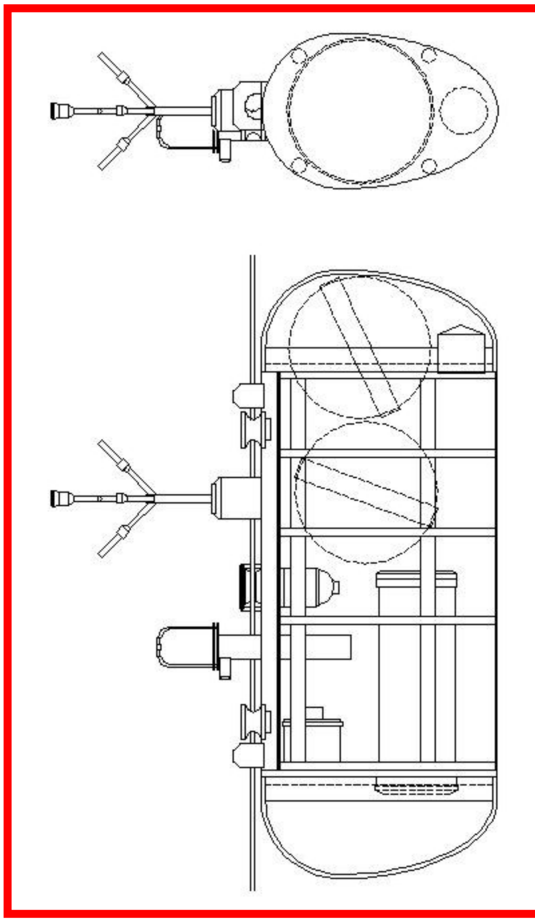
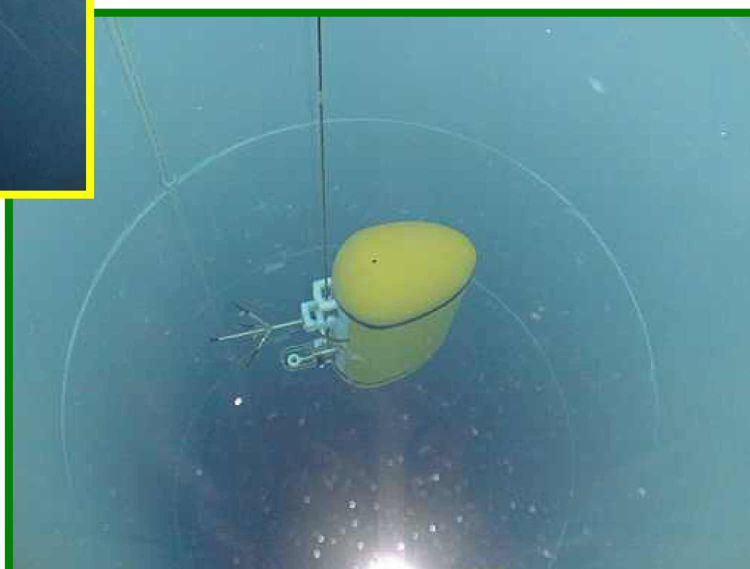
The McLane Moored Profiler





