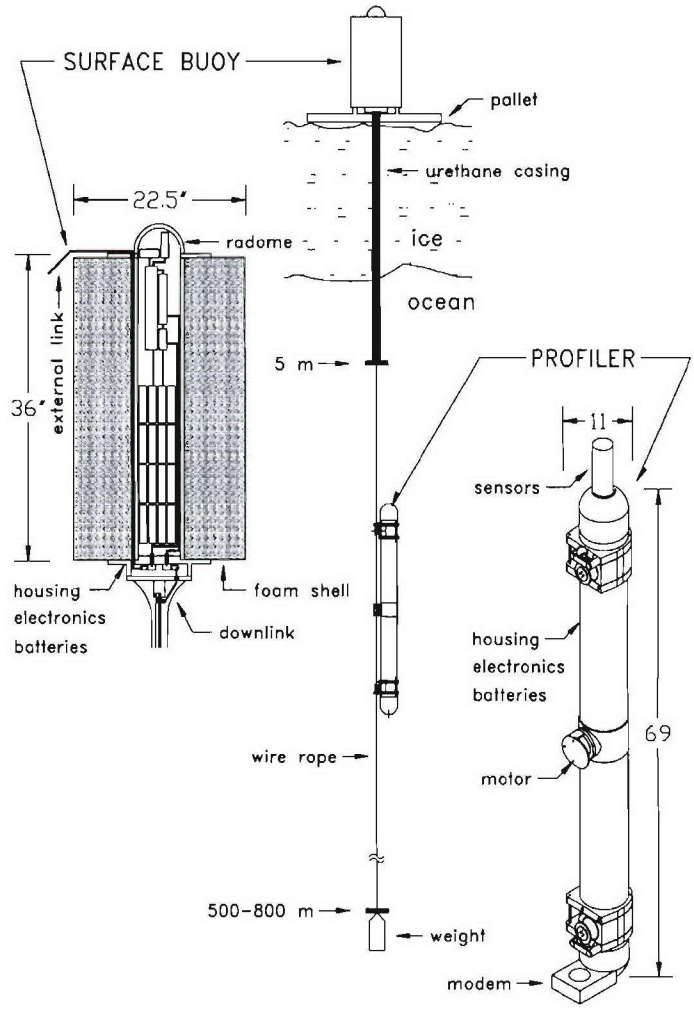


Figure 1: Ice-Tethered Profiler Schematic

A new variation of the WHOI Moored Profiler (in shape and size much like an ARGO float) mounts on this tether and cycles vertically along it. The ITP employs the same CTD sensor package that is currently used on many of the ARGO floats (the Sea Bird Electronics, Inc. model 41CP) mounted in the instrument's top hemispherical end cap. Communication between the Profiler and surface controller is supported by an inductive modem utilizing the wire tether (Figure 2). The raw CTD and associated engineering data are downloaded at the completion of each one-way profile then telemetered to shore. The buoy transmits all data in near-real time and

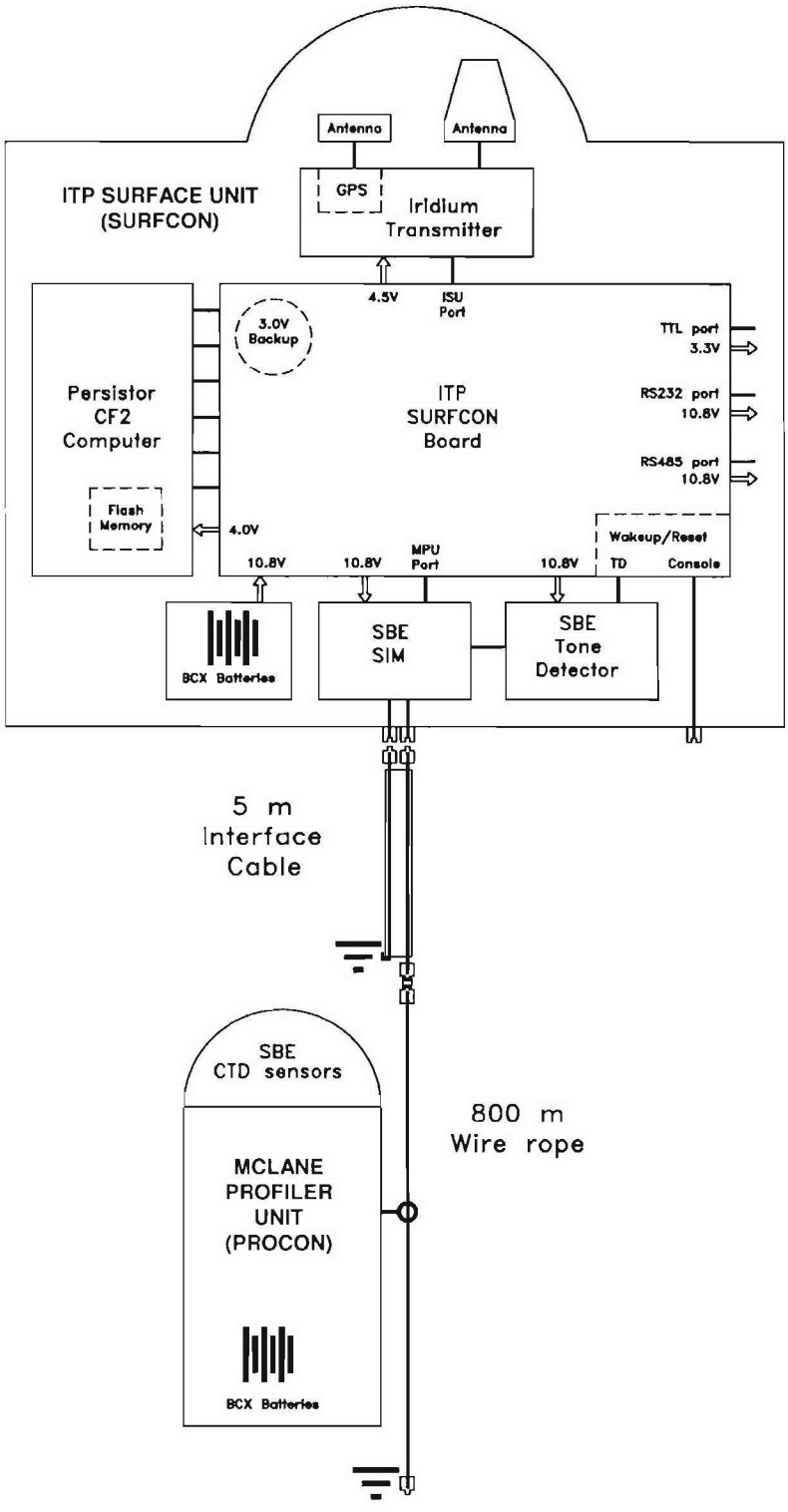


Figure 2: ITP Electronic Diagram

is low-cost, allowing systems to be considered expendable (thus alleviating the need for expensive recovery operations).

The size and weight of the system and the deployment gear were minimized in order to facilitate handling and transportation. Altogether with the tether ballast weight, the ITP hardware totals approximately 1000 lbs, allowing transport to remote sites by a medium lift helicopter or Twin Otter aircraft (along with the deployment technicians, emergency survival gear, and the deployment equipment).

A total of three ITP prototypes were deployed in 2004 and 2005, together with US Army Cold Regions Research and Engineering Laboratory (CRREL) IMB buoys. Thousands of profiles later, data from these systems support the IBO concept as a practical means to return sustained observations of the Arctic air-ice-ocean environment in all seasons.

HARDWARE SPECIFICATIONS

Mooring length: 10 to 800 m

Profiling range: 1,500,000 m on standard battery pack

Duration: 2.5 to 3 years returning two 750 m (one way) profiles per day (2000 total)

Temperature specification: -35° C for prototypes

Data telemetry: typically 50 Kbytes per profile (totaling 100 Mbytes over 3 years)

Sensors: Sea-Bird 41-CP CTD (same as many ARGO floats)

Telemetry: Sea-Bird inductive link from profiler to surface unit;

Iridium link to shore

Power: lithium BCX "DD" battery packs;

3300 Wh in surface package (after derating for temperature), 2500 Wh in profiler

Size: Profiler fits through a 10.5-1" diameter hole in the ice

Surface Package

The surface expression of the ITP (Figure 3) is a cylindrical buoy that is deployed on a multiyear ice floe. Balancing durability and disposability, the surface unit incorporates a foam collar for shock absorption in order to increase the lifetime of the drifter during ridging, and depending on size may either sink or buoy the system should the ice fracture. The surface collar (22 or 26" outer diameter) is constructed from Surlyn ionomer foam, and surrounds an aluminum electronics compartment (36" long, 6.5" diameter tube) that contains an Iridium modem, GPS receiver, inductive modem interface to underwater sensors, a data controller and lithium batteries. The Iridium and GPS antennae are mounted internally on a chassis beneath an UHMW hemispherical radome, which forms the top endcap. The bottom endcap provides space for penetrators to feed the electrical signals into the compartment, and a mount for the tether. Space for an additional bulkhead connector for interfacing with other external sensors is provided, as well as extra tube length for batteries to meet additional power requirements in the future. The yellow surface package is propped on a wooden palett during deployment (to minimize the ablation of ice in contact with the unit).

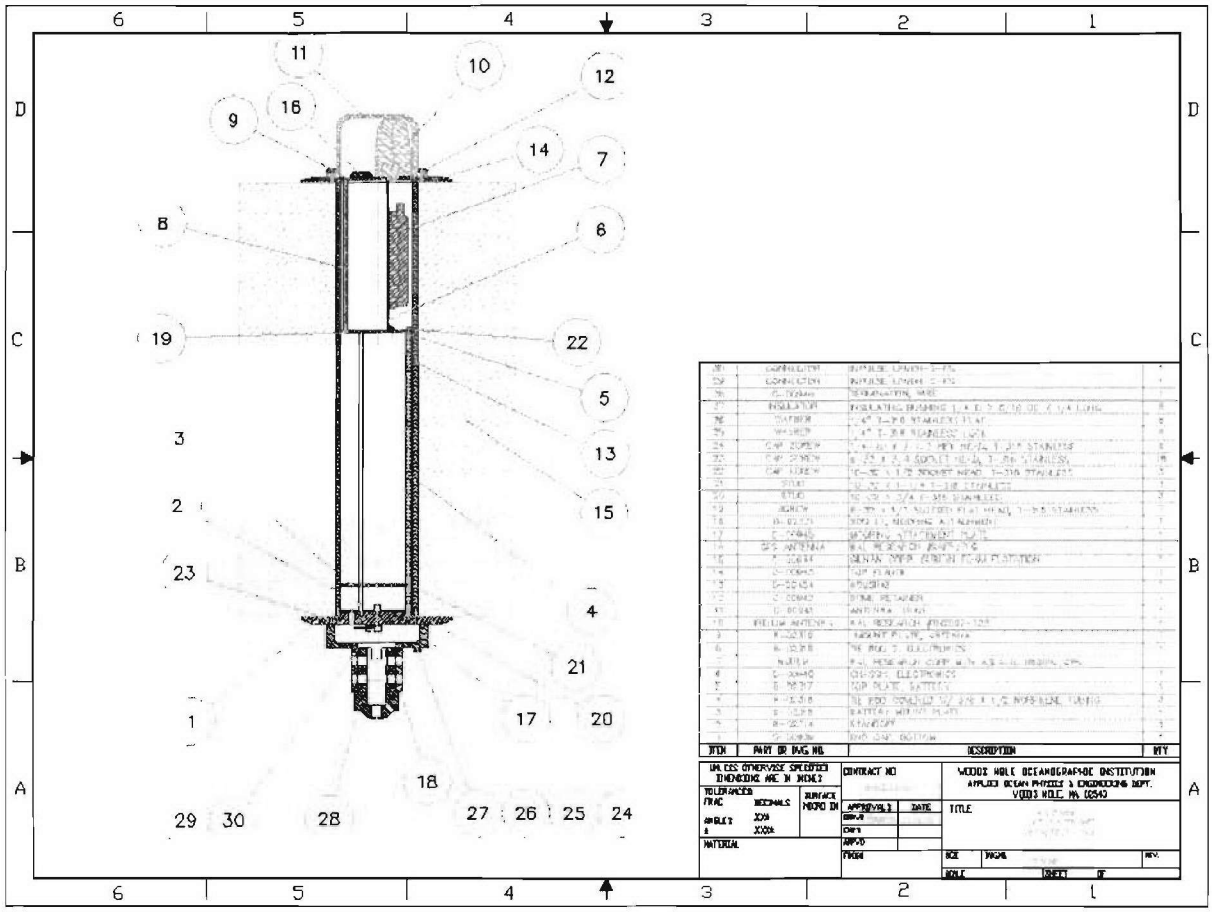


Figure 3: ITP Surface Assembly

Surface controller

The data controller in the surface package (SURFCON) operates the inductive modem interface, obtains the data from the instrument on the subsurface tether, formats and feeds the information to the Iridium satellite transmitter (Figure 4). The computer at the heart of the controller is a Persistor CF2 commercially available, low power, C programmable micro-controller with a 128 Mb compact flashcard memory. The Persistor computer is only 0.7"x2"x3" in size and it and the flashcard are rated to operate to -40°C. The flashcard memory should be sufficient to store all acquired instrument and engineering data, status, and log files for the lifetime of the system. The SURFCON interface board was designed at WHOI to regulate power to the computer, waken upon detecting a tone from the underwater inductive modem (UIM), communicate via the surface inductive modem (SIM), acquire location information from a GPS receiver, control command and data transmissions with WHOI based servers via an Iridium satellite link (ISU), provide console access (or RS232 port), and provide spare logic and RS485 (multidrop) serial ports.

The main UART is used to program the Persistor and communicate with the operator via the console access port. The console port is wired to a bulkhead connector on the base of the surface package for access with the battery packs installed and fully assembled. Time Processor Unit (TPU) channels are configured either as logic I/O bits or software UARTs to interface with the tone detector (TD), SIM, Iridium telephone modem, and other serial device ports (logic level, RS232, and RS485). One serial device port on the SURFCON board acquires the GPS data. The other device ports are not presently used on the ITPs, but are integrated in the design to support communications to other instruments in the future.

The TD board is a product of Sea-Bird Electronics (product number 41247), and is used to waken the SURFCON board, which will apply power to the CF2 computer. Non volatile storage allows the computer to resume operation where it left off when suspended.

Lithium battery (BCX) packs at 10.8 V powers SURFON which converted 4.0 V for the CF2, and 4.5 V for the ISU. A 3 V backup battery for the CF2 is also included. During operation, current drain is typically less than 120 μA in sleep mode (almost entirely from TD board), while the interface board draws 10 μA from its backup battery. The operation of the surface controller has been tested functionally to –48 °C, and though the Iridium unit will not transmit at that temperature, normal operations resume after warming without data loss.

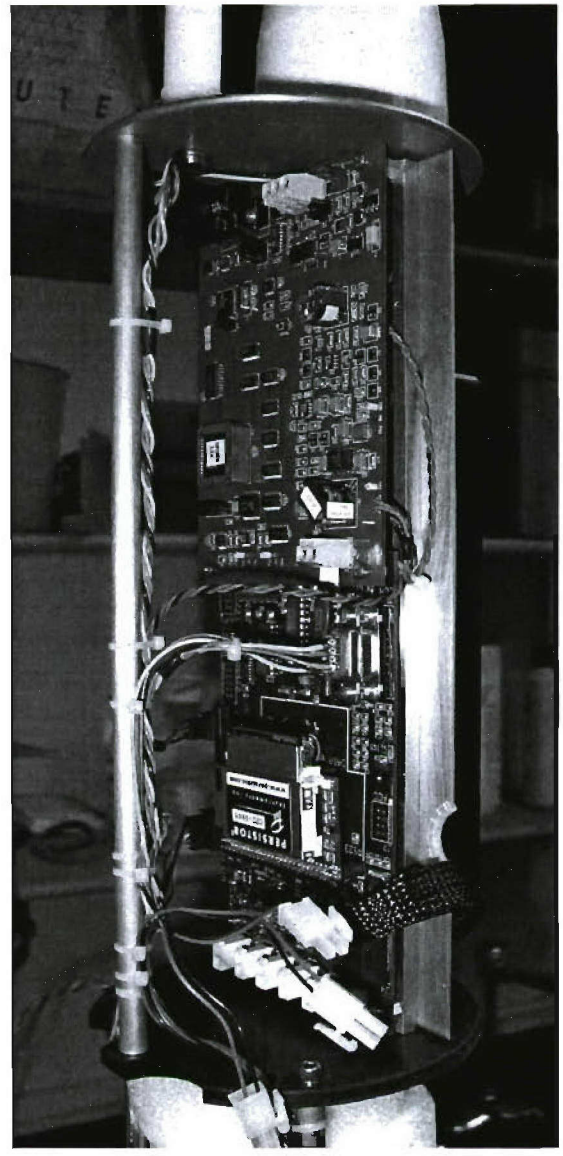


Figure 4: SURFCON board, Persistor CF-2 computer, and SeaBird SIM mounted in ITP surface electronics chassis. The TD board is mounted under the SIM board.

Inductive modem

A commercially available (Sea-Bird, Inc.) SMODEM-2 SIM (and TD board) in the surface unit (Figure 4) is electrically connected to the tether conductor and the tether passes through a corresponding modem toroid that is carried by the Profiler. The inductive circuit for

communications is completed by grounding plates on the conductors and the seawater path. The data link from the SIM to the computer is at 9600 baud and the link to the underwater instrument is 1200 baud.

Formerly, only ASCII data could be transferred, but SeaBird agreed to upgrade their transmission protocol to allow binary data transfers. Firmware changes add a command that allows the SIM to request an 8-bit transfer from the UIM. During the binary transfers, control of the half duplex link is effected by a programmable transmission gap at both SIM and UIM ends, rather than by the special characters employed in ASCI transfer. Files of any length are sent in packets of 4 Kbytes with about a 2 second gap between each (at a nominal 1200 baud with net throughput of approximately 90 bytes/s).

It is worth noting that other devices equipped with inductive modems could also be mounted on the mooring cable and configured to communicate with the data controller.

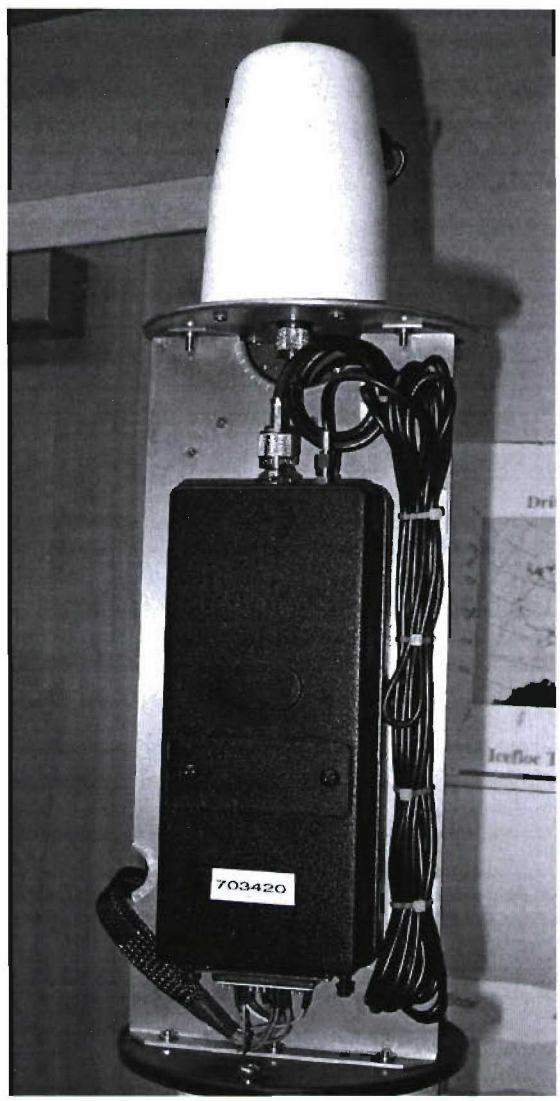


Figure 5. NAL Iridium modem and antenna on ITP electronics chassis.

Iridium transceiver

The Iridium 9522 LBT modem (Figure 5) dials up, logs in and uploads the profiler data, locations and status information to a dedicated computer at WHOI. The NAL model A3LA-IG modems on the first ITPs also obtained GPS fixes and that information was added to the instrument data, but the GPS receiver is separate from the modem on later ITPs.

In the ITP application, the SURFCON controller powers the modem when it is time to download data via Iridium and uses Hayes modem commands over a serial connection to check registration with the Iridium satellite (AT+CREG?), check signal strength (AT+CSQ) and dial-up (ATDT...).

The Iridium modems (or ISU) that were used on the prototypes had specified operating temperatures down to -30°C, but extended

environmental testing of all the surface electronics found some that operated reliably as cold as -38°C. However, the ISUs with integrated GPS needed an increasingly long off period as temperature decreased (as long as one hour at -40 °C) to assure proper functionality at power up. This did not seem to be a problem on ISUs without integrated GPS.

A "dial-up" data account with a commercial company is required for billing the Iridium telemetry charges, and a SIM card (*not to be confused with the surface inductive modem*) is obtained for each ITP. Besides the cost of the SIM card, telemetry charges include an activation fee, monthly charge, and per minute charges (about $1/min in 2004) using the "Data Only" service. At current rates, the cost to transmit a typical 750 m ITP profile is about $4.

The SIM cards are installed in the Iridium transmitters in each ITP surface unit and typically come with a default password ("1111") which needs to be deleted to enable dial-up capability. The Hayes commands for deactivating the default password (PIN) is: AT+CLCK= "SC",0,"1111". Change from PIN to no PIN with AT+CPIN= "1111". Response should be OK.

GPS receiver

On the first 3 ITPs, Iridium modems with integrated GPS were used. However, since the modems were not equipped with battery backup for the GPS receiver, every location had to be acquired from a cold start every time, which consumes excess time and energy. Consequently, on later ITPs separate Navman Jupiter 21 GPS receivers are connected to an unused logic level port on the SURFCON board, and provided with a separate back up battery to store locations between acquisitions, thus reducing the time and energy required for a location fix.

Profiler

The Profiler unit (Figure 6) adapts elements of the operational ARGO float and Moored Profiler instruments. The cylindrical pressure case houses the batteries, drive system, instrument controller, CTD and underwater inductive modem (UIM) as well as provides buoyancy for the neutrally buoyant unit. The instrument controller and software are products of McLane Research Laboratories, Inc. and use the same electronic hardware and software scheme as the commercially available McLane Moored Profiler (MMP; Morrison et al., 2000). Hardware wiring diagrams are given in Appendix B, profiler assembly instructions in Appendix D, and detailed operating instructions in Appendix F.

Taking advantage of the extensive CTD development effort for ARGO floats, ITPs are equipped with identical SBE-41CP CTD sensors. These low-power instruments (drawing about

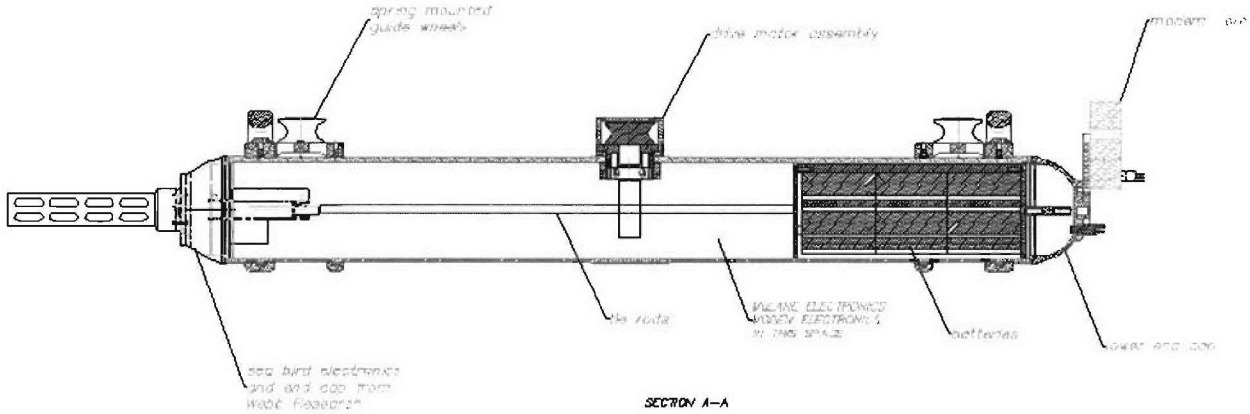


Figure 6: ITP Profiler Unit

0.25 W in continuous operation), manufactured by Sea-Bird Electronics, Inc. mount to a hemispherical end cap on the cylindrical pressure case. The ITP samples while profiling in either direction, although data from the down-going profiles is degraded by the wake of the ITP body. Sea-Bird SBE-44 UIMs are integrated to transfer the acquired profile data to the surface controller. With the relatively fast data rate of the Iridium link, we are able send full 1 Hz sensor sample rate CTD data to shore. High resolution sampling will facilitate study of diffusive layering, intrusions and other finescale structure. Wake errors in down-going profiles largely depend on the strength of the ice-water velocity difference in comparison to the profile speed (dictating the shape of the instrument wake relative to the CTD sensing volume). Data from the first prototype ITPs indicate that there is obvious smoothing of the fine structure in the down profiles versus the up profiles.

In order to facilitate deployment of the devices (Figure 7), the ITP was designed so that it can be deployed through an 11" hole in the ice floe (the maximum diameter that can be bored using conventional hand augers). The ARGO float cylindrical pressure case (6.5" OD) nicely met this requirement. Rather than use the pumped, variable buoyancy system of the float, a traction drive unit (very similar to that used on the Moored Profiler) is mounted roughly midway along the ITP case. (A buoyancy drive like the floats was considered, but a traction drive can develop greater force than the present float-buoyancy unit and thus is better able to function in strong currents with large wire angles.) Torque from a small, brush-type motor running in air within the pressure case is transferred with a magnetic coupler to the drive wheel in the seawater. The wheel is held in tension against the wire by two spring-loaded guide sheaves at the top and bottom of the Profiler. To hold at the rest depth between profiles, the drive motor leads are shorted; the induced EMF associated with motion of the drive wheel serves as a dynamic brake.

The ITPs are typically ballasted to be neutrally buoyant slightly above their profiling mid-depth. Modest errors in ballasting incur no penalty in performance as the additional energy needed to work against buoyancy in one profile direction is recouped in the other direction. The power requirements are approximately 1 W to profile at 25 cm/s.

The profiler controller (PROCON) is designed around the operational MMP system, with the CTD and engineering data passed inductively via the UIM to the surface controller (SURFCON) at the end of each ITP profile. The computer is a Tattletale 8 micrologger from Onset Computer, with 512 Mb flashcard memory.

The standard MMP operating software was modified by McLane for the ITP (software version 3.13 was used in the latest prototype ITPs). The profiler takes profiles based on user programmable sampling depths and schedule, either in regular (evenly spaced) or burst sampling modes. The profiler timing and engineering data (including motor current) are stored in one set of files (Exxxxxx.DAT), while the CTD data are stored in a separate set (Cxxxxxxx.DAT). To prevent the flash card memory root directory from filling up, the software only allows at most the last 40 profiles to be stored on the card -- older files are deleted. The complete raw binary files are sent to SURFCON and subsequently telemetered to a computer at WHOI. Though the present system samples only temperature and conductivity versus pressure, the hardware could support other on-board sensors (such as dissolved oxygen, some bio-optical sensors, and a current meter).

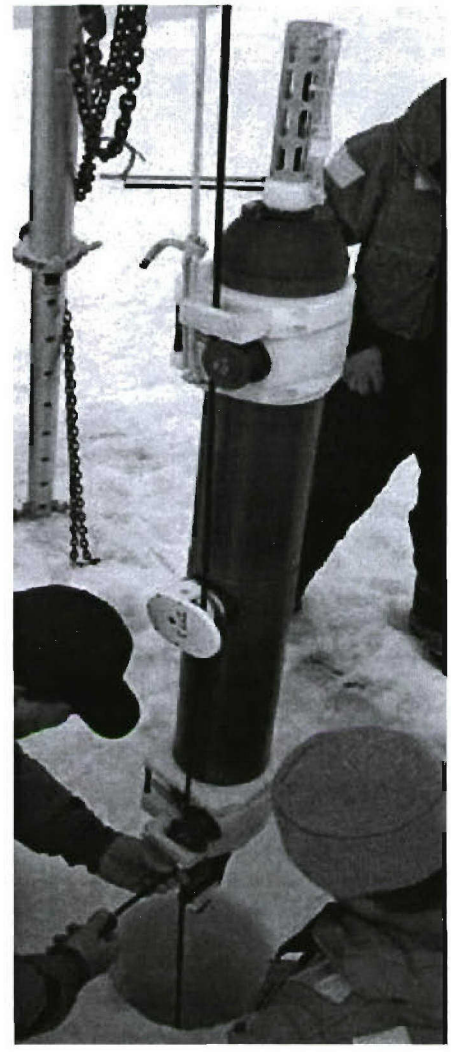


Figure 7: Attaching ITP to mooring wire during deployment.

Tether

The tether for the ITP (Figure 8) is standard 1/4" plastic-jacketed wire rope with threaded, insulated terminations providing an inexpensive, but durable mechanical and electrical connection. The steel wire acts as the electrical conductor, with a seawater return. The upper 5 m segment of the tether is encased in urethane, and includes a return wire for the inductive modem circuit that spirals and is encased with the wire rope. At the top end the tether threads

into a machined fitting which is coupled to the electronics tube and has an electrical breakout connector. The return wire is electrically connected through a similar bulkhead penetrator. At the bottom of the urethane encased section, the return wire is attached to a grounding plate. The termination at the bottom end of the tether acts as the other grounding plate. Shock-absorbing spring bumpers are clamped onto the wire at the top and bottom of the programmed profiling interval to prevent the ITP from impacting the tether terminations. The tether length on the prototypes was 805 m, but shorter lengths could be used in regions of shallow bathymetry (such as the 260 m Chukchi Cap). Despite the fact that the tether has quite a few turns of the seawater return side of the loop about the jacketed steel center cable, there seems to be no noticable effect on the ability of either SIM or UIM to detect the signal driven by the other over the length of the ITP mooring cable in seawater.

A 250 lb ballast weight (made of 50 lb plates to facilitate transportation) is fixed to the bottom wire termination to add tension to the wire and minimize its catenary. The WHOI CABLE model (Gobat and Grosenbaugh, 2000) was used to determine the attitude of the ITP mooring due to 25, 38, and 51 cm/s ice floe drift speeds using several different wire lengths. The model predicts about 5 m of vertical uplift of the bottom termination at 25 cm/s, about 32 m at 38 cm/s and about 85 m at 51 cm/s. Horizontal displacement of the bottom termination is indicated to be about 100 m, 220 m, and 350 m, respectively. To accommodate the catenary of the ITP mooring at times of ice floe drift speeds up to 35 cm/s, 25 or 30 m of extra cable (beyond the programmed maximum profiling depth) is needed. So mooring cables of about 790 m length should allow for profiles as deep as 760 m in the vast majority of ice drift conditions. At the extreme instances when drift rates approach 51 cm/s drift, it may be impossible for the profiler to climb the wire against the current, making the maximum depth of the tether moot.

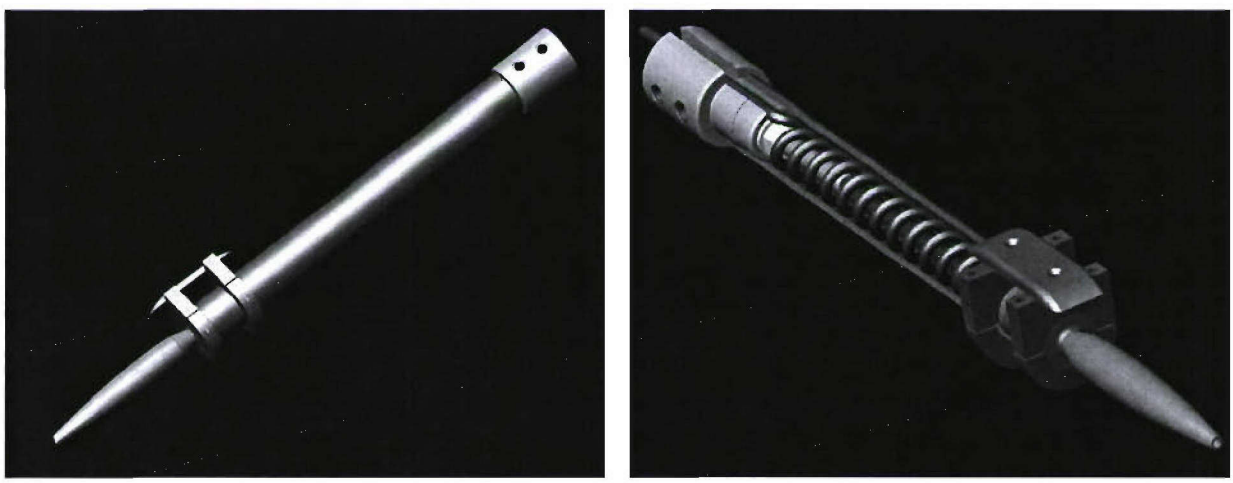


Figure 8: ITP Cable Assembly, upper 5 m of 805 m segment: external (left), internal (right).

Power

Based on operation of the prototype ITPs in the field, battery packs totaling 36 lithium BCX "DD" batteries should be capable of powering the surface electronics for over 4 years at 2 profiles per day (after derating the batteries to account for cold temperature degradation), while 24 cells should sustain the underwater profiler for over 2.5 years.

Individual battery slices (each nominally 1250 Wh) supply power to the surface electronics, with connectors on the SURFCON board accommodating as many as six packs (but the present tube length of the surface buoy limits space to 4 battery slices at once). A 12-cell 10.8 V battery slice consists of three cells wired in series with a diode and four series wired in parallel. A 3 A fuse also guards against accidental short circuiting. Together, three packs should produce at least 3300 Wh after derating for temperature. Based on a data throughput of 100 kbytes/day from the profiler (2 profiles), 100 bytes/s inductive modem link, and 200 bytes/s Iridium link, the power requirements are estimated to be less than 2 Wh/day.

The profiler has its own battery pack consisting of 24 lithium "DD" cells totaling 2500 Wh and sufficient for an estimated system endurance of 1.5 million meters of profiling (derated for temperature) based on a total energy consumption rate of 1.35 W during profiling operations (= CTD + motor + UIM transfer + overhead). Consequently, with a standard battery pack, ITPs scheduled to profile once per day (either up or down) are expected to have sufficient power for at least 4.5 years, twice per day (one each way) for 2.5 years, and 4 profiles per day (2 up, 2 down) for 1.25 years. Furthermore, there is sufficient room in the profiler tube for an additional 1250 W-hr battery which would increase the lifetime by 50%.

SOFTWARE OPERATION

SURFCON

The data controller in the surface package (SURFCON) obtains technical status information, locations from GPS, operates the surface inductive modem (SIM) interface, communicates with the underwater inductive modem (UIM) on the profiler, obtains the data from the instrument (PROCON), and feeds the information to the Iridium satellite unit (ISU). Hardware wiring diagrams are given in Appendix A, and the operating instructions summarized here are detailed in Appendix C.

There are two programs that are used for ITP testing and deployment: "xbt" is a diagnostic program for testing the individual components prior to deployment, and "surfcon" is the acquisition program.

The program "xbt" exercises different components of the system including: writing files to flash memory; reading voltages from the ADC; turning on each device for serial communications; the suspend function; placing a call with the ISU and sending a test message; displaying the GPS RMC string, date and time; setting the real-time clock (RTC); and powering SIM and UIM, and reading status from UIM.

The "surfcon" software is the automated program for operating the surface package during a deployment with a profiler to obtain and telemeter the data back to the laboratory (Figure 9). In order to ensure reliability, the operating software is written to accommodate all known states, but a hardware watchdog timer is included to increase the likelihood of recovery from stalled states or a genuine processor problem. On powerup (or reset) the Persistor CF-2 controller begins running the ITP operation program (SURFCON.PXE) indicated in its AUTOEXEC.BAT file. After initializing the hardware, loading the operating variables (by reading the configuration file ITPSYS), and opening a logfile to record operating events, the program enters the main program loop which responds to interrupts from the tone detector to receive data from the profiler, and keeps two separate schedules: one for obtaining engineering status (and GPS location) information, and one for transferring the queued files via Iridium.

The main loop begins by determining the next status and transmission times, updating and saving the status and location file at the first occurrence of a new day, then reverts the SURFCON controller to suspend mode until the earlier of the status or transmission times is encountered. Suspend mode is essentially a power-off condition whereby the realtime clock maintains time and main memory while drawing only 10 μA. SURFCON will awaken from the suspended condition for two reasons: 1) wake on time, when either the next status check or time to conduct ISU operations has been reached, or 2) wake due to tone detect, from the UIM or RESET switch.

When the time for a status update (including GPS location) is reached, then SURFCON saves the buoy temperature and voltages information in the status and log files and begins QCHECK. When the time for an ISU transmission is reached, then SURFCON begins QCHECK. When the tone detector signals, SURFCON awakens and enters a loop to conduct communications between the SIM in the surface package and the UIM in the profiler instrument. The complete IM protocol is described in Appendix G. Briefly, SURFCON prompts with REQNEW and PROCON responds with the name of each new profiler file to be relayed, the file, and checksum info. This process repeats until all the new files are transferred to SURFCON, which stores the files in subdirectories by year and adds the filenames to the queue for transmission. Upon completing the SIM/UIM communications, SURFCON begins the QCHECK routine.

Scheduled Iridium uploads occur during QCHECK, where SURFCON reads filenames from the queue, powers and registers the ISU, dials the WHOI data serving computer, sends all files in the queue, then terminates the call. The SURFCON-to-logger computer communications, including provisions to allow the logger to pass some simple commands to SURFCON via the Iridium link, are described in Appendix H. At the present time, the commands are limited to specific file requests and directory listings from both SURFCON and PROCON. Upon completing QCHECK, SURFCON operates on any received command files, and then returns to the start of the main loop.

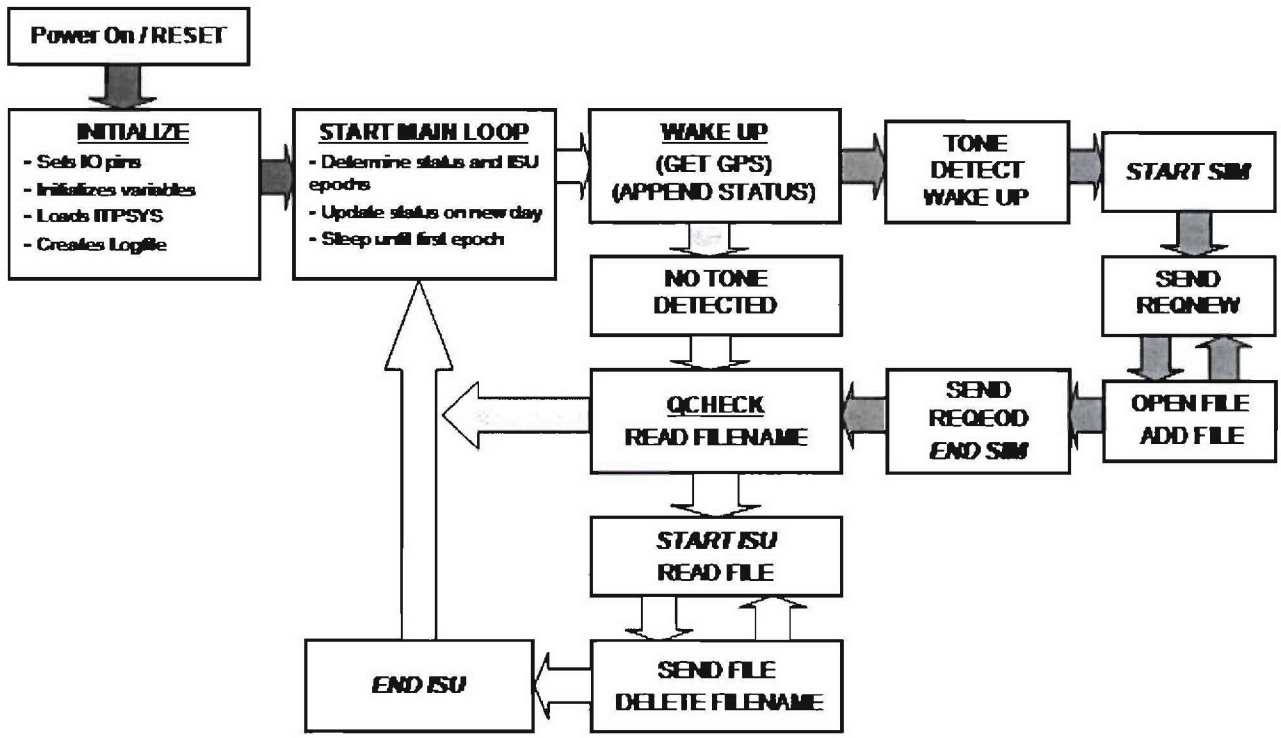


Figure 9. SURFCON operation block diagram

The only way to break out of SURFCON externally is by activating the RESET line via the console port (or with a push button switch on the SURFCON board). In addition, there is a watchdog timer that will cause the PF-2 operating system to restart after 20 minutes of inactivity, to protect against software code failure. After resetting the operating software, the user has 5 seconds to break out the SURFCON program by entering CTRL-X twice. Resets are incremented and recorded in the status files, and a new log file is opened.

PROCON

The electronic hardware and operating program of the profiler controller, or PROCON, is based on the McLane Moored Profiler (MMP) Board Stack with a Sea-Bird Underwater Inductive Modem (SBE-44) OEM Stack. PROCON controls the drive motor, operates the CTD, records the files on a flash card, and communicates the data to SURFCON via the inductive modem link. The ITP profiler software allows for either all, or a limited revolving number of profiles to be saved on the flash memory card. A limitation of the file allocation in the prototype PROCON software dictated that a maximum of about 2045 profiles (2 files per profile) could be saved in the root directory. The battery capacity of the profiler with a standard pack is expected to be between sufficient for 1600 to 2000 (750 m long) profiles, so it is unlikely that this software limitation will be reached. However, since ITPs are not expected to be recovered, PROCON is usually configured for file deletion after each profile (keeping only the prior 40 files). A detailed description of the PROCON operating instructions is provided in Appendix F.

At the end of each profile, PROCON downloads data from the CTD into one file, formats engineering information into a second file, and relays both via the inductive modem to the surface unit (SURCON). These data files are queued along with the SURFCON status files and relayed to shore.

TESTING

A series of bench tests, environmental tests, tank tests, and dock tests were performed on each prototype ITP prior to deployment to ensure full functionality in the field (Figure 10). Bench tests are used to qualify individual components. Environmental tests to the electronics in the surface packages of the prototypes indicated reliable operation and data transmission at temperatures as cold as -38 °C. Profilers were exercised and wet weighed (for ballasting) in the McLane Research 15-m-deep freshwater tank. Finally, each ITP surface unit and matching profiler were operated together while suspended from the WHOI pier using a 15-m long test mooring cable.