MMP Operator's Manual

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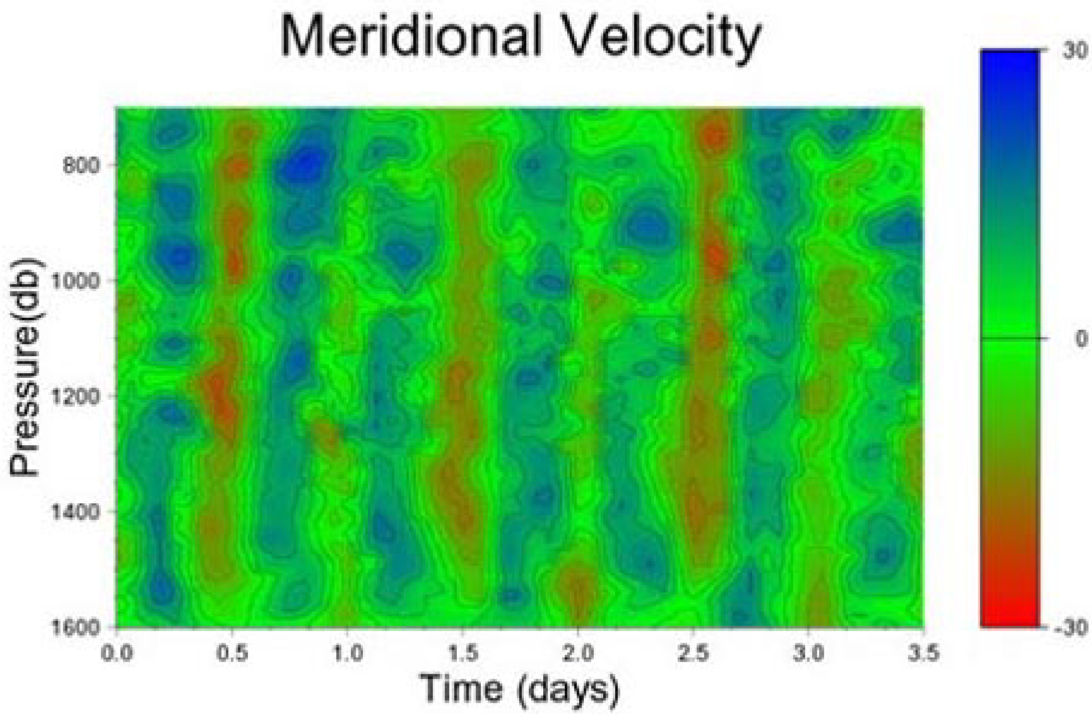
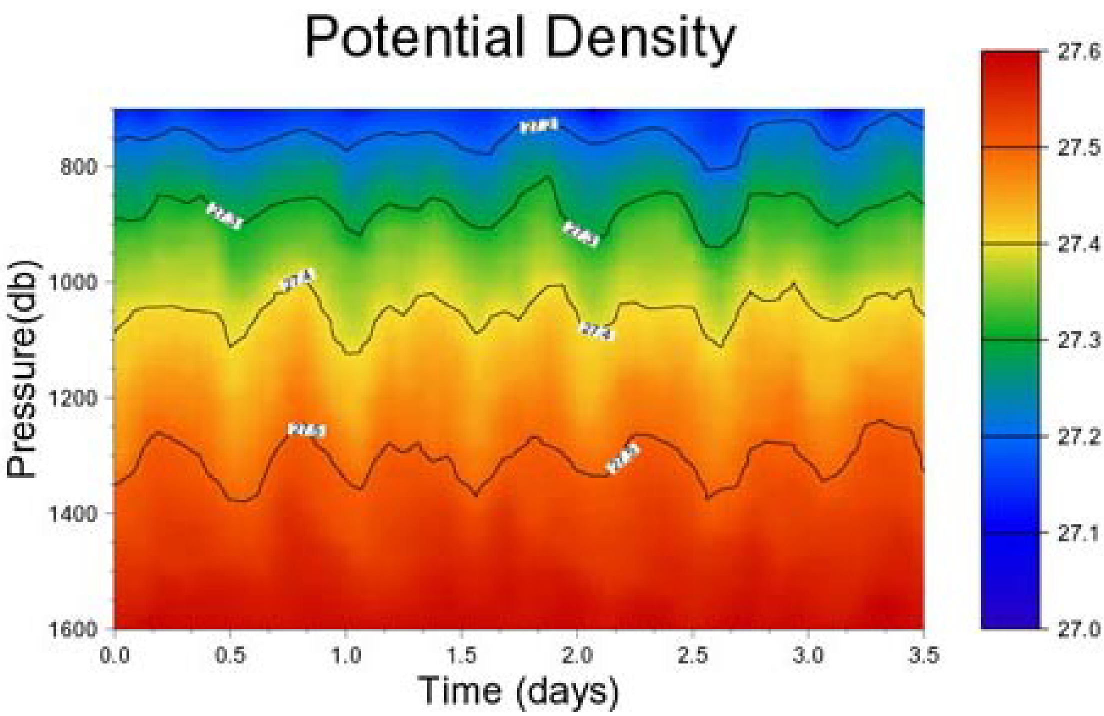
McLANE
RESEARCH LABORATORIES, INC





Barotropic tides scatter into baroclinic motions above the southern flank of the Hawaiian Ridge. The site is west of Kaena Point in the Kauai Channel between the islands of Kauai and Oahu. The data were collected by a McLane Moored Profiler during a short field trial, January 9 - 13, 2001.

Images courtesy of John Toole, Woods Hole Oceanographic Institution

MMP Operator's Manual

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I. The McLane Moored Profiler

The McLane Moored Profiler (MMP) is an autonomous, instrumented platform designed to collect a long time-series of *in situ* oceanographic profiles. The standard suite of instruments carried by the MMP includes a conductivity-temperature-depth (CTD) sensor and an acoustic current meter (ACM). Additional sensors can be added to the system. The MMP follows a programmed trajectory along a vertical mooring cable, automatically sampling the water column and logging the results. Profiles can span the full depth of the water column down to 6000 meters. Mission duration is 1 to 1.2 million meters and deployments of a year or more are possible.

This manual describes the operation and maintenance of the McLane Moored Profiler. The manual is organized into several chapters. The first is a Mechanical Description of the profiler, including a discussion of handling, maintenance, and cleaning procedures. The next chapter is System Architecture, a description of active system components and the links through which they communicate and interact.

The architecture chapter is followed by a complete description, illustrated with examples, of system operation through the User Interface. We encourage you to read this section while interacting with an MMP. Bench top operation of the MMP is an invaluable aid to system familiarization. Through the user interface the operator can easily and flexibly set and test the profile and sampling parameters that define a deployment. The interface also provides the operator with access to system diagnostic routines, file system and data offload utilities, and support for system and component testing and operability assessment.

Operation of a PC executable, high-speed, profiler data processor is described in Data Offload, Processing, and Interpretation. That chapter also discusses the interpretation of information in the data files, and presents algorithms for preliminary processing of the sensor data.

The remaining chapters include Deployment Parameter Selection, a discussion based on hypothetical deployment scenarios, Operating Crosscut and TattleTerm, instructions for the installation and operation of the PC/MMP communication software supplied with the system, and Compass Calibration, instructions for installing and operating the compass correction software.

In addition to this manual, the McLane Research Laboratories (MRL) offer a one to two day MMP training course, taught at our facility in East Falmouth, Massachusetts, USA. The course begins with a classroom lecture focusing on the material of Chapters II through IV. The class then moves into our main laboratory for hands-on instruction. This portion of the course involves participants in system testing, deployment preparation and programming, launch and recovery using the 17-meter MRL test well, and data offload. Expect to get wet. Throughout, participants will have the chance to ask questions and work directly with members of the MRL engineering staff. A 2 hour video presenting the course material in abbreviated form is also available.

We encourage you to take advantage of these training materials and opportunities. The MMP is a complex, full featured, instrument system. You should not expect to deploy it successfully immediately after removing it from the shipping crate for the first time. In addition to review of the training materials, we strongly endorse the practice of conducting trial deployments in the laboratory under controlled conditions. This practice, an integral part of our training course, is the most direct path to the high level of familiarity with system operation that should be reached before undertaking investigations in the field. Trials both with and without an active communications link to a PC during the autonomous portion of the deployment are recommended. Personnel at the McLane Research Laboratories are available to provide assistance and advice as you go through this process.

We wish you every success in your future investigations. But first, learn the system!