It became apparent during the testing of ITP1 that the GPS locations contained spikes at regular intervals while the antenna was fixed to single location. Due to the location spikes and cable loss along approximately 40' of low-loss coaxial cable between the transceivers located in the environmental chamber and the antennae mounted outside, mean location errors were over 100 m. Installed in the ITP surface packages, field tests documented occasional location deviations up to 60 m. This noise was more apparent when voltage decreased as battery packs were exhausted. These spikes are relatively easy to identify and edit from the recovered GPS

time series. Only a few large position spikes were documented while testing ITP3 (Figure 10), but the field data also exhibit occasional position errors. In the next generation ITPs, the GPS sensor is separate from the Iridium transmitter and includes a backup battery to save the last location and reduce location errors.

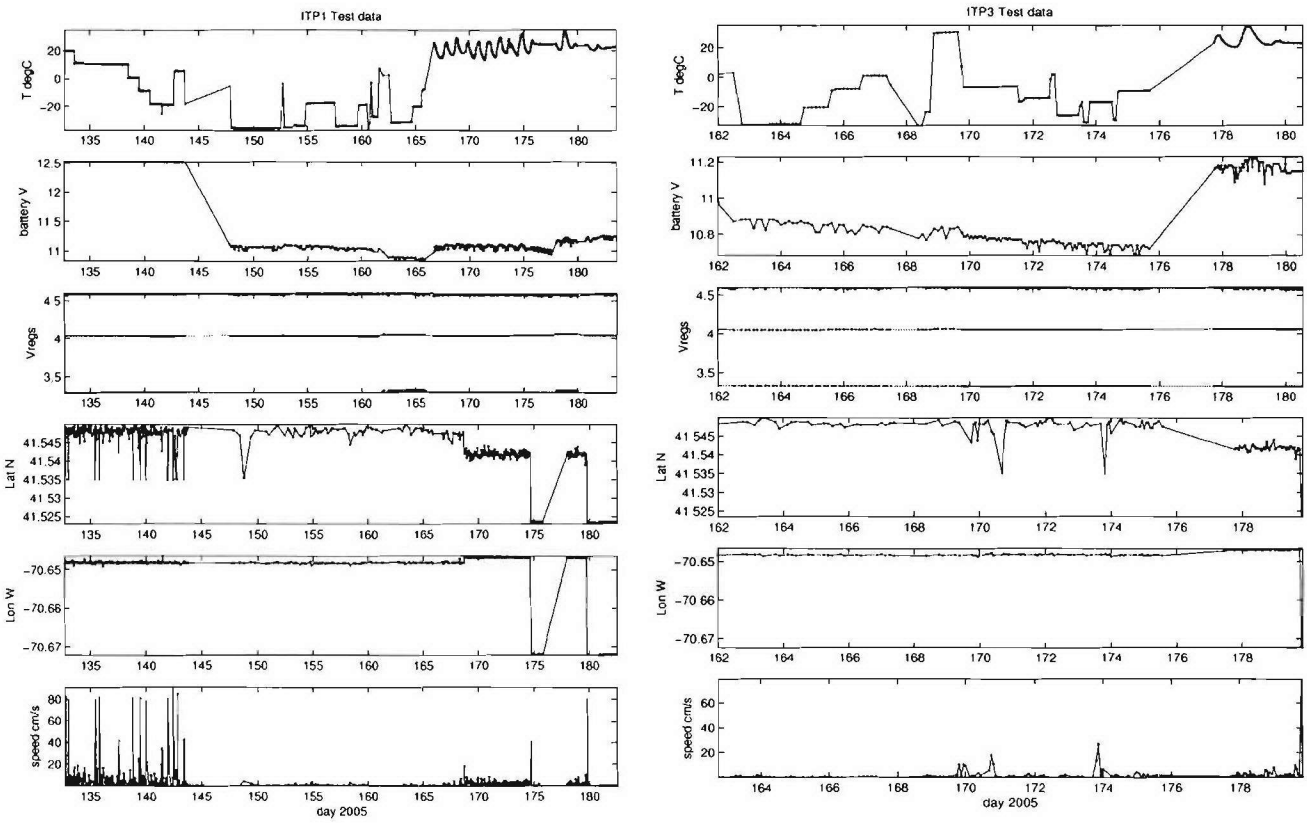


Figure 10: Temperature, voltage, and locations from ITP1 (left) and ITP3 (right) cold, dock, and field tests.

CTD Sensor Care

The first three ITPs incorporated Sea-Bird Electronics 41-CP CTD sensors. Calibrations are performed by Sea-Bird prior to installation on the ITP, and calibration coefficients are stored in non-volatile memory. Instructions on how to configure the CTD sensors for PROCON are given in Appendix E.

To avoid altering the calibration, it is extremely important to keep the conductivity cell clean if the sensors are immersed during testing. Users will typically fill the CTD plumbing with ultra-clean DI water, taking care to get air bubbles out, and then cap the intake and exhaust ports

or loop a tygon tube from the TC duct intake to the exhaust barb. Care must be exercised during shipping and deployment that this water does not freeze and damage the sensors. If the cell has been fouled, one can attempt to clean it by washing/rinsing the cell with warm triton solution or running the warm solution in a closed loop with the CTD pump for half an hour. In either case,a laboratory conductivity calibration will be required to achieve 0.002 pss accuracy in derived salinity.

To prevent wear to the pump, it should not be powered when testing the profiler in air. The pump power feed from PROCON (J7) pin 6 to the 41CP 10-pin header connector (JP-1) pin 10 may be temporarily removed if a deployment is being simulated.

Profiler Ballasting

For optimal performance, the profilers should be ballasted to be neutrally buoyant near the mid-depth of the planned profiling interval. Ballasting will, in turn, depend on the seawater conditions at the deployment site (which must be estimated before deployment) and on the *in situ* volume (V) of the instrument. The ITP profiler body is nearly neutrally buoyant in freshwater at laboratory temperature. For typical polar ocean applications (where the seawater is denser), additional mass will be required.

Instrument ballasting is an application of Archimedes principle: buoyancy force equals the weight of the displaced water, $\rho\ V\ g = m\ g$, where m is the instrument mass (weighed in air), g is gravitational acceleration, and ρ is the *in situ* seawater density. The difficult part is estimating the change in V for the different pressure and temperature conditions on site. V_{bath} is estimated from the air weight, water weight and the density of the bath water. For a given estimated ocean *in situ* density (ρ_i), the change in mass is related to ρ_i multiplied by V_i, where V_i is the *in situ* volume. Based on the properties of the materials in the instrument, temperature (α) and compressibility (β) adjustment terms are estimated in:

$$V_i = V_{bath} * [1 + \alpha\ * (T_i - T_{bath}) - \beta * (\rho_i - \rho_{bath})]$$

Normally , α and β will be positive (instrument volume contracts under pressure and at colder temperatures). For the prototype ITPs, α was estimated to be 3.25 cc/°C and β was estimated to be 0.1 cc/db. Operation of the prototypes in the field verified the selection of these estimates. Finally, the amount of ballast to be added to an ITP for a given ocean temperature and density is the difference of the air weight minus $\rho_i * V_i$.

To determine the expected seawater conditions, salinity and temperature profiles from the planned deployment region from previous hydrographic surveys or climatological databases need to be obtained. The ranges and midpoints of temperature and density need to be calculated over

the vertical depth that the profiler will operate. Based on this information a mean seawater density is selected, and the water weight of the profiler may be adjusted accordingly.

To determine the water weight of the profiler, the instrument (complete with CTD sensors and battery packs) must be lowered into a freshwater tank and weighed to at least 1 gram accuracy. Since the instrument without ballast is positively buoyant, this entails adding a small known ballast weight (typically less than 5 kg of lead weights) to the instrument. For a stable water weight determination, the temperature of the instrument must be allowed to equilibrate with the temperature of the bath. Space inside the battery compartment and bottom endcap is provided for adding lead ballast. When the ballast is stored inside the profiler pressure vessel, as it typically is, then the weight of the lead ballast that goes into the calculations is the same as the air weight.

IMPLEMENTATION

Field Installation

The ITP system is designed so that it may be deployed directly from an icebreaker using man hauling or helicopter ferrying, or up to 300 hundred miles from fuel depots using a single small aircraft (Figure 11). This was achieved by minimizing the size and weight of the system and the deployment gear. The ITP surface buoy weighs 70 kg (150 lb), the profiler weighs 30 kg (70 lb), and a 805 m wire tether on an aluminum spool is 255 kg (560 lb). Altogether with the tether ballast, the ITP hardware totals approximately 450 kg (1000 lb). Deployment technicians, emergency survival gear, and the minimum deployment equipment bring the payload up to 1000 kg (2200 lb). This weight may be transported up to a maximum 280 miles roundtrip by a medium lift helicopter (such as the Bell 212), or over 600 miles roundtrip by the DeHavilland Twin Otter airplane. Of course, the amount of equipment that can be transported during any single flight is a function of the distance of the site from the ship. If the roundtrip distance is reduced, several ITP systems could be loaded onto and deployed from a single Twin Otter.

The ITP deployment operations conducted to date have been conducted as part of the Beaufort Gyre Exploration Program (BGEP; http://www.whoi.edu/ beaufortgyre) during Joint Western Arctic Climate Studies (JWACS) cruises, and supported by the Canadian Coast Guard icebreaker *Louis S. St. Laurent* utilizing BO-105-CB helicopters for reconnaissance to select an appropriate icefloe, and to transport gear and people for the deployment. These particular helicopters can carry up to 4 passengers and have a stated payload (fuel and cargo) of approximately 675 kg (1500 lb), so several flights were needed to transport a single ITP system, deployment apparatus, and personnel.

Reconnaissance flights to select the icefloe include 1-2 scientists (in addition to pilot and rifle bearer) with a 2" hand auger and measuring tape. Multiyear icefloes are identified, landed upon and drilled to determine ice thickness. The ideal platform for an ITP deployment is a multi-year ice floe (which can be identified by the lighter shade of blue color in melt ponds in summer) that is relatively thick (2.5 to 4.5 m), level, and sparsely ponded.

For the deployment operation, 2-3 technicians (plus rifle bearer) and as much as 1100 kg (2400 lb) of gear must be transported to the selected site. Using helicopters or by man hauling, each ITP system can be transported to the deployment site in several pieces: surface package, wire tether on aluminum spool, anchor weight, and the Profiler unit. Typically 4-5 slingloads (or sled loads) of gear only are transported to the site, then another 1-2 flights transport personnel and equipment stored in the cargo bay.

With the aid of a light weight, portable tripod, the tether ballast weight and subsurface tether is deployed through a 10.5-11" diameter hole augered through the icefloe (Figure 12). At a convenient point, the ITP is mounted on the wire (two bracket connections) and eased down the wire through the ice hole. After making one mechanical and electrical connection at the surface unit, the package is positioned onto a wooden palett over the hole and the tripod is disassembled. Based on the preprogrammed sampling plan entered in the ITP profiler, the instrument will then start working.



Figure 11: Transporting ITP gear to deployment sites using hand sleds and helicopters (in slings and cargo).

The operations to deploy the prototype ITPs each took between 2-4 hours, with 3-4 helicopter flights (sled loads) to return the deployment gear and personnel to the ship. From first landing to last departure, the full ITP system can be deployed in 4-8 hours.

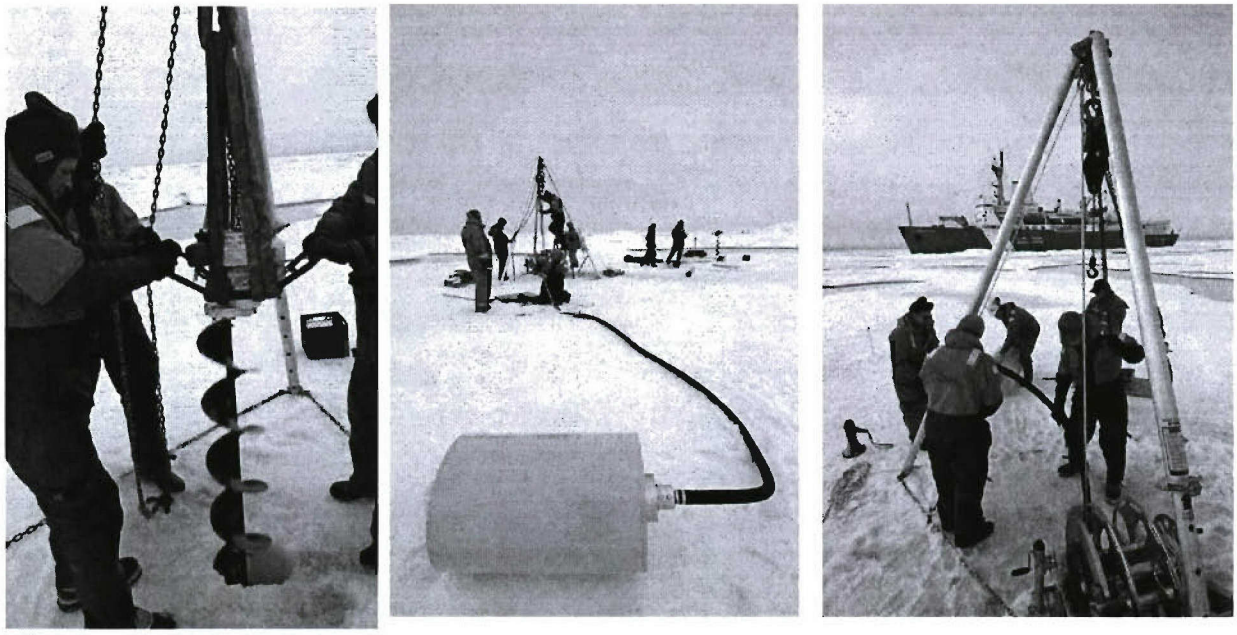


Figure 12: Augering 11" deployment hole with tripod assistance (left). Surface package after attachment to ice-strengthened cable (center). Lowering surface package and cable through ice hole with slip line (right).

Prototypes

One ITP (serial number 2) was deployed in 2004 and two were deployed in 2005 (serial numbers 1 and 3) from JWACS cruises on the *CCGS Louis S. St. Laurent* (Figure 13). Both ITP 1 and 2 utilized helicopter transport, while ITP 3 was deployed by lowering equipment over the side of the icebreaker and man hauling it into position. All three ITPs were deployed with IMB buoys several meters away and installed where the ice was expected to drift through the BGEP bottom-tethered mooring array over the following year. Developed and built at the US Army CRREL, the IMB primarily acquires time series of ice temperature profiles and measures the growth and ablation of sea ice (and snow) at the top and bottom ice surfaces. The combination of the ITP systems and IMB systems are an example of an Ice-Based Observatory (IBO) that obtains cotemporaneous sea ice and seawater properties for a sustained duration.

ITP #2 was deployed in the Beaufort Sea on August 19, 2004 at 77.174° N, 141.238° W during the JWACS 2004 cruise. ITP 2 together with IMB (07413) buoy were deployed on a 4 m thick multiyear ice floe. ITP 2 collected 244 profiles on a fast sample schedule of 6 one-way profiles between 10 and 750 m depth each day.

ITP #1 was deployed in the Beaufort Sea on August 15, 2005 at 78° 51.1' N, 150° 15.9' W as part of the JWACS 2005 cruise. ITP 1 and IMB (07949) were deployed on a 4.6 m thick multiyear ice floe.

ITP #3 was deployed in the Beaufort Sea on August 23, 2005 at 77° 36.1' N, 142° 11.8' W (about 200 km to west of ITP1), also part of the JWACS 2005 cruise. ITP 3 and IMB (07950) were deployed on a 3.5 m thick multiyear ice floe.

Both ITP1 and ITP 3 are operating on a fast sample schedule of 4 one-way profiles between 10 and 760 m depth each day.

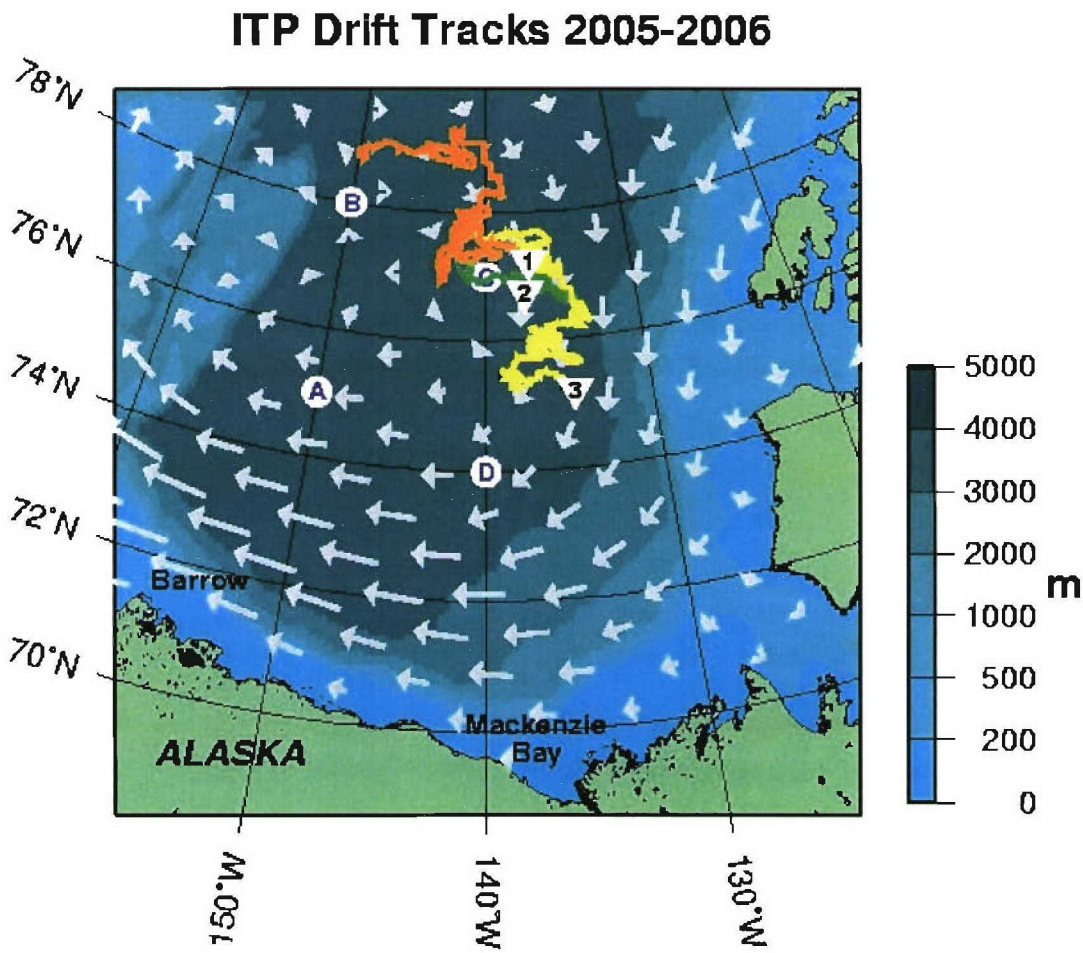


Figure 13: ITP prototype drift tracks (as of June 2006): ITP2 in 2004 (green), ITP1 (orange) and ITP3 (yellow) in 2005. Numbers mark most recent locations. Letters indicate locations of BGEP moorings. Climatological ice drift vectors from the IABP are grey vectors superimposed on shaded bathymetry.

DATA DISTRIBUTION

Iridium Upload

Each ITP is expected to return 1600 or more daily high-vertical-resolution measurements of upper Arctic Ocean temperature and salinity in near real time spanning all seasons over a three-year lifetime. To receive all the data uploads, two logger computers running Linux are connected by a Rev 2 Hayes modem to dedicated telephone lines at WHOI (Appendix H). The logger computers are configured for binary data acquisition and can handle partial file transfers (due to Iridium link loss) by instructing SURFCON to retransmit incomplete files starting after the last correct packet received by the logger. This entails switching the master-slave responsibilities in the protocol such that once a call connects, SURFCON prompts the logger. The expected response is a request to either restart a failed transmission, transmit a new file (most often the case), or receive a command packet.

SURFCON normally sends 2 files per profile (about 20 kbytes and 30 kbytes, respectively), as well as a daily (~4 kbyte) status file at the first transmission epoch after 0000Z. When SURFCON sends a file via Iridium to the logger computer at WHOI, it is done in 2048 byte packets, each with a similar header. If a packet is received correctly, the logger strips off the header bytes and appends the current file, so there is no re-assembly necessary once data or engineering files arrive, and standard MMP data extraction programs may be used to access the data (Appendix H).

Data (Cxxxxxxx.DAT) and engineering (Exxxxxxx.DAT) files from SURFCON are sent to the logger preceded with a 50 character PROCON metastructure and appended with a 70 character SURFCON metastructure. Note that the 2 structures are identical for the first 49 characters in order to assure that the description source of each file is embedded in that file and likely recoverable from at least one place or the other.

The status file is of the name type mmddyyyy.STA, where: mm=month, dd=day and yyyy=year. A status file is typically a sequence of entries of the form:

```
08/15/2005  22:01:01 Surfcon status: 3.23  11.20  4.59  4.04  3.29  0.01
Last Profiler contact: No contact yet
22:01:01.75  78 51.986N  150 16.4851W   15/08/2005
Space remaining on CF is 124882944
Restarts=0  contime=10800  max daily ISU time=5400
IMtime=0  dailyISUtime=0
```

where the first date and time represent when the SURFCON awoke at the specified interval to assemble the status information; the 6 floating point numbers are the Celsius temperature inside the controller housing, the lightly loaded SURFCON battery voltage, the 4.5 V DC/DC converter

voltage for the ISU, the 4.0V DC/DC converter voltage for the SURFCON board power, the output of the Persistor 3.3V regulator and the unused auxiliary 3.3V regulator. On the next line, there is normally a date and time specifying the last time the PROCON contacted the SURFCON for a data transaction. The third line is the time, latitude, longitude and date from the GPS receiver. The GPS time, if acquired, is used to reset the Persistor realtime clock. The remaining lines indicate the space (in bytes) remaining on the SURFCON flash card, and other operational information. The last line in the status file includes the number of IM wakeups and the time in seconds that the Iridium link has been in use during that day.