II. Mechanical Description

The mechanical design of the McLane Moored Profiler emphasizes low hydrodynamic drag, ease and reliability of operation, and low maintenance. Three papers describing the development and early use of the MMP may be of interest to readers. The papers can be downloaded in .pdf format from the MMP page on the McLane web site, http://www.mclanelabs.com/mmp.html. The meridional velocity and potential density plots presented on page 2 are discussed in the third paper, Morrison, et al., 2001.

- Morrison, A. T., III, Billings, J. D., Doherty, K. W., Toole, J. M., "The McLane Moored Profiler: A Platform for Physical, Biological, and Chemical Oceanographic Measurements", *Proceedings OCEANOLOGY International 2000*, March 2000, pp. 397-414.
- Morrison, A. T., III, Billings, J. D., Doherty, K. W., "The McLane Moored Profiler: An Autonomous Platform for Oceanographic Measurements", *Proceedings of OCEANS 2000*, MTS/IEE/OES, October 2000,Vol. I, pp. 353-358.
- Morrison, A. T., III, Toole, J. M., Lukas, R., Worrilow, S. E., Doherty, K. W., "Results from the First Successful Field Deployment of the McLane Moored Profiler", *Proceedings of OCEANS 2001*, MTS/IEE/OES, November 2001,Vol. II, pp. 949-955.

You may wish to refer to the line drawing of the MMP on the following page during the discussion that follows. The convention used in this manual is that the "front" of the profiler is the side on which the current meter "sting" is mounted. In the elevation drawing the MMP is facing to the left and the reader is viewing the left or port side of the profiler.

Tool Kit

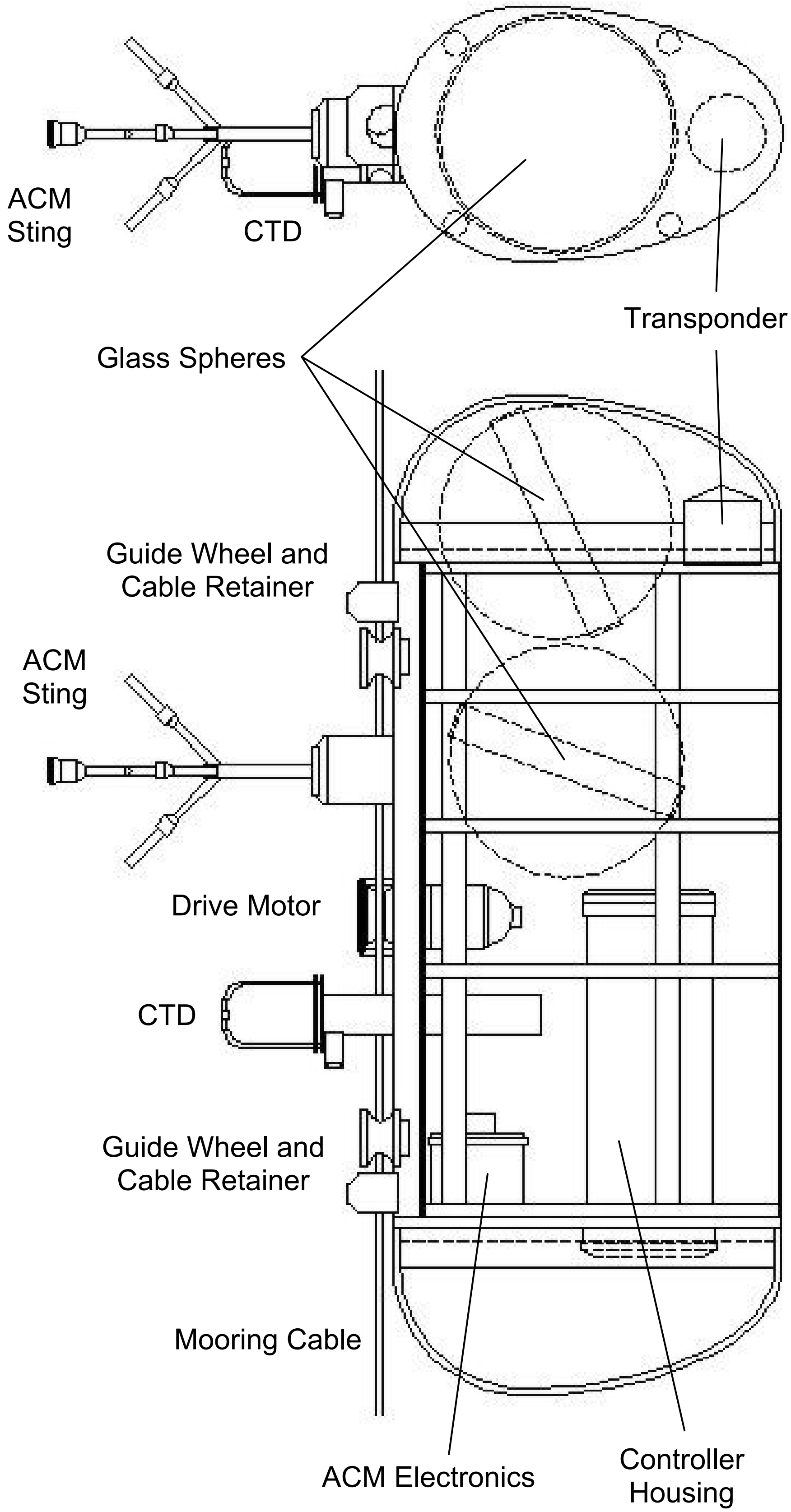
A tool kit with a selection of wrenches, screwdrivers, and ball-hex drivers sized for the profiler hardware is supplied with each MMP. Use the provided tools when performing the operations described below. The tool kit also contains a small selection of spare parts (pressure housing o-rings, nylon and stainless steel screws and bolts, ballast weights), a communications cable, a CD with the sensor manuals, software for communication between a PC and the MMP, and software for correcting ACM compass measurements during post-processing.