SURFCON also supports commands to allow access to specific data files both on its own flash card and on PROCON, as well as directory lists on each, SURFCON status and profiler UIM status. Consequently, the logger is also capable of handling outbound traffic, i.e. a command packet, from logger to SURFCON (Appendix H).

Preliminary Processing

All of the telemetered data are processed and made publicly available on the ITP internet web site (http://www.whoi.edu/itp/data) as soon as they are received. Within a couple of hours after arriving on the WHOI logger computer, the files from each profile are accessed by a separate computer that acquires the binary data files from the logger computer, extracts and de-spikes the data, averages profiles into convenient 1 or 2 m bins, produces plots and saves the data in ASCII and MATLAB format files.

The raw GPS buoy location data are also made available on the ITP web site in an ASCII file: itp*N*rawlocs.dat. On ITP 1 and ITP 3 ITP, GPS fixes were scheduled every hour, but are sometimes missed if the acquisition time exceeds 2 minutes. The raw locations provided on the web site are currently not screened to remove spurious glitches, but the location time series are filtered and interpolated to produce locations for each profile data file.

Depth-bin-averaged profiler data files (with interpolated location) are available in two formats: itp*N*grddata.tar.Z or itp*N*grddata.zip, where *N* is the ITP number. Each profile is named itp*N*grd*nnnn*.dat, where *nnnn* is the profile number. Each file has one line of header data: "%year day longitude(E+) latitude(N+) ndepths", the next line contains the values, the third line is a header for the profile data: "%year day pressure(dbar) temperature(C) salinity", and the remaining lines are the data, except for the last line which is: "endofdat". The convenient gridded data are for general use, but the raw data files are also available by ftp.

Sample data from ITP2

ITP 2 was programmed with an accelerated sampling plan of 6 one-way profiles per day between 10 and 750 m depth. Profiling speeds of 25-28 cm/s were achieved with profile-averaged motor current from the 10-11 V battery supply ranging between 120 and 260 mA (averaging 140 mA). Larger motor currents were observed at times of fast ice floe motion (exceeding 25 cm/s on occasion) when we presume that drag on the Profiler and wire are increased (Figure 14).

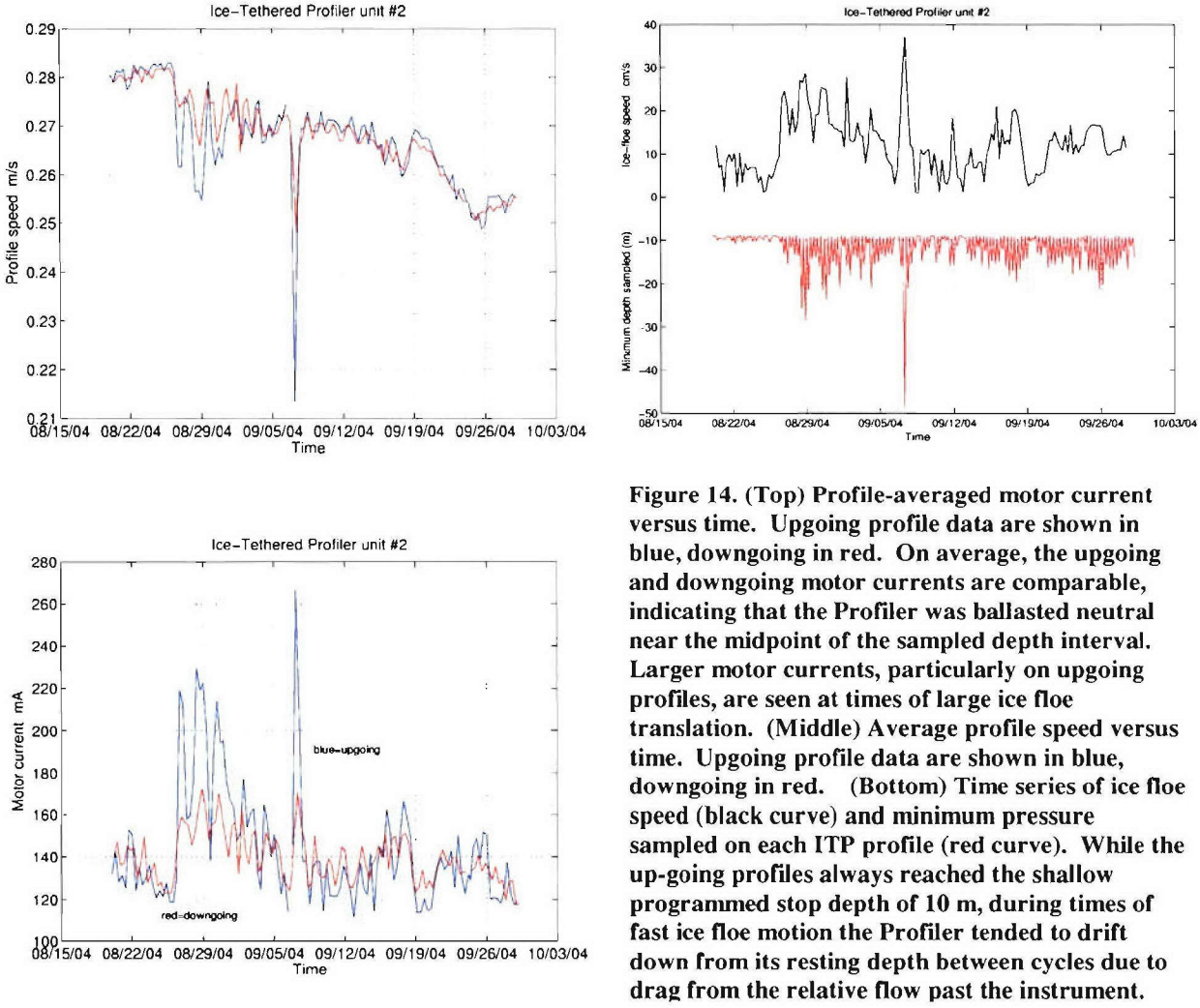


Figure 14. (Top) Profile-averaged motor current versus time. Upgoing profile data are shown in blue, downgoing in red. On average, the upgoing and downgoing motor currents are comparable, indicating that the Profiler was ballasted neutral near the midpoint of the sampled depth interval. Larger motor currents, particularly on upgoing profiles, are seen at times of large ice floe translation. (Middle) Average profile speed versus time. Upgoing profile data are shown in blue, downgoing in red. (Bottom) Time series of ice floe speed (black curve) and minimum pressure sampled on each ITP profile (red curve). While the up-going profiles always reached the shallow programmed stop depth of 10 m, during times of fast ice floe motion the Profiler tended to drift down from its resting depth between cycles due to drag from the relative flow past the instrument.

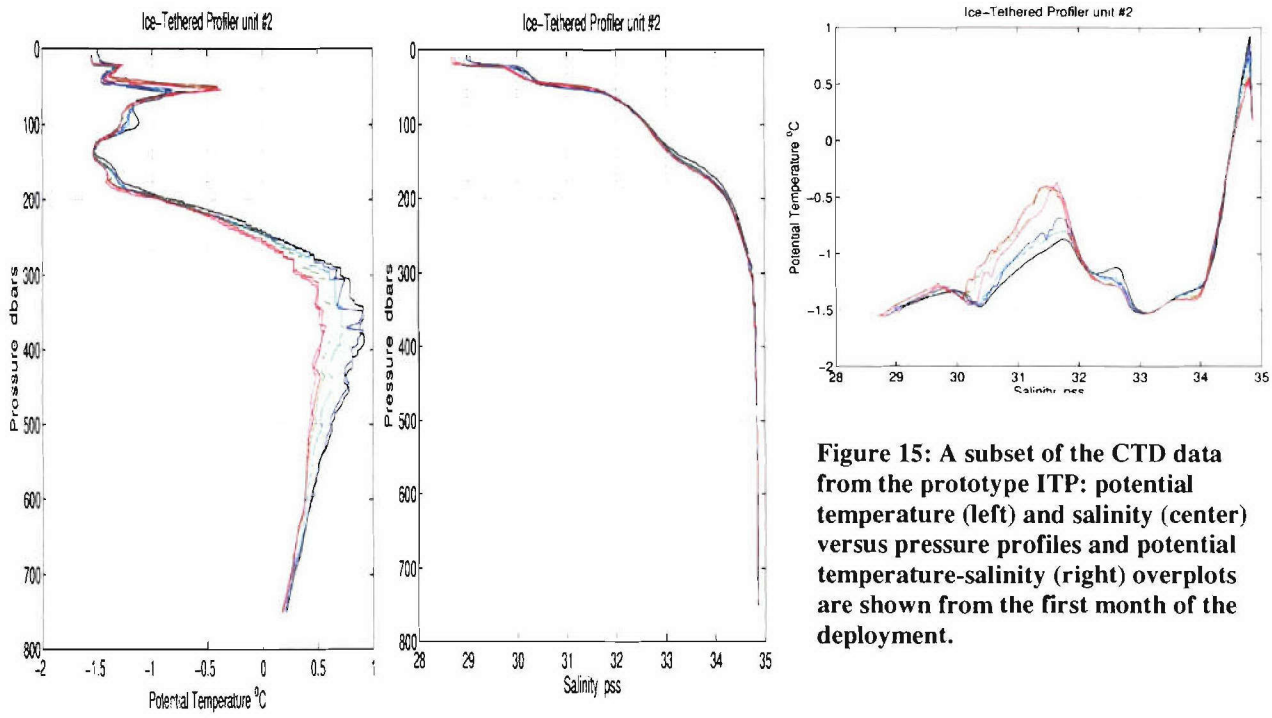


Figure 15: A subset of the CTD data from the prototype ITP: potential temperature (left) and salinity (center) versus pressure profiles and potential temperature-salinity (right) overplots are shown from the first month of the deployment.

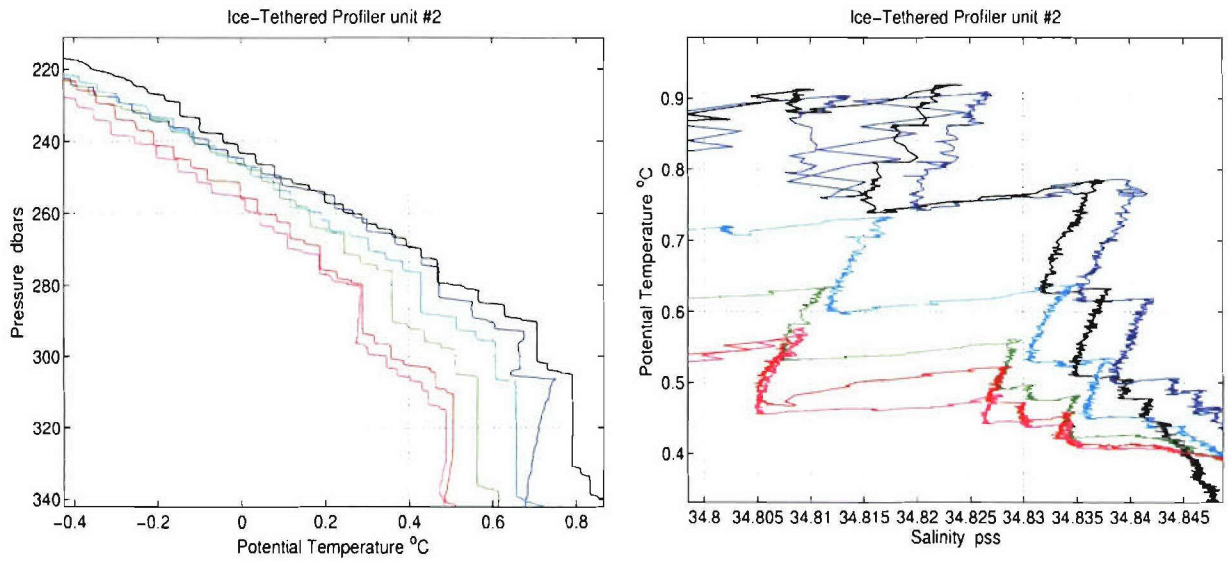


Figure 16: Expanded views of the potential temperature profiles and potential temperature - salinity diagrams. Above the Atlantic Layer, temperature and salinity both decrease with height: a stratification subject to the diffusive layering form of double diffusion that is manifested by the staircase profile resolved by the ITP (a). Overplotted potential temperature-salinity curves at the level of the Atlantic Layer (b) clearly document intrusions that erode this warm salty water mass.

The CTD profile data so far obtained document interesting spatial variations in the major water masses of the Beaufort Gyre including the low-salinity surface mixed layer, the complex forming the Pacific Halocline Waters characterized by multiple temperature extrema between 40 and 180 m depth indicative of the Alaska Coastal Water, the Summer and Winter Bering Strait Waters and winter shelf waters emanating from Barrow and possibly Herald Canyons, and the temperature maximum around 350 m depth characterizing the Atlantic Water (Figure 15).

Additionally, the recovered 1 Hz CTD data resolve well the thermohaline staircase stratification above the Atlantic Layer thought to be caused by double diffusion and the "nested" intrusive structures that incise the Atlantic Water (Figure 16). CTD data from the staircase stratification has additionally proven valuable for quantifying sensor response mismatches in the SBE CTD. Due to the placement of the CTD at the top of the Profiler, these small-scale structures are poorly resolved on down profiles when the CTD inlet lies within the wake of the Profiler body. Ideas for alternative CTD ducting are under discussion.

FUTURE PLANS

The practical, cost-effective and proven ITP design enables a sustained Arctic observation program in the spirit of the Argo program that is now operating in the temperate oceans (http://www.argo.ucsd.edu/). We envision a loose array of approximately 20 of these ITPs being maintained throughout the ice-covered Arctic Ocean to observe the annual and interannual variations of the upper ocean (Figure 17). Being low-cost, systems should be able to be deployed and maintained in sufficient numbers to map the upper Arctic Ocean thermohaline

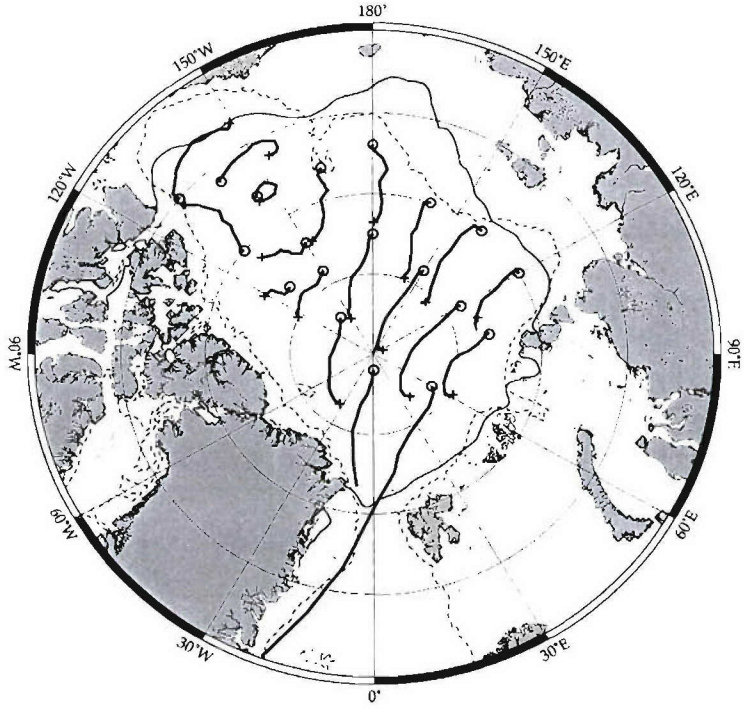


Figure 17: Simulated drift tracks for one year from 20 ITPs deployed in the Arctic at the circles and forced with climatological monthly ice drift vectors from the IABP.

properties at daily to weekly time scale. High vertical resolution data will also be valuable for documenting and assessing double-diffusive layering, thermohaline intrusions and mesoscale eddies, all possibly important to the evolution of the Arctic ice-ocean system.

In collaboration with the polar research community, we have begun initializing an array of IBOs by deploying ITPs in conjunction with CRREL IMB buoys and Naval Postgraduate School heat flux buoys. With support from the NSF Arctic Sciences Section, 4 new ITP systems are presently being prepared for deployment on the JWACS cruise in 2006 and on the NPEO expedition in 2007. Plans to augment the array for multiple years have been accepted by the ICSU/WMO Joint Committee for the International Polar Year 2007-2008 (Toole, "An Array of Arctic ITPs"; EoI #905), and submitted to NSF Office of Polar Programs, and to the European DAMOCLES community. Data from the array will provide the basis for operational activities as well as process studies and model validation/assimilation research, work that will ultimately lead to better understanding of the Arctic Ocean's response and role in global climate change.

One additional ITP being constructed in 2006 using internal WHOI funding will include a dissolved oxygen sensor on the profiler. Addition of other sensors (such as a current meter, PAR, fluorometer, and turbidity sensor) and additional fixed-depth modules such as surface meteorological sensors and subsurface acoustic systems are also being considered. In the future we will also exploit the two-way capability of the transmitter to allow users to modify the sampling schedule of the Profiler or other instrumentation that may be interfaced to the ITP over the RS-422/RS-485 network. The combination of subsurface acoustics with the Iridium telemetry could constitute a telecommunications link through the surface ice pack and serve as a future backbone for two-way transmissions to buoys, AUVs, and subsurface moorings in the Arctic Ocean.

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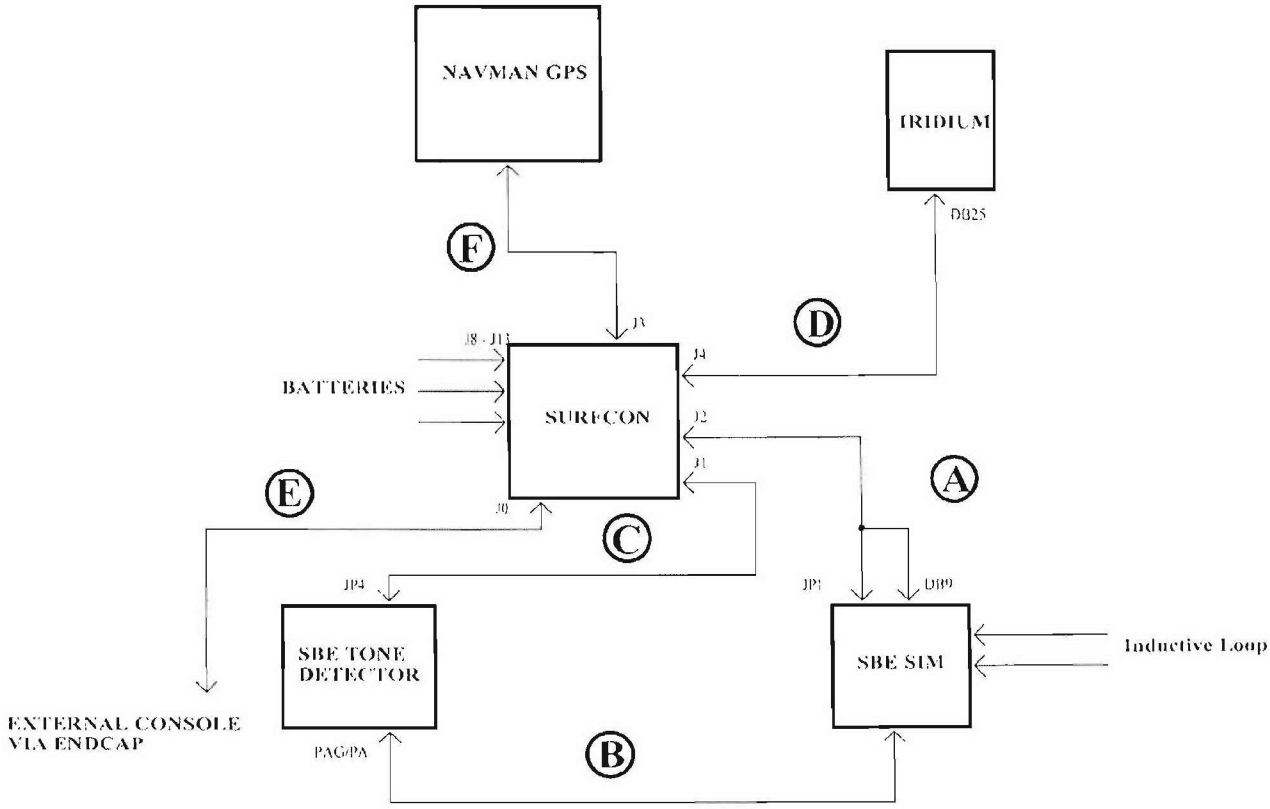
Morison, J. H., K. Aagaard, M. Steele, Recent Environmental Changes in the Arctic: A Review, *Arctic*, 53, 4, 2000.

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Appendix A: SURFCON Wiring Diagrams

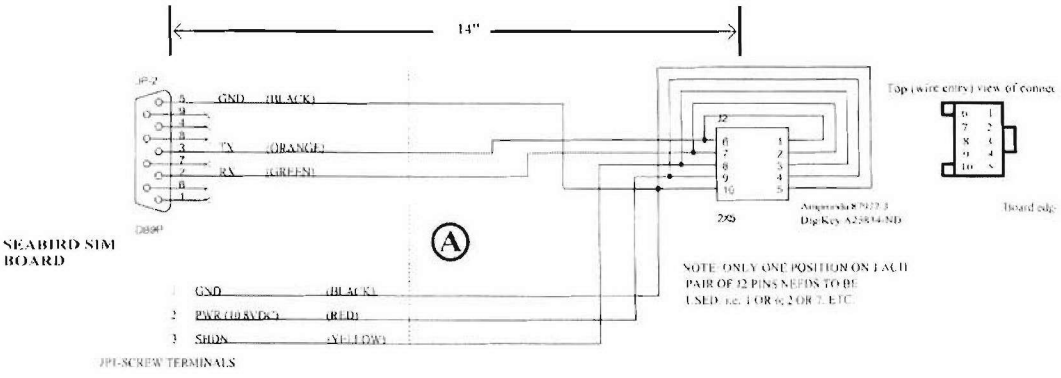


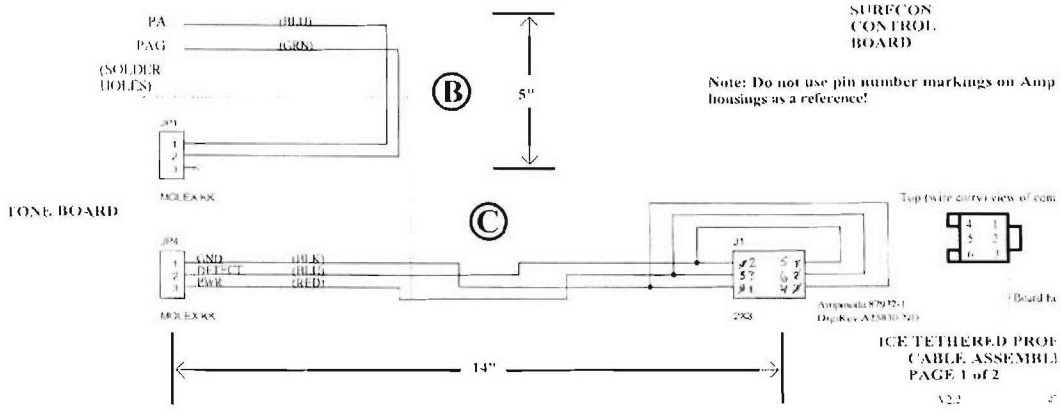
Ice Tethered Profiler
Surface Controller
Block Diagram

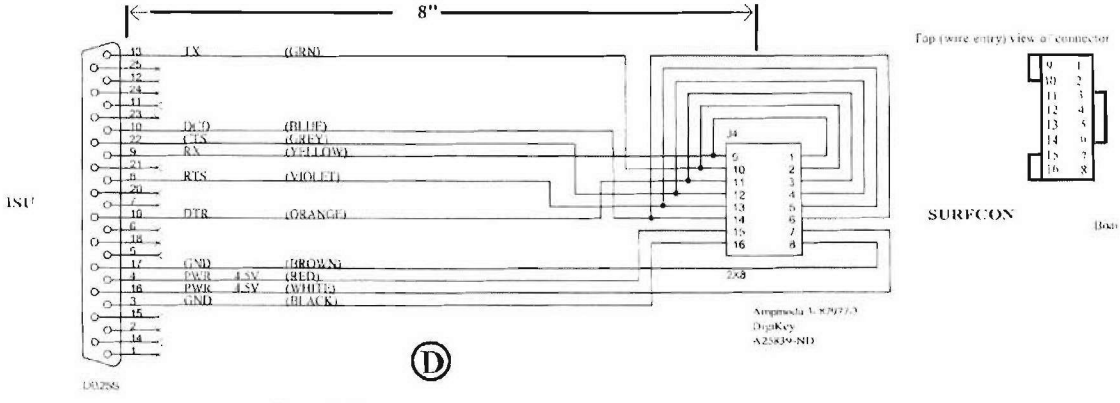
Jumpers must be properly set on SURFCON and SIM boards.

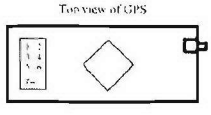
Surface mount R13 should be removed from SBE TD board.

Phone card with dial up data modem capability must be installed in Iridium ISU.

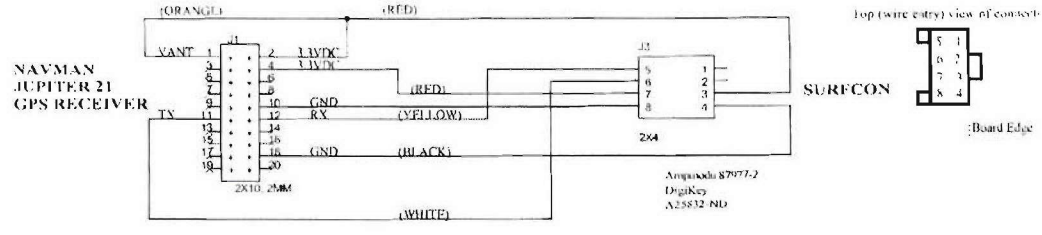








Note: Do not use pin number markings on AmpModu housings as a reference!



Appendix B: ITP Profiler wiring connections

MMP/Host Communications Port1:

COM1	J3-2	RSR1 (MMP RxD)
	J3-3	RST1 (MMP TxD)
	J3-4	DGND

MMP/Sea-Bird CTD/Pump Power & Communications (CMOS Voltage Levels):

FREQ	J7-1	DGND
	J7-2	FREQ1 (MMP TxD)
	J7-3	FREQ2 (MMP RxD)
	J7-6	VSW4 (CTD/Pump POWER)

MMP/Sea-Bird UIM Power:

ANALOG	J8-1	DGND
	J8-9	VSW3 (UIM POWER)

MMP/Sea-Bird UIM Communications Port2:

FREQ	J7-4	RSR2 (MMP RxD)
	J7-5	RST2 (MMP TxD)

MMP/Sea-Bird UIM Tone Detect Discrete:

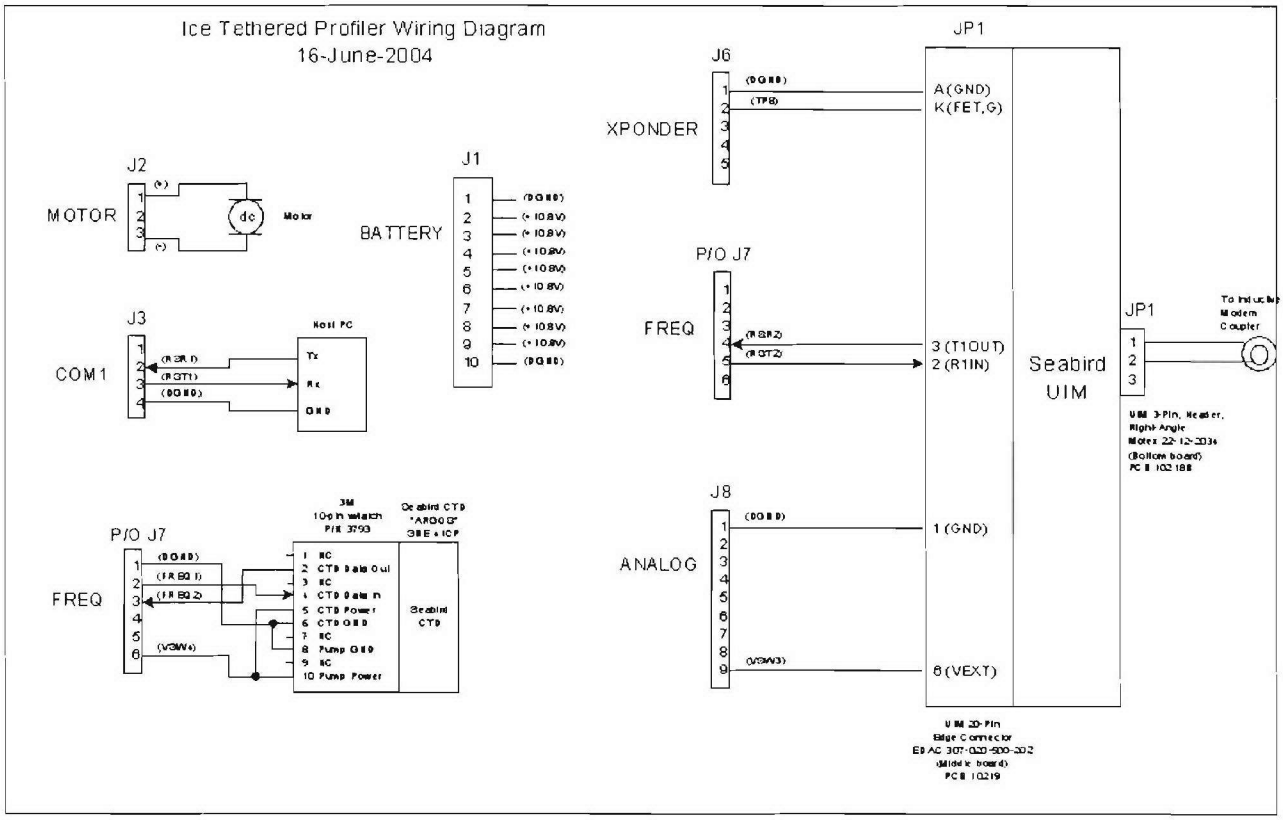
XPONDER	J6-1	DGND
	J6-2	TP8

MMP/Motor:

MOTOR	J2-1	(+)
	J2-3	(-)

MMP/Power:

BATTERY	J1-1	NEG (DGND)
	J1-2	POS1 (10.8Vdc)
	J1-3	POS2 (10.8Vdc)
	J1-4	POS3 (10.8Vdc)
	J1-5	POS4 (10.8Vdc)
	J1-6	POS5 (10.8Vdc)
	J1-7	POS6 (10.8Vdc)
	J1-8	POS7 (10.8Vdc)
	J1-9	POS8 (10.8Vdc)
	J1-10	NEG (DGND)


Ice Tethered Profiler Wiring Diagram
16-June-2004
J2
MOTOR
Motor
J1
BATTERY
J3
COM1
Host PC
P/O J7
FREQ
3M
10-pin Header
P/N 3793
Seabird CTD
"ARGO"
SBE 41CP
Seabird
CTD
JP1
XPONDER
A(GND)
K(FET,G)
P/O J7
FREQ
3 (T1OUT)
2 (R1IN)
Seabird
UIM
JP1
To Inductive
Modem
Coupler
UIM 3-Pin, Header,
Right Angle
Molex 22-12-2036
(Bottom board)
PCB 102188
J8
ANALOG
1 (GND)
6 (VEXT)
UIM 20-Pin
Edge Connector
EDAC 307-020-500-202
(Middle board)
PCB 10219

Appendix C: Operating the ITP surface package

Console connection

Do not connect a standard DB9P cable to the SURFCON console port if more than TX, RX and GND are wired as the connection is designed to accept a reset connection as well as communications. Either use the special console cable with the pushbutton reset switch on the DB9S end or an adapter to make sure that pins other than 2, 3 and 5 are not connected. SURFCON is DCE so it connects directly, without null modem, to a DTE computer serial port. A longer console cable for use in the field connects to the 5 pin water tolerant connector emerging from the top of the ITP package, which should permit communications with the system from a helicopter seat in the field while checking operation just after deployment. Fifty feet is a practical limit for standard RS232 comms over such a cable. There is a manual RESET switch on the SURFCON board which does the same thing as the pushbutton at the end of the console cables. This is more than just a reset directly connected to the Persistor as it must be able to awaken the system from sleep mode when the Persistor is unpowered. The effect of the button is to awaken SURFCON as would the WAKE from the TONE DETECTOR, which causes SURFCON to be powered up, then after a 1.6s delay, hits it with a hard reset resulting in a command line prompt at the console rather than continuing where the program code left off...if a program had been running when it entered sleep mode. Depending on the state of the SURFCON processor, a RESET may be indicated on the console as "TD" wakeup.

Configuration

There are 2 programs at this time. XBT is a test program and SURFCON is the acquisition program. Configuration information for the SURFCON operating parameters are stored in an ASCII text file "ITPSYS" on the Persistor flash card. An AUTOEXEC.BAT file in the root directory containing the line "surfcon" causes the program to run on powerup. There is a watchdog facility that will cause a reboot should nothing happen for about 20 minutes. Prior to deployment, there are a few software items that should be configured, as follows:

- The root directory file "ITPSYS" should be edited (captured or pasted) to reflect the desired parameters shown below. It is important that they are in this order on separate CRLF terminated lines and the parameters themselves must be immediately preceded by a colon ':'.

  "Itpsys number" specifies the serial number of the ITP system;

"Status epochs per day" specifies the number of equally spaced times per day that the ITP will assemble status information including a GPS fix to add to the daily status file;

"Console active time" specifies the time in seconds that SURFCON state information will be written to the console. After this time has elapsed, very little information will be sent to eliminate the power used by the RS232 drivers since for most of its life, nobody will be watching;

"Max daily ISU time" specifies the daily limit in seconds that ISU operations are permitted to reduce the risk that excessive ISU power will be expended. The times must be set to comfortably allow transmissions of the expected amount of data at approximately 250 Byte/sec plus about 2 minutes per expected connection. In addition the time should be sufficient to allow sending a few days worth of data in case the iridium link cannot be established possibly due to temperature below -30 C.

"Initial ISU transmit delay" typically 0, so that ISU transmission can be forced if desired at start up.

"Max Daily IM Wakeups per day" specifies a limit on the occurrences of TE wakeup due to UIM activity, to reduce power consumption should spurious UIM wakeups occur repeatedly. SURFCON is still awakened but immediately returns to the suspended state rather than power up the SIM and wait for DATA while the timeout elapses.

"ISU transmission epochs" specifies that the number of occasions equally spaced in time that SURFCON will attempt to establish an Iridium connection if there are files to send. This is another measure to limit energy use

A sample ITPSYS file:

```
Itpsys configuration file for ITP SURFCON
itpsys number :0
status epochs per day :24
Console active after restart, seconds :100000
Max daily ISU time, seconds, :7200
Initial ISU transmit delay, seconds :0
Maximum daily IM wakeups, per day :25
ISU transmission epochs, per day :4
```

- Two system environment variables must be set. Typing "SET" by itself will return the settings, which should be:
    - SYS.BAUD=19200,N

- SYS.QPBCS=3

If these variables are set to any other values, the program will not function. Changing the values of these variables is done by typing, "SET SYS.BAUD=19200, N" and "SET SYS.QPBCS=3" at the command line. All environment variables can be cleared by typing "SET= <CRLF>".

- The root directory file "RESTARTS" should be deleted, which will force the start of a new one. The sole purpose of this file is as a place to keep count of the number of times that the controller reboots, which typically in the field would be caused by a WatchDog Reset. Its value is reported in the daily STATUS file.

- Make sure an AUTOEXEC.BAT file exists in the root directory with the sole line "SURFCON" followed by a return.

- Delete garbage and test files from the root, \LOG, \CMD and \DATA directories.

Board Test

XBT is an executable program to exercise functions of SURFCON with a serial console connected, for diagnosing faults in the hardware, and for testing exchanges with PROCON.

```
Usage: xbt –options

ITP Surface Controller board tests.  Select & hit return
f....Continuously open and write small files in default dir
a....Run 8 channel ADC and report converted values
p....Turn on selected device and run serial port thru console
s....Suspend SURFCON and wait for /TD_WAKE or /EXT_RESET
m....Place ISU call & send test message
g....Output GPS RMC string
t....Read GPS date/time and set RTC
u....Power up SIM & UIM, read status from UIM
c....Monitor ISU signal strength
l....Dial up and login to logger & immediately bailout
q....Quit

Options list:
        -H                  printf this menu
        -cont   interval    Applies to 's' suspend, 'g ' GPS, and 'm' message menu options
                                    If 's' ops, suspend, recover, give testor a chance to exit, repeat
                                    If 'g' ops, powerup ISU, read RMC lines until fix, ISU off, repeat
                                    If 't' ops, same as 'g' except RTC is set w/ GPS time
                                    If 'm' ops, ISU on, send test message, repeat
                                    The intention is to test reliability of ISU turn-on which
                                    has been problematic as temperature decreases.
                                    The interval is in seconds and needs to be >=300 to get to -20C
        -susp                       If doing continuous ops, suspend during wait period
                                    Works for 'm' and 'g' tests
```

-gto timeout	Set the wait time for a valid GPS fix. This has been used primarily to speed up the ISU turnon check using the 'g' menu test Just set gpstimeout to something small like 2, default is 120s which should usually be more than enough time to get a valid fix
-nogps	Do not get GPS info for test file, menu option
-crc initval	Compute 16 bit CCITT CRC for testfile using spec'd init value
-creq	After a test file transmission 'm', send CREQ to get MESG pkt from logger
-dial 10digit#	Specify 10 digit US phone number, no intervening spaces
-reqdir	Specify reqdir command for after suspend ops
-reqfil fname	Specify reqfil command for after suspend ops
-reqnew	Specify reqnew command for after suspend ops
-scto #	Specify SIM intercharacter timeout in ms <2000>
-user username	Specify username to which Linux logger will respond <itpsys1>

To deactivate ISU PIN, first enable using current pin (default=1111), at+cpin="1111"
Then issue: at+clck="sc",0,"1111" where 1111=old pswd

To power and give direct commands to the Iridium transceiver command P is used:

```
Selection....p
Select port, I=ISU, S=SIM, L=logic, 2=spare RS232, 4=RS422, ^X to QUIT....
Select baudrate, 0 for default --> ISU:19200, else 9600...19200
ISU port  Rx chan is TPU4, Tx chan is TPU3
# bits = 8
parity = N
baudrate = 19200
Receive channel TPUPriority = -1
Transmit channel TPUPriority = -1
Receive queue size = 1024
Transmit queue size = 1024
Transmit channel printf buffer size = 512
Selected port should be open @19200 baud
*** Break from PORT test with ^X
at
OK
at+creg?
+CREG:000,004
OK
at+creg?
+CREG:000,001
at+cpin?
+CPIN:SIM PIN2
OK
at+csq?
+CSQ:4
at+cgmi
Motorola
at+cgmm
9522 Satellite Series
at+cgmr
Call Processor Version: SAC0309
DSP Version: SAC0108
NVM Version: SAC0200
at+cgmi
Motorola
```

```
at+cgsn
```

To obtain a GPS location, enter command G:

```
Selection....g
Select baudrate, 0 for default of 4800, else as specified....4800
Using logic level port for GPS, baudrate=4800
$GPRMC,184357,V,0000.0000,N,00000.0000,E,0.000,0.0,130406,0.0,E*6D
$GPRMC,184358,V,0000.0000,N,00000.0000,E,0.000,0.0,130406,0.0,E*62
$GPRMC,184359,V,5047.2079,N,07445.4188,W,0.000,0.0,130406,0.0,E*7
$GPRMC,184400,V,5047.3811,N,07445.1414,W,0.000,0.0,130406,0.0,E*75
$GPRMC,184401,A,4132.0785,N,07038.9015,W,0.000,0.0,130406,15.3,W*46
$GPRMC,184402,A,4132.0658,N,07038.8932,W,0.000,0.0,130406,15.3,W*49
$GPRMC,184403,A,4132.0675,N,07038.8881,W,0.177,148.2,130406,15.3,W*40
$GPRMC,184404,A,4132.0656,N,07038.8895,W,0.159,150.7,130406,15.3,W*43
```

To set the RTC time to the GPS time, enter command T:

```
Selection....t
Select baudrate, 0 for default of 4800, else as specified....0
Using logic level port for GPS, baudrate=0
$GPRMC,184449,A,4132.0929,N,07038.8980,W,0.000,0.0,130406,15.3,W*46
GPS time ok=7
SetRTC 18:44:49  04-13-2006   1144953889
```

To automatically dial up and hang up with the Iridium transceiver, enter command L:

```
Selection....l
at+creg?
+CREG:000,004
04/13/2006  18:57;54, 20.93  10.66  4.59  4.08  3.32  3.30  0.00  0.00
ISU startup ok
ATZ
OK
at+creg?
+CREG:000,001
OK
at+csq
+CSQ:1
OK
at+csq
+CSQ:1
OK
at+csq
+CSQ:1
OK
at+csq
+CSQ:3
OK
at+csq
+CSQ:5
Sending dial string ATDT001xxxxxxxxxx
...waiting for CONNECT...
ATDT001xxxxxxxxxxx
```

```
CONNECT
04/13/2006  18:58;45, Received CONNECT in 14 seconds, attempt 1
login
04/13/2006  18:59;07, Received LOGIN in 22 seconds, sigstren=5 attempt 1
```

Inductive Modem Testing

In order for the SIM and UIM to communicate properly, the SIM should initially be off, the UIM should turn on (nominally after obtaining a profile) and waken the SIM with a 4800 Hz tone. If both the SIM and UIM are listening on the inductive loop at the same time, both units will report garbage characters.

When an ITP is deployed, XBT command U can be used (after breaking out of the SURFCON program) to verify the inductive modem communications with the deployed profiler. The profiler UIM remains on until the first profile (down profile 0), so will respond to DS commands:

```
ITP Surface Controller board tests
Selection....u
ECHOOFF
AUTOPWRON
RELAYMAX
BINARYGAP=5000
DS
wait time for relay command response = 600 seconds
binary relay character timeout = 5000 msec
SBE 37 SURFACE MODEM
sending wake up tone, wait 4 seconds
SBE 44 UNDERWATER MODEM V 1.8
sensor baud rate = 9600
break character length = 1000 milliseconds
time out after 30 seconds without receiving a valid command termination character is 62, char = > Relay
Command Settings:
  relay termination characters = <CR><LF>
  total time for response = 600 seconds
  wait 0 milliseconds before sending the command
  halt relay after a gap of 5500 milliseconds between characters GDATA Command Settings:
  total time for response = 30 seconds
  wait 0 milliseconds before sending the command
  halt acqisition after a gap of 1000 milliseconds between characters
  GDATA command string = NO STRING
include gdata reply delay in datann reply
do not enable control line on power up
disable control line logic for relayed commands
disable control line logic for GDATA command
do not switch power to sensor on power up
disable switch power logic for relayed commands
disable switch power logic for GDATA command
send tone on powerup
transmitter is disabled
```

Operating program

Surface controller data acquisition program (SURFCON) is normally called automatically upon power up or reset of electronics within an AUTOEXEC.BAT command script, and with all default settings by invoking no options.

Program 'surfcon' usage: surfcon -options [options specified in upper case]

Options list:

-contime	#	Time console output will be active after startup <14400s>
-simto	#	Specify SIM TIMEOUT in sec <3600> , then quit
-stepoch	#	Specify number of status data collections per day <4>
-nogps		Do not operate the GPS
-gto	#	Specify time to get GPS time/fix each occasion <300>, then quit
-DIAL1	#	Specify primary number for ISU dial, 10 digit
-DIAL2	#	Specify secondary number for ISU dial, 10 digit
-TXDLY	#	Specify delay of forced initial ISU transmission attempt, sec <10>; Note, if no file in FILELIST, there will be no transmission
-MAXDIM	#	Specify max number of accepted IM Tone detect wakeups per day <10>
-ISUTXEP	#	Specify the number of times per day the ISU will attempt transmissions <4>

SURFCON awakens from SUSPEND mode either as a result of TD or internal RTC alarm at the GPS (status epoch) or telemetry (transmission epoch) intervals. SURFCON initiates status transmissions to home daily regardless of the operation of the profiler. Data that arrives from PROCON is transmitted the number of times per day specified by the transmission epoch.

TD wakeup will under some conditions, have priority over other operations that might be in progress. If the PROCON attempts to awaken the SURFCON when the latter is assembling a status entry, SURFCON will complete the status entry as it will often finish before the PROCON times out in its attempt to contact SURFCON. However if an ISU transmission is in progress, SURFCON will check for PROCON contact and break out if a TD is detected. The rationale is that we don't want to miss a status check and the time to do so is usually less than 45 s whereas an ISU transaction can be much longer and can easily be resumed where it was disconnected..

Fundamentally, SURFCON initiates all ISU transactions at least once daily according to the parameter ISU_transmission_epochs which specifies the number of times per day ISU ops can be attempted should there be files in the queue. The actual transmission times are offset in time as a function of the ITPSYS# to minimize dialup conflicts as all ITPs currently call one of 2 phones. There should always be at least 1 status file per day. Files are assumed to be binary and are sent as packets that include a short header followed by a payload of 4096 bytes. The header consists of the ASCII characters "DATA", and 3 ASCII numbers specifying the packet sequence number, the payload length and a 4 hex digit algebraic checksum. A file transmission is announced by sending a FILESPEC packet which consists of the keyword "FILE", a space, the filename in 8.3 format, a space and the file length in decimal ASCII characters. The logger

running on the receiving server responds with an "RSTR" packet that indicates whether part of the file has already been received during a previous session and which packet should be received next or if it thinks this is a new file in which case the current transmission will begin with the first packet.

Each packet is acknowledged by the server and the SURFCON waits for an acknowledge packet when 2 data packets remain unacknowledged. The operation is subject to timeout and retry limits on each occasion as well as a limit on total ISU time per day. Typical net data thruput is about 300 bytes per second once the overhead of dial-in is achieved which can take a minute or more

The daily SURFCON status file are always sent home at the first transmission time after 0000Z on the next day which includes ITPSYS number, date, time, GPS fixes at the preset interval, SURFCON power voltages, internal temp, SURFCON date/time of last communication from PROCON, and total time of ISU usage for the day. The state of the TD wakeup is monitored during status transmission operations to preserve priority for response to the PROCON.

Upon awakening by PROCON, SURFCON requests file; if timeout, SURFCON suspends; else PROCON sends packet; if timeout for packet tx, SURFCON sends NAK; else if packet error, SURFCON sends NAK; else if ok, SURFCON sends ACK; if on 2^{nd} transmission attempt of a given packet, packet error, then SURFCON sends NAK; if no response to ACK or NAK, repeat; if no response to 2^{nd} ACK or NAK, SURFCON suspends. SURFCON always waits for at least 1500 msec beyond last char received from PROCON to make sure UIM has switch to binary receive mode.

When a command file from the logger is received, an "ACK" file is generated by the SURFCON as acknowledgement of command receipt and sent immediately back to the logger with filename of the form mmddhhnn.ACK.

SDIR, SFIL and SCMD commands are executed immediately upon receipt and if a file results, it is sent in the current session with the logger.

PDIR and PFIL commands are accepted and held for the next session with the Profiler Controller, hence any results will at the earliest, be returned to the logger at the end of the next Profiler session.

The directory structure that is created by SURFCON is:

C:\cmd All ".ACK", ".PDR" and ".SDR" files

C:\dat All PROCON ".DAT" files and SURFCON ".STA" files

C:\log All ".LOG" files of software operations

A sample ISU transaction excerpted from screen log:

```
Q_CHECK  nte=1149781166 now=1149781166
06/08/2006 15:39:26 15.8 11.4  #69 GetTimeToNextTransmissionEpoch:
now=1149781166 interval=10800 tn 14554 ntt=1149795720
06/08/2006 15:39:27 15.8 11.4  #12 Read filename c:\DATA\E0000000.DAT from
list, bare filename is E0000000.DAT
ISUon: after 5s
at+creg?

+CREG:06/08/2006 15:39:32 15.8 11.3  #69 GetTimeToNextTransmissionEpoch:
now=1149781172 interval=10800 tn 14548 ntt=1149795720
000,004

OK
ATZ

OK
at+creg?

+CREG:000,001

OK
at+csq?

+CSQ:5
CALL: Sent config string AT+CBST=07,0,1
AT+CBST=07,0,1

OKCALL: config response OK
06/08/2006 15:40:02 15.7 11.3  #61 CALL: Sent dial string ATDT001xxxxxxxxxx
...waiting for CONNECT...
ATDT001xxxxxxxxxx

CONNECT
06/08/2006 15:40:14 15.8 11.3  #13 CONNECT in 16s 1 attempt

login
06/08/2006 15:40:33 15.1 11.0  #58 Received LOGIN
1 file(s) erased
06/08/2006 15:40:38 15.8 11.1  #14 Deleted file c:\DATA\E0000000.DAT from
FileList
06/08/2006 15:40:38 15.8 11.2  #42 228 B/s, 137 B/s net 1149781233 1149781235
1149781238 71 684 684
06/08/2006 15:40:39 15.8 11.0  #12 Read filename c:\DATA\C0000000.DAT from
list, bare filename is C0000000.DAT
SendFilePkt:
FILE C0000000.DAT 2598 C

RSTR 0001
06/08/2006 15:40:40 15.8 11.3  #39 RSTR pkt= 0001 start @pkt 1
pktsize=2048 seqnum=1, read 2048 bytes from file
06/08/2006 15:40:41 15.8 10.7  SendDataPkt, pkt #001 sent, hold=0 acks_out=1
pktsize=2048 seqnum=2, read 550 bytes from file
06/08/2006 15:40:41 15.8 10.7  SendDataPkt, pkt #002 sent, hold=1 acks_out=2
```

```
1 file(s) erased
06/08/2006 15:40:49 15.8 11.3  #14 Deleted file c:\DATA\C0000000.DAT from
FileList
06/08/2006 15:40:49 15.8 11.3  #42 289 B/s, 205 B/s net 1149781233 1149781240
1149781249 82 3282 2598

1 file(s) erased
looking for MESG pkt

MESG CREQ: Got MESG, looking for \n
0088 171C
CREQ: rec'd 11 chars, got \n
06/08/2006 15:40:50 15.9 11.2  #43 CREQ: MESG payload len=88
SDIR c:\
found dir c:\
06/08/2006 15:40:50 15.9 11.3  #45 Loaded file \CMD\06081540.SDR with SC
directory info
06/08/2006 15:40:50 15.8 10.8  #10 Added file \CMD\06081540.SDR to FileList
06/08/2006 15:40:51 15.8 11.3  #46 CREQ: Adding SDIR
filespec=\CMD\06081540.SDR to Inbound list
06/08/2006 15:40:51 15.8 11.3  #52 CREQ: writing cmd acknowledgment file, cmd
sequence SDIR c:\
 received:
SFIL c:\itpsys
06/08/2006 15:40:51 15.8 11.2  #10 Added file c:\itpsys to FileList
06/08/2006 15:40:51 15.9 11.2  #44 CREQ: Adding SFIL filespec=c:\itpsys to
Inbound list
06/08/2006 15:40:51 15.1 11.1  #52 CREQ: writing cmd acknowledgment file, cmd
sequence SFIL c:\itpsys
 received:
SDIR C:\DATA
found dir C:\DATA
06/08/2006 15:40:52 15.8 11.0  #45 Loaded file \CMD\06081540.SDR with SC
directory info
06/08/2006 15:40:52 15.8 11.3  #10 Added file \CMD\06081540.SDR to FileList
06/08/2006 15:40:52 15.8 11.3  #46 CREQ: Adding SDIR
filespec=\CMD\06081540.SDR to Inbound list
06/08/2006 15:40:52 15.7 10.8  #52 CREQ: writing cmd acknowledgment file, cmd
sequence SDIR C:\DATA
 received:
PFIL IRQ_XCPT.LOG
06/08/2006 15:40:52 15.9 11.3  #49 CREQ: PFIL filespec=IRQ_XCPT.LOG
reqfilnames= IRQ_XCPT.LOG, len=13
06/08/2006 15:40:52 15.8 11.1  #52 CREQ: writing cmd acknowledgment file, cmd
sequence PFIL IRQ_XCPT.LOG
 received:
PFIL LASTSENT.DAT
06/08/2006 15:40:52 15.9 11.2  #49 CREQ: PFIL filespec=LASTSENT.DAT
reqfilnames= IRQ_XCPT.LOG LASTSENT.DAT, len=26
06/08/2006 15:40:53 15.7 10.7  #52 CREQ: writing cmd acknowledgment file, cmd
sequence PFIL LASTSENT.DAT
 received:
PCDS
06/08/2006 15:40:53 15.8 11.3  #51 CREQ: Adding PCDS request
06/08/2006 15:40:53 15.8 10.7  #52 CREQ: writing cmd acknowledgment file, cmd
sequence PCDS
 received:
EOTX06/08/2006 15:41:23 15.9 11.0  #53 Couldn't find crlf delimiter in payload
section of MESG pkt
06/08/2006 15:41:23 15.9 11.3  #10 Added file \CMD\06081540.ACK to FileList
06/08/2006 15:41:23 15.9 11.3  #12 Read filename \CMD\06081540.SDR from list,
bare filename is 06081540.SDR
SendFilePkt:
FILE 06081540.SDR 737 C
```

```
RSTR 0001
06/08/2006 15:41:24 15.9 11.3  #39 RSTR pkt= 0001 start @pkt 1
pktsize=2048 seqnum=1, read 737 bytes from file
06/08/2006 15:41:25 15.9 11.2  SendDataPkt, pkt #001 sent, hold=0 acks_out=1

1 file(s) erased
06/08/2006 15:41:27 15.9 11.3  #14 Deleted file \CMD\06081540.SDR from
FileList
06/08/2006 15:41:28 15.9 11.2  #42 184 B/s, 73 B/s net 1149781233 1149781284
1149781288 121 4019 737
06/08/2006 15:41:28 15.9 11.2  #12 Read filename c:\itpsys from list, bare
filename is itpsys
SendFilePkt:
FILE itpsys 296 C

RSTR 0001
06/08/2006 15:41:29 15.9 11.3  #39 RSTR pkt= 0001 start @pkt 1
pktsize=2048 seqnum=1, read 296 bytes from file
06/08/2006 15:41:29 15.8 10.8  SendDataPkt, pkt #001 sent, hold=0 acks_out=1

1 file(s) erased
06/08/2006 15:41:33 15.9 11.2  #14 Deleted file c:\itpsys from FileList
06/08/2006 15:41:34 15.9 11.3  #42 59 B/s, 71 B/s net 1149781233 1149781289
1149781294 127 4315 296
06/08/2006 15:41:34 15.9 11.2  #12 Read filename \CMD\06081540.SDR from list,
bare filename is 06081540.SDR
SendFilePkt:
FILE 06081540.SDR 737 C

RSTR 0001
06/08/2006 15:41:35 15.9 11.3  #39 RSTR pkt= 0001 start @pkt 1
pktsize=2048 seqnum=1, read 737 bytes from file
06/08/2006 15:41:36 15.9 11.2  SendDataPkt, pkt #001 sent, hold=0 acks_out=1

1 file(s) erased
06/08/2006 15:41:41 15.9 11.3  #14 Deleted file \CMD\06081540.SDR from
FileList
06/08/2006 15:41:41 15.9 11.2  #42 123 B/s, 74 B/s net 1149781233 1149781295
1149781301 134 5052 737
06/08/2006 15:41:41 15.9 11.3  #12 Read filename \CMD\06081540.ACK from list,
bare filename is 06081540.ACK
SendFilePkt:
FILE 06081540.ACK 210 C

RSTR 0001
06/08/2006 15:41:42 15.9 11.3  #39 RSTR pkt= 0001 start @pkt 1
pktsize=2048 seqnum=1, read 210 bytes from file
06/08/2006 15:41:43 15.9 11.3  SendDataPkt, pkt #001 sent, hold=0 acks_out=1

1 file(s) erased
06/08/2006 15:41:44 15.9 11.3  #14 Deleted file \CMD\06081540.ACK from
FileList
06/08/2006 15:41:44 15.9 11.3  #42 105 B/s, 74 B/s net 1149781233 1149781302
1149781304 137 5262 210

1 file(s) erased
looking for MESG pkt

MESG CREQ: Got MESG, looking for \n
0000 FFFF
CREQ: rec'd 11 chars, got \n
06/08/2006 15:41:46 15.9 11.1  #43 CREQ: MESG payload len=0
06/08/2006 15:41:46 15.9 11.3  #54 Aborted CREQ ops, MESG payload len=0
06/08/2006 15:41:46 15.9 11.2  #16 End ISU ops, daily ISU connect time=139
```

```
06/08/2006 15:41:46 15.9 11.4  #70 GetTimeToNextStatusEpoch: now=1149781306
interval=3600 tn=1149782400 ntt=0
06/08/2006 15:41:46 15.8 11.4  #18 suspend for 1094 s, next status 1094 s,
next ISU Tx 14414 s
```

To verify or access that the files on the logger from the field, it should be possible to connect a laptop to an ISU with antenna and invoke a dial-up connection as one would do with any desktop modem via a serial port. However, the Iridium link operates at more like 2400 baud and can be hesitant, but will make it possible to login to the logger computer to observe whether files are indeed being received at home.

Appendix D: Assembly of ITP Profiler

The main housing of the ITP Profiler is an anodized aluminium cylinder 6.5" in diameter and 48" long, with o-ring surfaces on the faces at either end, and a snap-ring groove in the bottom end. A hole is located midway between the ends, where the drive motor protrudes. The modem core is mounted on the bottom endcap of the Profiler totalling 6" in length (plus several inches of cable), while the top endcap of the instrument supports the CTD sensors and extends 13". Springed guide wheels and nylon wire guides are clamped externally near both ends of the housing, everywhere protruding from the sides of the instrument by less than 3".

Assembly of the Profiler begins by positioning the main housing cylinder horizontally on a surface, secured from rolling, and with both ends accessible. The nylon clamps with guide wheels should be preassembled, and then may be mounted near both ends of the cylinder. With the (snap ring grooved) bottom of the cylinder oriented south, the springs are oriented on the west and wheels on the east. Grooves and pins in the clamps align with machined hollows on the cylinder, preventing the assemblies from slipping and keeping the orientation of the guide wheels and drive motor exact.

The drive motor and roller assembly is mounted through the hole in the middle of the main housing and oriented so that the open roller face is facing east with the bottom of the tube oriented south. A sleeve is slipped into the hole, and an o-ring cleaned, greased and placed into the groove on the motor face seal, before inserting the motor into the hole in the tube. The motor is secured on the inside by a large diameter washer and plastic nut that must be tightened firmly by hand. The two wires from the motor fit into a 3-pin connector that plugs into the PROCON electronics boards. To reverse the direction of the motor, reverse polarity by switching places of the wires.

With the motor and roller assembly in position, the electronics chassis is installed next. If the instrument is being prepared for deployment, then the battery packs should be installed and the electronics powered and initialized (see Implementation text) before the chassis is inserted into the cylinder. Position the chassis so that the two long tie rods will pass on either side of the motor during insertion, and plug in the motor connection. Slide the chassis into the tube, ensuring that the CTD connector reaches to the other end, and that the 5-pin modem/console connector feeds past the bottom end plate and is accessible from the near side. Insert the chassis into the cylinder until the bottom end plate is just beyond the snap-ring groove, and insert the snap ring. Pull the bottom of the chassis until it is snug against the snap ring to facilitate attaching the bottom endcap.

Before the bottom endcap is attached, the inductive modem coil should be mounted on the endcap. Clean and grease the face seal o-ring (#163) and place it in the groove on the endcap. Plug in the modem/console connector and place the endcap in position, so that the modem mount lines up with clamp mount, and modem core lines up with where the wire will pass by guide wheels. Insert and tighten the socket head bolt through the hole in the center of the endcap. Ensure that the endcap faces seals the cylinder completely, and lightly grease and screw in the endplug in the center hole of the endcap.

Before the top endcap is attached, the CTD sensors and interface boards should be already mounted on the endcap. First, from the top end of the cylinder, attach the top chassis endplate (with large holes) to the two chassis tie rods inside the tube so that the threaded bolt in the center is accessible. Feed the CTD connector through a hole in the top endplate. Clean and grease the face seal o-ring (#163) and place it in the groove on the endcap. The circular orientation of the endcap on the cylinder is not important. Plug in the CTD connector, and attach the endcap using a long 3/16" socket head driver through the attaching port on the endcap. Facing the endcap, the attaching port is the most counterclockwise hole covered by a plastic socket head plug. Ensure that the endcap faces seals the cylinder completely, and replace the socket head plug that seals the attaching port.

Appendix E: CTD configuration for PROCON

The 41CP must be properly configured for the McLane PROCON software to acquire data from the CTD. When the sensor assembly first comes from the factory, several commands may need to be given to the unit to ensure that the 41CP does not cease profiling in air and does not echo scan numbers or pressure values during profiling. Several commands may have to be given to the 41CP once (and the settings will remain in memory). This may be done with PROCON powered, operating the MMP software, and with the 41CP endcap connected. From the main menu select "<5> Bench Test," then select "<1> CTD Communication." PROCON will respond:

```
Applying power and enabling COMMs to CTD . . . ready.

 Initializing TT8 communication channels . . .
 TX channel open.
 RX channel open.

 Hailing frequencies open.
 <CTRL>-<C> to terminate session.

SBE 41CP McLane V 2.0
S>
```

The last two lines are the wake up message from the 41CP. To ensure compatibility with the McLane PROCON software type:

```
S>outputsn=n
S>outputpressure=n
S>pcutoff=-100
S>initprofile
```

To determine the instrument status type:

```
S>ds
```

Here is a sample expected response:

```
SBE 41CP McLane V 2.0  SERIAL NO. 0755
stop profile when pressure is less than = -100.0 decibars
automatic bin averaging when p < -100.0 disabled
number of samples = 0
number of bins = 0
top bin interval = 10
top bin size = 10
top bin max = 100
middle bin interval = 50
middle bin size = 50
middle bin max = 1000
bottom bin interval = 100
bottom bin size = 100
do not include two transition bins
```

The calibration coefficients for the device may be listed, for example:

```
S>dc
SBE 41CP McLane V 2.0  SERIAL NO. 0755
temperature:  20-jan-04
    TA0 =  4.927449e-05
    TA1 =  2.627505e-04
    TA2 = -1.328194e-06
    TA3 =  1.274588e-07
conductivity:  20-jan-04
    G = -9.976563e-01
    H =  1.495371e-01
    I = -2.135162e-04
    J =  3.834244e-05
    CPCOR = -9.570001e-08
    CTCOR =  3.250000e-06
    WBOTC =  5.575877e-06
pressure S/N = 5194, range = 2900 psia:  16-jan-04
    PA0 =  5.485121e-01
    PA1 =  1.383957e-01
    PA2 = -3.698467e-08
    PTCA0 = -3.232085e+01
    PTCA1 =  3.163942e-01
    PTCA2 = -6.264882e-03
    PTCB0 =  2.491763e+01
    PTCB1 = -2.750000e-04
    PTCB2 =  0.000000e+00
    PTHA0 = -7.808043e+01
    PTHA1 =  4.664468e-02
    PTHA2 = -9.268599e-08
    POFFSET =  0.000000e+00
```

Appendix F: Operating the profiler

Applying Battery/Power

The power connector for the PROCON electronics expects two grounds and eight +10.8 voltages connections. When powering PROCON from a single two-wire power source, an adapter must be used which jumpers the two ground leads together and jumpers the eight power leads together.

A cable for ITP serial communications should be connected to the serial port of a computer and a terminal emulation program started (9600 baud, no parity, 8 data bits, 1 stop bit). The communications cable should be connected to the ITP after connecting the battery. Likely, the beginning of the startup message will be missed, and the first words received from the ITP will be the countdown seconds. **It is important that the operator assert control over the software by typing <CTRL-C> within 30 seconds after applying power.** Otherwise the independent watchdog timer will not be properly initialized and may reset the software schedule at a later date.

```
MMP-3_13


Welcome to the McLane Moored Profiler
operator interface.  The MMP operating
system is initialized and running.

Type <CTRL>-<C> within 30 seconds to
assert operator control and complete
system initialization.


30 seconds
29 seconds
28 seconds
27 seconds
26 seconds
25 seconds

Independent system watchdog successfully initialized.
Watchdog alarm IRQ has been activated.

Sizing flash card (~2 seconds / 100 Mbytes) . . . done.

512.066 Mbyte flash card installed
511.205 Mbyte currently free

File system can accommodate  4091 data files
Deployment can include up to 1361 file sets
```

Set Time

```
Clock reads 06/23/2004 08:52:30
```

```
Change time & date (Yes/No) [N] ? y

Enter date as MM DD YY HH MM SS
Enter year 2001 as 1, 01, 101, or 2001

Enter correct time [06/23/2004 08:52:38] ? 06/23/2004 08:52:38

Clock reads 06/23/2004 08:52:38
Change time & date (Yes/No) [N] ?

Setting watchdog clock . . . done.
```

Set Trip Meter

```
Profiling odometer
  Total profiling distance:        7452 meters
  Battery trip meter:              2116 meters

Reset trip meter (new battery) (Yes/No) [N] ?
```

Main Menu

```
      McLane Research Laboratories, USA
           McLane Moored Profiler
    Version: MMP-3_13.c  S/N: ML11743-01C

     É͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸»
     °            Main Menu              °
     È͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸¼
           Wed Jun 23 08:52:50 2004


    <1> Set Time          <5> Bench Test
    <2> Diagnostics       <6> Deploy Profiler
    <3> Flash Card Ops    <7> Offload Deployment Data
    <4> Sleep             <8> Contacting McLane

      Selection  ?
```

Configuration Menu

```
      Selection  ? c   Password:  configure

Synchronizing system configuration files . . . done.


    É͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸»
    °       System Configuration          °
    È͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸¼

    System Parameters:
      <E> Nominal Endurance          1.0 million meters
      <I> Inductive Telemetry        Enabled
      <T> Acoustic Transponder       Disabled
      <F> File Deletion              Enabled

    Sensor Suite:
      <1> FSI EM        CTD          Disabled
```

```
  <2> SeaBird 41CP  CTD          Enabled
  <3> FSI 2D        ACM          Disabled
  <4> Nobska MAVS3  ACM          Disabled
  <5> SeaPoint      Fluorometer  Disabled   (Chlorophyll à)
  <6> SeaPoint      Turbidity    Disabled   (IR)

Exit:
  <X> Save Changes and Exit

  Selection  ?


Enable file deletion  (Yes/No) [N] ?
```

Diagnostics

```
  Selection  ? 2

Press any key to pause/continue display, <X> to exit.

RTC: 06/23/2004 09:00:15   WDC: 06/23/2004 09:00:15   11.4 Vb      1 mA
RTC: 06/23/2004 09:00:27   WDC: 06/23/2004 09:00:27   11.4 Vb      1 mA
RTC: 06/23/2004 09:00:30   WDC: 06/23/2004 09:00:30   11.4 Vb      0 mA
RTC: 06/23/2004 09:00:33   WDC: 06/23/2004 09:00:33   11.4 Vb      1 mA
RTC: 06/23/2004 09:00:42   WDC: 06/23/2004 09:00:42   11.4 Vb      0 mA
RTC: 06/23/2004 09:00:44   WDC: 06/23/2004 09:00:44   11.4 Vb      1 mA
RTC: 06/23/2004 09:00:45   WDC: 06/23/2004 09:00:45   11.4 Vb      1 mA
RTC: 06/23/2004 09:00:46   WDC: 06/23/2004 09:00:46   11.4 Vb      0 mA
```

Flash Card Operations

```
  Selection  ? 3

É͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸»
°      Flash Card Operations      °
È͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸¼

<1> Flash card size/free
<2> List flash card files
<3> Hex dump profile count
<4> Delete all files
<5> Exchange flash cards
<6> Format flash card
<7> Command line interface
<M> Main Menu

  Selection  ? 1


Sizing flash card (~2 seconds / 500 Mbytes) . . . done.

512.066 Mbyte flash card installed
511.205 Mbyte currently free

File system can accommodate  4092 data files
Deployment can include up to 2042 file sets


Press any key to continue.


É͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸»
```

```
°      Flash Card Operations      °
ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼

<1> Flash card size/free
<2> List flash card files
<3> Hex dump profile count
<4> Delete all files
<5> Exchange flash cards
<6> Format flash card
<7> Command line interface
<M> Main Menu

  Selection  ? 2

Directory of A:
MMP-3_10.RUN        325,260 06-18-04 14:49
AUTOEXEC.BAT             12 06-18-04 14:49
DEPLOY.DAT              138 06-22-04 21:09
PROFILES.DAT              4 06-23-04 08:40
IRQ_XCPT.LOG             84 06-23-04 08:46
E0000007.DAT            304 06-22-04 22:46
C0000007.DAT          4,274 06-22-04 22:46
E0000008.DAT            304 06-22-04 23:06
C0000008.DAT          4,274 06-22-04 23:06
E0000009.DAT            304 06-22-04 23:26
C0000009.DAT          4,274 06-22-04 23:26
.
.
.
E0000028.DAT            304 06-23-04 05:46
C0000028.DAT          4,274 06-23-04 05:46
E0000029.DAT            304 06-23-04 06:06
C0000029.DAT          4,274 06-23-04 06:06
E0000030.DAT            304 06-23-04 06:26
C0000030.DAT          4,274 06-23-04 06:26

     511,205,376 bytes free


 Press any key to continue.
```

Command Line Interface (available for diagnostics, but not normally used)

```
  Selection  ? 7


=====  PicoDOS Intrinsic Commands  (plus .RUN and .BAT Files)  =====
COPY        source dest               DATE        (prompts)
DEL         filename                  DIR         [file | wildcards]
ERASE       filename                  FORMAT      [/Q][/E][/F]
TIME        (prompts)                 TYPE        filename
REN         oldname newname           VER         (PicoDOS version)
G           or GO[address]            LO          [ofs][;Bx[+]] [;G]
MD          [address]                 MM          [address]
XS          [/Q][/X][/C]file          XR          [/Q][/X][/C][file]
YS          [/Q][/G]file[,file...]    YR          [/Q][/G]
BAUD        [newrate] [/Q]            SAVE        file[start][end]
DUMP        file[start[,end]]         CAPTURE     file[delim] [/N]
BOOT        [PICO][TOM8]              CCC         (card change)
RESET       (hard reset)              TOM8        (exit to TOM8)
```

```
CAUTION:  Some of these commands can erase,
          halt, damage, or hide the system
          program resident in flash memory.

<?>-<ENTER> for list of commands
<CTRL>-<C> to exit

Enter command >>
```

Software Reboot (not normally used)

```
        McLane Research Laboratories, USA
             McLane Moored Profiler
      Version: MMP-3_13.c  S/N: ML11743-01C

       É͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸»
       º                Main Menu                 º
       È͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸¼
             Wed Jun 23 10:38:19 2004


      <1> Set Time          <5> Bench Test
      <2> Diagnostics       <6> Deploy Profiler
      <3> Flash Card Ops    <7> Offload Deployment Data
      <4> Sleep             <8> Contacting McLane

        Selection  ? q   Password:  mclane

Tattletale Model 8
Onset Computer, Pocasset MA USA
TOM8 V1.09,  PIC V1.00,  Copyright 1994

TOM8>g

jumping to address 00000008

MMP-3_10


 Welcome to the McLane Moored Profiler
 operator interface.  The MMP operating
 system is initialized and running.

 Type <CTRL>-<C> within 30 seconds to
 assert operator control and complete
 system initialization.


 30 seconds
 29 seconds
 28 seconds
 27 seconds
```

Sleep Mode

```
        Selection  ? 4
```

Verify sleeping mode current is approximately 180 uA.

Bench Test

```
        Selection  ? 5


      É͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸»
      °              Bench Tests                °
      È͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸¼
           Wed Jun 23 09:06:58 2004


  Sensor Utilities:
    <1> CTD Communication       <4> CTD Temperature Record
    <2> CTD Pressure            <5> ACM Communication
    <3> CTD Average Pressure    <6> ACM Tilt and Compass

  System Evaluation:
    <7> Motor Operation         <9> Independent Watchdog
    <8> Brake on.  Change?

  System Options Tests:
    <I> Inductive Telemetry      <F> Chl à Fluorometer
    <P> Acoustic Transponder     <T> IR Turbidity
    <O> Offload routines         <U> Power UIM

  Exit:
    <M> Main Menu
```

CTD Communication

```
        Selection  ? 1


 Applying power and enabling COMMs to CTD . . . ready.

 Initializing TT8 communication channels . . .
 TX channel open.
 RX channel open.

 Hailing frequencies open.
 <CTRL>-<C> to terminate session.

SBE 41CP McLane V 2.0
S>ds
SBE 41CP McLane V 2.0  SERIAL NO. 0755
stop profile when pressure is less than = -100.0 decibars
automatic bin averaging when p < -100.0 disabled
number of samples = 0
number of bins = 0
top bin interval = 10
top bin size = 10
top bin max = 100
middle bin interval = 50
middle bin size = 50
middle bin max = 1000
bottom bin interval = 100
bottom bin size = 100
do not include two transition bins
S>
```

```
TX channel closed.
RX channel closed.

Shutting down power to CTD.

Press any key to continue.
```

Verify current is approximately 29mA. Ctrl-C to power off CTD

CTD Average Pressure

```
Selection  ? 3
```

Verify N pressure measurements recorded.

CTD Temperature

```
Selection  ? 4
```

Verify N temperature measurements recorded.

Motor Verification

```
Selection  ? 7

Motor direction (Up/Down)        [U] ? u
Enter ramp duration [sec] (2 to 60) ? 10

Beginning start ramp.


Full speed reached.  Setting low power run mode.
Monitoring motor current and battery voltage.
<R> to begin stop ramp.  <CTRL>-<C> to stop and exit.

06/23/2004 09:07:50   45 mA   11.3 V
06/23/2004 09:07:51   48 mA   11.3 V
06/23/2004 09:07:52   49 mA   11.3 V
06/23/2004 09:07:53   42 mA   11.3 V
06/23/2004 09:07:54   48 mA   11.3 V
06/23/2004 09:07:55   47 mA   11.3 V
06/23/2004 09:07:56   31 mA   11.3 V
06/23/2004 09:07:57   32 mA   11.3 V
06/23/2004 09:07:58   31 mA   11.3 V

Motor disabled.  Brake set.

Press any key to continue.
```

<U> Up or <D> Down
Verify current is approx. 40mA during ramp up
Verify current is approx. 30mA steady-state

<R> to begin stop ramp
Verify current is approx. 40mA during stop ramp
Verify current is approx. 10mA at motor stop
Verify current returns to approx. 2.3mA

Brake test

```
Selection  ? 8
```

Independent Watchdog

```
Selection  ? 9


<1> Test Watchdog IRQ    ( 2 seconds)
<2> Test Watchdog RESET (68 minutes)
<B> Bench Tests Menu

Selection  ? 1

Initializing . . . done.

Waiting for IRQ (2 seconds) . . . IRQ detected.

Watchdog IRQ test complete.
Watchdog is functioning normally.


<1> Test Watchdog IRQ    ( 2 seconds)
<2> Test Watchdog RESET (68 minutes)
<B> Bench Tests Menu

Selection  ? 2
```

UIM Verification

```
Selection  ? U
```

Verify current is approx. 14-15mA
Verify current is approx. 19mA when tone is present
Verify tone waveform is 4800Hz (approx. 0.2mS period) and approx. 20mVp-p
Verify tone waveform is on for approx. 3 seconds
Verify current is approx. 14-15mA after tone
Verify after 40 seconds from step 4, current is approx. 2.5mA
Verify UIM is configured as follows:

- SBE 44 UNDERWATER MODEM V 1.8
- senor baud rate = 9600

- break character length = 1000 milliseconds
- time out after 30 seconds without receiving a valid command
- termination character is 62, char=>
- Relay Command Settings:
- relay termination characters = <CR><LF>
- total time for response = 600 seconds
- wait 0 milliseconds before sending the command
- halt relay after a gap of 5500 milliseconds between characters
- GDATA Command Settings:
- total time for response = 30 seconds
- wait 0 milliseconds before sending the command
- halt acquisition after a gap of 1000 milliseconds between characters
- GDATA command string = NO STRING
- include gdata reply delay in datann reply
- do not enable control line on power up
- disable control line before relaying command
- disable control line before sending GDATA command
- do not switch power to sensor on power up
- disable switch power to sensor before relaying command
- disable switch power to sensor before sending GDATA command
- send tone on powerup

Deployment procedure

```
        Selection  ? 6


Clock reads 06/23/2004 09:09:38
Change time & date (Yes/No) [N] ?

Setting watchdog clock . . . done.

Profiling odometer
  Total profiling distance:        7452 meters
  Battery trip meter:              2116 meters

Reset trip meter (new battery) (Yes/No) [N] ?


Verification of sensor settings

<A> Automated (standard settings only)
<M> Manual    (operator controlled)
<S> Skip Verification

 Selection  ?

Terminating deployment because of
operator command, sensor failure,
or sensor communication failure.

Press any key to continue.
```

```
        McLane Research Laboratories, USA
             McLane Moored Profiler
      Version: MMP-3_13.c  S/N: ML11743-01C

       É͸»
       º            Main Menu            º
       È͸¼
             Wed Jun 23 09:09:51 2004


      <1> Set Time         <5> Bench Test
      <2> Diagnostics      <6> Deploy Profiler
      <3> Flash Card Ops   <7> Offload Deployment Data
      <4> Sleep            <8> Contacting McLane

        Selection  ? 6


 Clock reads 06/23/2004 09:09:55
 Change time & date (Yes/No) [N] ?

 Setting watchdog clock . . . done.

 Profiling odometer
   Total profiling distance:        7452 meters
   Battery trip meter:              2116 meters

 Reset trip meter (new battery) (Yes/No) [N] ? y
 Battery trip meter reset to 0 meters


 Verification of sensor settings

 <A> Automated (standard settings only)
 <M> Manual    (operator controlled)
 <S> Skip Verification

  Selection  ? a


 Automated verification of sensor settings.

 Applying power to CTD . . .
 Starting verification . . .

SBE 41CP McLane V 2.0
S>

 Sending command  initprofile

S>

 Expected response received.
 Proceeding to next command.

 Sending command  ds

SBE 41CP McLane V 2.0  SERIAL NO. 0755
stop profile when pressure is less than = -100.0 decibars
automatic bin averaging when p < -100.0 disabled
number of samples = 0
number of bins = 0
top bin interval = 10
```

```
top bin size = 10
top bin max = 100
middle bin interval = 50
middle bin size = 50
middle bin max = 1000
bottom bin interval = 100
bottom bin size = 100
do not include two transition bins
S>

 Expected response received.

 Standard CTD settings verified.


 Sensor suite initialized and ready for deployment.

 Press any key to continue.
```

Deployment Settings (example from ITP2)

```
 ID         M| Mooring ID              =   2

 Start      Z| Scheduled start         =   08/19/2004 20:00:00

 Schedule   I| Profile start interval = 000 04:00:00 [DDD HH:MM:SS]
            R| Reference date/time     =   08/19/2004 00:00:00
            B| Burst Interval          =     Disabled
            N| Profiles per burst      =     Disabled
            P| Paired profiles               Disabled
            F| Profiles / file set     =            1

 Stops      S| Shallow pressure        =         10.0 [dbar]
            D| Deep pressure           =        750.0 [dbar]
            H| Shallow error           =         20.0 [dbar]
            E| Deep error              =        100.0 [dbar]
            T| Profile time limit      =     01:16:40 [HH:MM:SS]
            C| Stop check interval     =            5 [sec]
            L| Fluorometer       =     Disabled
            O| OBS Turbidity     =     Disabled

 Deploy     V| Verify and Proceed
```

Verify and Proceed

```
        Selection  ? v

 Checking entries . . . done.
 All entries are within allowed ranges.

 Checking profile schedule . . . done.
 Calculated minimum profile duration:         01:13:40
 Profile schedule selections are consistent.

 Checking burst schedule . . . done.
 Burst mode disabled.

 Estimated Profile 1 start time:   08/20/2004 00:00:00
```

```
Profiling distance will reach 1.0 million meters
on 04/02/2005 after 1351 profiles.

Accept and store schedule selections (Yes/No) [Y] ? y

Storing deployment definition parameters . . . done.


WARNING:  If you have not already done so,

          REMOVE the flow path CAPS from the CTD NOW.

          Failure to remove the caps will prevent proper
          CTD operation during the deployment and may
          cause permanent damage to the sensor.

          After removing the caps, press any key
          to continue.


CAUTION:  Deployment will erase all data
          files stored on the flash card.

System status:

RTC: 08/19/2004 03:50:56   WDC: 08/19/2004 03:50:56   11.3 Vb      0 mA


Proceed with the deployment (Yes/No) [N] ? y


>>> Initializing autonomous operation <<<

  Do NOT remove the communication cable
    until initialization is complete.

Setting motor to Free Wheel during launch . . . done.

Powering on the UIM . . .done.

Initializing data pointers and status flags . . . done.

Initializing flash card . . .
  Deleting all previous data files
    (process may take several minutes) . . . .
                                       . . .
  Initializing flash pointers . . .
  Creating DEPLOY.DAT . . .
  Creating PROFILES.DAT . . .
  Creating IRQ_XCPT.LOG . . .
  Creating LASTSENT.DAT . . .
Flash card initialization complete.

08/19/2004 03:51:16

Sensor warm-up will begin at               08/19/2004 19:58:00
Initial dive to bottom stop will begin at  08/19/2004 20:00:00.


System is ready to deploy.
```

```
Remove communication cable NOW, apply dummy
plug to communications port, and attach
faired bottom cap to vehicle.

08/19/2004 03:51:18 Sleeping . . .
```

Recovery procedure

```
Enter <CTRL-C> now to wake up?•

 Deployment terminated by operator.

 Deployment complete.

 Unattended recovery successfully completed.
 Autonomous deployment began:  07/14/2004 01:07:05


        McLane Research Laboratories, USA
             McLane Moored Profiler
      Version: MMP-3_11.c  S/N: ML11743-02C

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       º                  Main Menu                  º
       È͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸¼
             Fri Jul 16 15:10:51 2004


      <1> Set Time          <5> Bench Test
      <2> Diagnostics       <6> Deploy Profiler
      <3> Flash Card Ops    <7> Offload Deployment Data
      <4> Sleep             <8> Contacting McLane

        Selection  ? 2

 Press any key to pause/continue display, <X> to exit.

 RTC: 07/16/2004 15:11:28   WDC: 07/16/2004 15:11:31   11.3 Vb      0 mA
 RTC: 07/16/2004 15:11:29   WDC: 07/16/2004 15:11:32   11.3 Vb      0 mA
 RTC: 07/16/2004 15:11:30   WDC: 07/16/2004 15:11:34   11.3 Vb      0 mA
 RTC: 07/16/2004 15:11:31   WDC: 07/16/2004 15:11:35   11.3 Vb      0 mA
 RTC: 07/16/2004 15:11:33   WDC: 07/16/2004 15:11:36   11.3 Vb      0 mA
 RTC: 07/16/2004 15:11:34   WDC: 07/16/2004 15:11:37   11.3 Vb      0 mA
 RTC: 07/16/2004 15:11:35   WDC: 07/16/2004 15:11:39   11.3 Vb      0 mA
 RTC: 07/16/2004 15:11:36   WDC: 07/16/2004 15:11:40   11.3 Vb      0 mA
 RTC: 07/16/2004 15:11:38   WDC: 07/16/2004 15:11:41   11.3 Vb      0 mA
 RTC: 07/16/2004 15:11:39   WDC: 07/16/2004 15:11:42   11.3 Vb      0 mA
 RTC: 07/16/2004 15:11:40   WDC: 07/16/2004 15:11:43   11.3 Vb      0 mA
```

Dump Log Files

```
        McLane Research Laboratories, USA
             McLane Moored Profiler
      Version: MMP-3_11.c  S/N: ML11743-02C

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       º                  Main Menu                  º
       È͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸¼
             Fri Jul 16 15:11:41 2004
```

```
     <1> Set Time         <5> Bench Test
     <2> Diagnostics      <6> Deploy Profiler
     <3> Flash Card Ops   <7> Offload Deployment Data
     <4> Sleep            <8> Contacting McLane

       Selection  ? 7

     É͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸»
     °  Serial Dump Files From FLASH  °
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          Fri Jul 16 15:11:55 2004

Stream serial data from:
   <D> Deployment
   <S> Single profile
   <R> Range of profiles

   <L> Logging files

Exit to:
   <M> Main menu

       Selection  ? 1
Select log file to download:
<1> Profiles.dat
<2> Deploy.dat
<3> IRQ/Xcpt Log
<4> Profile Termination Log

Exit to:
<M> Main menu

      Selection  ? 1
Profile count: 169

     É͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸»
     °  Serial Dump Files From FLASH  °
     È͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸͸¼
          Fri Jul 16 15:11:59 2004

Stream serial data from:
   <D> Deployment
   <S> Single profile
   <R> Range of profiles

   <L> Logging files

Exit to:
   <M> Main menu

       Selection  ? 1
Select log file to download:
<1> Profiles.dat
<2> Deploy.dat
<3> IRQ/Xcpt Log
<4> Profile Termination Log

Exit to:
<M> Main menu

      Selection  ? 2
```

```
DEPLOYMENT PARAMETERS
---------------------

Countdown delay                00:30:00 [HH:MM:SS]
Profile start interval     000 01:00:00 [DDD HH:MM:SS]
Reference date/time          07/01/2004 00:00:00
Burst interval             010 00:00:00 [DDD HH:MM:SS]
Profiles per burst             Disabled
Paired profiles                Disabled
Profiles / file set                   1
Shallow pressure                    3.0 [dbar]
Deep pressure                      13.0 [dbar]
Shallow error                       2.0 [dbar]
Deep error                          3.0 [dbar]
Profile time limit             00:25:00 [HH:MM:SS]
Stop check interval                   1 [sec]
Transmission duration                15 [min]


SYSTEM CONFIGURATION
--------------------

Nominal Endurance              1.0 million meters
Inductive Telemetry            Enabled
Acoustic Transponder           Disabled
FSI EM         CTD             Disabled
SeaBird 41CP   CTD             Enabled
FSI 2D         ACM             Disabled
Nobska MAVS3   ACM             Disabled
SeaPoint       Fluorometer     Disabled
SeaPoint       Turbidity       Disabled (IR)
File Deletion                  Disabled  with profiles stored = 30


INTERNAL PARAMETERS
-------------------

FullSpeed                         0.250 [dbar/sec]
PR_Threshold                      0.045 [dbar/sec]
PR_TimeThreshold                    180 [sec]
sensor_warmup                       120 [sec]
sensor_warmdown                     120 [sec]
InfiniteDeployment              Enabled


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     °  Serial Dump Files From FLASH  °
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          Fri Jul 16 15:12:07 2004

Stream serial data from:
   <D> Deployment
   <S> Single profile
   <R> Range of profiles

   <L> Logging files

Exit to:
   <M> Main menu

       Selection  ? 1
Select log file to download:
```

```
<1> Profiles.dat
<2> Deploy.dat
<3> IRQ/Xcpt Log
<4> Profile Termination Log

Exit to:
<M> Main menu

      Selection  ? 3

Opening file IRQ_XCPT.LOG, the processor interrupt
and exception processing log file.

07/09/2004 16:20:14  Log file creation time.
07/09/2004 16:57:11  Unattended system reset by watchdog.
07/09/2004 17:04:49  Critical fault recovery and reset.
07/09/2004 18:13:42  Unattended system reset by watchdog.
07/09/2004 19:01:00  Watchdog IRQ acknowledged.
07/09/2004 20:01:00  Watchdog IRQ acknowledged.
07/09/2004 21:01:00  Watchdog IRQ acknowledged.
07/09/2004 22:01:00  Watchdog IRQ acknowledged.
07/09/2004 23:01:00  Watchdog IRQ acknowledged.

           .
           .
           .

End of file mark reached for file IRQ_XCPT.LOG

     É͸»
     °  Serial Dump Files From FLASH  °
     È͸¼
          Fri Jul 16 15:13:08 2004

Stream serial data from:
   <D> Deployment
   <S> Single profile
   <R> Range of profiles

   <L> Logging files

Exit to:
   <M> Main menu

       Selection  ? 1
Select log file to download:
<1> Profiles.dat
<2> Deploy.dat
<3> IRQ/Xcpt Log
<4> Profile Termination Log

Exit to:
<M> Main menu

      Selection  ? 4

The profile termination log consists of data from
the last 10 profiles stored in a non-volatile rolling
buffer.  The display below is not date sorted.

Profile:                160
Motion start:    07/16/2004 06:00:05
Motion stop:     07/16/2004 06:00:54
Start pressure:         2.1 [dbar]
Stop pressure:         13.8 [dbar]
```

```
Ramp exit:          SMOOTH RUNNING
Profile exit:       BOTTOM PRESSURE
Log time:           07/16/2004 06:03:09

Profile:                   161
Motion start:       07/16/2004 07:00:05
Motion stop:        07/16/2004 07:00:52
Start pressure:           13.7 [dbar]
Stop pressure:             2.4 [dbar]
Ramp exit:          SMOOTH RUNNING
Profile exit:       TOP PRESSURE
Log time:           07/16/2004 07:03:07

Profile:                   162
Motion start:       07/16/2004 08:00:05
Motion stop:        07/16/2004 08:00:54
Start pressure:            2.3 [dbar]
Stop pressure:            13.7 [dbar]
Ramp exit:          SMOOTH RUNNING
Profile exit:       BOTTOM PRESSURE
Log time:           07/16/2004 08:03:09

              .
              .
              .

Profile:                   167
Motion start:       07/16/2004 13:00:05
Motion stop:        07/16/2004 13:00:52
Start pressure:           13.6 [dbar]
Stop pressure:             2.4 [dbar]
Ramp exit:          SMOOTH RUNNING
Profile exit:       TOP PRESSURE
Log time:           07/16/2004 13:03:07

Profile:                   168
Motion start:       07/16/2004 14:00:05
Motion stop:        07/16/2004 14:24:01
Start pressure:            0.2 [dbar]
Stop pressure:             0.2 [dbar]
Ramp exit:          SMOOTH RUNNING
Profile exit:       PRESSURE RATE ZERO
Log time:           07/16/2004 14:26:44

Profile:                   169
Motion start:       07/16/2004 15:00:05
Motion stop:        07/16/2004 15:00:38
Start pressure:            0.2 [dbar]
Stop pressure:             0.2 [dbar]
Ramp exit:          SMOOTH RUNNING
Profile exit:       TOP PRESSURE
Log time:           07/16/2004 15:02:52
```

Appendix G: IM Protocol

The order of events is: PROCON acquires data -> powers UIM -> awakens TD -> awakens SURFCON-> SURFCON powers SIM. Thereafter SURFCON prompts PROCON, subject to timeouts at either end, to transfer the information using 3 requests:

1) normally, REQNEW, to request a new file, presumably type *.DAT

2) REQFIL to request a specific file

3) REQDIR to request a limited directory of available files

The transmission protocol for 3 is that the directory is sent as a sequence of entries without delimiting characters. The protocols for the other two file types are more rigorous. In all cases SURFCON first sends a request packet, and PROCON responds first with a 50-character ASCII metadata packet. An example of the metastructure is ('*' represents a 0x00 and a ' ' represents a space 0x20):

E0000000.DAT*mm dd yyyy hh mm ss ccc*xxxxxxxxxxx*>

SURFCON then follows with a sequence of binary packets of length 4096 bytes. After receiving each packet, SURFCON responds with an "ACK" confirming proper reception, or "NAK" confirming errors and which will invoke up to 3 re-transmissions. After SURFCON gets a packet correctly from the PROCON, it strips off the header bytes and appends the current file. Each *.DAT or *.ENG file will be reassembled in SURFCON, and an associated metadata file will be flagged according to a CRC test. Approximately 50 Kbytes of data are transmitted per profile. In all cases, SURFCON expects that the PROCON UIM id = 01, which is used below in the description of operations. After receiving an entire file, the SURFCON metastructure which consists of the PROCON metadata and the file CRC, is appended:

E0000000.DAT*mm dd yyyy hh mm ss ccc*xxxxxxxxxxx*000000ff 00000000000

If a filename does not exist then the PROCON metadata structure will begin with ENDOFDAT.DAT.

The detailed sequence for protocols 1 and 2 is:

- Upon wakeup by PROCON, SURFCON normally requests a new file by sending the command #idREQNEW<CRLF>, it expects ASCII metadata (with 10 second timeout) if a new profile exists, else the metadata filename is "EOD". ["id" is always UIM number "01"]

Or, if SURFCON sends #idREQFIL filename.ext<CRLF> (including white space between #idREQFIL and filename.ext), it expects ASCII metadata (with 10 second timeout) for that specific file. If PROCON does not have the file, it sends filename "EOD" in the metadata.

[Example if file exists: "filename.ext mm dd yyyy hh mm ss mid xxxxxxxxxxx >"

Example if file does not exist: ENDOFDAT.DAT mm dd yyyy hh mm ss mid 0 >]

- If SURFCON timeouts waiting for a REQNEW or REQFIL response 3 times, it returns to suspend mode.

- If SURFCON receives reasonable metadata, it sends bidREQACK<CRLF> (where "b" stands for binary transmission and "id" = "01") and expects a sequence of 1 or more binary packets, with header and up to 4096 bytes of data.

[The PROCON data packet header is defined as 4 ASCII characters "DAT_" 16 bit binary length count in bytes of this packet, little endian (low byte first), and 16 bit binary CRC<CRLF> (little endian).]

- If SURFCON receives data packet correctly, it sends bidREQACK<CRLF> and expects the next data packet, etc.

- If SURFCON receives packet with errors, or times out, it sends bidREQNAK<CRLF> and expects repeat of the previous packet.

- If SURFCON receives the same packet with errors 3 times in sequence, it re-requests same file specifically, #idREQFIL filename.ext.

- If SURFCON receives the PROCON CRC file terminating packet, it responds with bidREQACK<CRLF> and closes the file.

[The PROCON CRC packet is defined as 4 ASCII characters "CRC_" 16 bit binary length count in bytes of this packet, little endian (low byte first), and 16 bit binary CRC<CRLF> (little endian).]

The detailed sequence for protocol 3 is:

- If SURFCON sends #idREQDIR<CRLF>, it expects an ASCII response, listing files PROCON has available in 23 byte entities each null terminated (example: filename.xxxnnnnnnnnnnn\0), each directory entry terminated with <CRLF>.

Finally, SURFCON sends #REQEOD<CRLF> to terminate the session with PROCON, ignores anything beyond this and suspends. No PROCON response is expected.

At the UIM/SIM level, the ASCII RELAY command termination character for the SIM (that causes it to switch from Tx to Rx is <CR>, 0x0d; it ignores <LF>, 0x0a. The UIM switches from Rx to Tx for ASCII RELAY on the same <CR>. The UIM knows that an ASCII RELAY response is done by reception of a '>' from the PROCON, which can be set to a different default character. The BINARY RELAY delay for the UIM should be longer than for the SIM which

means that the SIM must wait for the UIM turnaround delay before issuing the next relay request. This delay difference means that the SIM is never listening to an open line which would result in garbage characters when neither the SIM nor UIM are driving the loop. The relay length from PROCON to UIM and on must be less than 30 kbytes, due to a buffer limit. The maximum relay command length on both SIM and UIM is 128 chars, including everything but the terminating <CR>. Responses to SIM ASCII RELAY command by the UIM are terminated with '$' installed by the UIM. The reliability of the IM link is good so errors should be few. Care needs to be taken if testing with a long cable on a reel as the TD function may not work as well. The average inductive transmission rate of a long file between PROCON and SURFCON is about 70 characters/s over the 1200 baud link

A session overview for data transfer from ITP PROCON to SURFCON:

```
PROCON finishes profile and wakes UIM
UIM sends 4800 Hz tone to Surface TD for 2.5s
TD sends falling edge to SURFCON board /WAKE input
SURFCON awakens from suspend mode, powers up, waits 5s for UIM to be in Rx
mode
While (1)
      SURFCON sends #idREQNEW<CRLF>
      if PROCON sends ENDOFDAT packet, break
      else if  PROCON sends nothing or non-METADATA packet, continue
            (i.e. try again with #idREQNEW)
      else PROCON sends METADATA packet
      SURFCON sends bidREQACK<CRLF> ....
            (or bidREQNAK<CRLF>, if METADATA garbled or timeout)
      PROCON sends binary data packet
      SURFCON sends bidREQACK<CRLF> ....
            (or bidREQNAK<CRLF> if DATA packet garbled or timeout)
      PROCON sends next data packet or resends previous......
                                    •
                                    •
                                    •
      SURFCON sends bidREQACK<CRLF> ....
            (or bidREQNAK<CRLF> if DATA packet garbled or timeout)
      PROCON sends CRC packet
      SURFCON recognizes this as the end of the file and sends bidREQACK<CRLF>
End while
SURFCON may send #idREQFIL<CRLF> eliciting same transaction as for REQNEW
SURFCON may send #idREQDIR<CRLF> eliciting PROCON transmission of directory
SURFCON terminates session with #idREQEOD<CRLF>
```

An example of data transfer from ITP PROCON, excerpted from SURFCON screen log:

```
06/08/2006 16:34:10 16.0 11.4  #6 Wake from TD, IM wakeups=1
06/08/2006 16:34:10 16.1 11.4  #7 Starting SIM
sending ECHOOFF
sending AUTOPWRON
sending RELAYMAX=600
sending BINARYGAP=5000
sending DS
wait time for relay command response = 600 seconds
binary relay character timeout = 5000 msec
SBE 37 SURFACE MODEM06/08/2006 16:34:26 16.0 11.2  #22 SIM powerup confirmed
06/08/2006 16:34:42 16.0 11.2  #31 Pkt type is  DAT   Length=624  CRC=0a3e
06/08/2006 16:34:49 16.0 11.2  #31 Pkt type is  CRC   CRCpkt len=8  Computed
filelen=616 CRC=00ff
```

```
06/08/2006 16:34:49 16.0 11.2  #10 Added file c:\DATA\E0000002.DAT to FileList
06/08/2006 16:34:49 16.0 11.2  #33 IMFiletime after pkt loop = 21 sec, Total
IM time = 39
06/08/2006 16:34:49 16.0 11.2  #8 Sending REQNEW
C0000002.DAT 06 08 2006 14 30 46 001        2560 >
len of Meta response=50 sizeof metastruct=50
#parms parsed=9  datafilename=c:\DATA\C0000002.DAT
06/08/2006 16:34:51 16.0 11.2  #30 Openfile c:\DATA\C0000002.DAT for write
06/08/2006 16:35:28 16.0 11.2  #31 Pkt type is  DAT   Length=2568  CRC=06b4
06/08/2006 16:35:35 16.0 11.2  #31 Pkt type is  CRC   CRCpkt len=8  Computed
filelen=2560 CRC=00ff
06/08/2006 16:35:35 16.0 11.2  #10 Added file c:\DATA\C0000002.DAT to FileList
06/08/2006 16:35:35 16.0 11.2  #33 IMFiletime after pkt loop = 43 sec, Total
IM time = 85
06/08/2006 16:35:35 16.0 11.2  #8 Sending REQNEW
ENDOFDAT.DAT 06 08 2006 14 35 16 001          0 >
06/08/2006 16:35:40 16.0 11.2  #11 Sending REQEOD
06/08/2006 16:35:43 16.0 11.3  #34 IM time after task loop = 93 sec
06/08/2006 16:35:45 16.0 11.4  #35 IM time after SIM loop = 95 sec
Q_CHECK  nte=1149795720 now=1149784545
06/08/2006 16:35:45 15.9 11.4  #70 GetTimeToNextStatusEpoch: now=1149784545
interval=3600 tn=1149786000 ntt=0
06/08/2006 16:35:45 15.9 11.4  #18 suspend for 1455 s, next status 1455 s,
next ISU Tx 11175 s
```

Appendix H: SURFCON to Logger Communications

Two logger computers running the Linux operating system have been established at WHOI to receive data via the Iridium global phone system from multiple systems including ITPs, and deliver command files. ITPs may communicate with either logging system in case of failure of one, and are configured to primarily dial the primary logger, and after 5 failed attempts dial the backup logger. Five failed attempts at the backup logger reverts back to the primary logger, and so forth. The communication is via a conventional Rev 2 Hayes desktop modem connected to a dedicated analog phone line. Each receiving system logs data to a specific user directory structure using a Perl scripted logger program. Each ITP is assigned a username and password, although passwords are not necessary for logging operations as ITPs do not access the server directly but rather the logger script. The number of users, i.e. field systems, can be increased as needed with no change to the logger program, by simply adding users to each Linux system and configuring the field systems to dial-up and login as particular users.

Information is sent to the logger in 2048 byte packets. The logger computer reassembles the files from the packet format in which the files are transmitted. Data and engineering files from SURFCON are sent to the logger preceded with the 50 character PROCON metastructure and appended with the 70 character SURFCON metastructure (see Appendix G). Note that the 2 structures are identical for the first 49 characters. The duplication of metadata structures is a redundancy feature to assure that the description source of each file is embedded in that file and likely recoverable from at least one place or the other. The SURFCON metastructure does not include the terminating character '>'. Following the PROCON supplied file length, is the PROCON supplied CRC (9 characters including a trailing space) and SURFCON computed filelength (12 characters including a trailing space).

At each occasion that SURFCON makes an ISU connection, it transmits all files in its queue, and also requests a command list from the WHOI server. If such a command list exists on the server (typically composed manually by a person responsible for operation of the destination ITP), it is received by SURFCON and acknowledged by a short file (filename is of the form mmddhhnn.ACK), that echoes the command(s) received. A command list using the filename "outboundcmd" is composed and installed in the root directory of the particular ITP for which it is intended. Once transmitted, its name is appended with the date and time to show that it was transmitted and to prevent it from being re-transmitted. The formation of these files is simple and should be considered fixed field, i.e. additional white space characters are likely to cause problems. Command packets contain a string of commands, each followed by a <CRLF>. The form is CMND (upper or lower case), whitespace, parameters according to command. Parameters are separated by white space. Filenames normally include an 8 character name, '.'

and 3 character extension, although filenames shorter than 8 chars may arise. Multiple instances of a given command can be used. EOTX terminates the command list. Following are the command packets that can presently be handled by SURFCON:

SFIL filename <CRLF>	Get specified file from SURFCON
SDIR directory <CRLF>	Get an ASCII file of the specified SURCON directory
SCMD command <CRLF>	Send SURFCON system command and execute
PFIL filename <CRLF>	Get specified file from PROCON
PDIR <CRLF>	Get a file of the PROCON directory....up to 50 lines
PCDS <CRLF>	Get Profiler UIM status - not implemented.
EOTX <CRLF>	Terminates command list

The SURFCON system commands that could be invoked remotely are:

COPY	source dest [/V]
DEL	[drv:][pth][name] [/P
ERASE	[drv:][pth][name] [/P
REN	[d:][p]oldname newname
RESET	(hard reset)
SET	[var=[str]] [/SLFE?]

SDIR, SFIL and SCMD commands are executed immediately upon receipt and if a file results, it is sent in the current session with the logger. SDIR requests a listing of the specified directory on the SURFCON. SFIL requests transmission of a specific filename. SCMD requests that the SURFCON execute the specified command as if it was executed on the command line. Obviously great care is required with such a brute force facility.

PDIR and PFIL commands are accepted and held for the next IM communications session with the PROCON , hence any results from such commands will at the earliest, be returned to the logger at the end of the next Profiler session. PDIR requests the PROCON directory list which typically has a few control and status files and the 40 most recent data & engineering file pairs.

When a command packet is received by SURFCON, it is stored in a file with the extension *.ACK, and added to the transmission queue for the next cycle (to acknowledge receipt). Upon completion of the Iridium communications, commands for SURFCON are executed. Requested SURFCON files are added to the transmission queue for the next cycle,

while SURFCON directory requests are stored in *.SDR files and added to the queue. Commands for PROCON are relayed to PROCON and executed during the next IM cycle. Requested PROCON files are added to the transmission queue for the next cycle, while PROCON directory requests are stored in *.PDR files and added to the queue.

Examples of logger command files:

PFIL LASTSENT.DAT

PFIL IRQ_XCPT.LOG

EOTX

PFIL DEPLOY.DAT

PDIR

SDIR c:\log

SFIL c:\itpsys

EOTX

SCMD RESET

SCMD DEL c:*.ACK

EOTX

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16. Abstract (Limit: 200 words)

An automated, easily-deployed Ice-Tethered Profiler (ITP) has been developed for deployment on perennial sea ice in polar oceans to measure changes in upper ocean temperature and salinity in all seasons. The ITP system consists of three components: a surface instrument that sits atop an ice floe, a weighted, plastic-jacketed wire-rope tether of arbitrary length (up to 800 m) suspended from the surface instrument, and an instrumented underwater unit that profiles up and down the wire tether. The profiling underwater unit is similar in shape and dimension to an ARGO float except that the float's variable-buoyancy system is replaced with a traction drive unit. Deployment of ITPs may be conducted either from ice caps or icebreakers, utilizing a self contained tripod/winch system that requires no power. Careful selection of an appropriate multiyear ice floe is needed to prolong the lifetime of the system (up to 3 years depending on the profiling schedule). Shortly after deployment, each ITP begins profiling the water column at its programmed sampling interval. After each acquired temperature and salinity profile, the underwater unit (PROCON) transfers the data and engineering files using an inductive modem to the surface controller (SURFCON). SURFCON also accumulates battery voltages, buoy temperature, and locations from GPS at specified intervals in status files, and queues that information for transmission at the start of each new day. At frequent intervals, an Iridium satellite transceiver in the surface package calls and transmits queued status and CTD data files onto a WHOI logger computer, which are subsequently processed and displayed in near-real time at http://www.whoi.edu/itp. In 2004 and 2005, three ITP prototypes were deployed in the Arctic Ocean. Each system was programmed with accelerated sampling schedules of multiple one-way traverses per day between 10 and 750-760 m depth in order to quickly evaluate endurance and component fatigue. Two of the ITPs are continuing to function after more than 10 months and 1200 profiles. Larger motor currents are observed at times of fast ice floe motion when larger wire angles develop and drag forces on the profiler are increased. The CTD profile data so far obtained document interesting spatial variations in the major water masses of the Beaufort Gyre, show the double-diffusive thermohaline staircase that lies above the warm, salty Atlantic layer, and many mesoscale eddys. Deployed together with CRREL Ice Mass Balance (IMB) buoys, these ITP systems also operate as part of an Ice Based Observatory (IBO). Data returned from an array of IBOs within an Arctic Observing Network will provide valuable real time observations, support studies of ocean processes, and facilitate numerical model initialization and validation.

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