Dimensions, Weight, and Depth Rating

The MMP is 130.5 cm (51.39") tall, 33.3 cm (13.125") wide (port to starboard) and 50.5 cm (19.875") long (fore to aft). The sting of the ACM, including its hinged mount, protrudes forward an additional 45.2 cm (17.7995"). The mass of the MMP is 70±1 kg for an air weight of 154±2 lbs. The water weight is nominally 0±4 oz (0±100 gm) after ballasting. The housings and glass spheres are all depth rated to 6000 meters.

Frame and Skin

All components of the frame are machined from stock pieces of white, ultra high molecular weight polyethylene (UHMW). UHMW provides strength without a buoyancy penalty. The material is marginally buoyant in fresh water and floats well in salt water. UHMW is also durable, easily machined, and abrasion and oil resistant.


ACM
Sting
CTD
Transponder
Glass Spheres
Guide Wheel and
Cable Retainer
ACM
Sting
Drive Motor
CTD
Guide Wheel and
Cable Retainer
Mooring Cable
ACM Electronics
Controller
Housing

The primary structural member of the frame is the front plate. Oval ribs are mounted on the inner side of the plate and extend to the back of the profiler. The structure is stiffened with four columns of frame spacer posts. Two braces (not shown) maintain a right angle between the front plate and the ribs. The result is a stiff but light open beam or truss that can sustain bending and twisting moments and on which the system's components can be mounted.

The faired skin and end caps that give the MMP its low drag shape are made from high-visibility yellow, medium density polyethylene, a moldable material with good resistance to abrasion and impact. The skin material is negatively buoyant in both fresh and seawater. The skin and frame are free flooding. The shape of the MMP and the location of attachment to the mooring cable make the MMP self-aligning; the sting of the acoustic current meter always points into the flow.

Note that while the skin and frame are "abrasion resistant", they are not impervious to abrasion. Dragging the MMP across, for example, non-skid deck paint will permanently mar the skin and frame.

The leading edge of the skin on either side is recessed in a groove machined in the edge of the front plate. Protruding edges would increase the horizontal component of hydrodynamic drag. See the listed papers, particularly Morrison, et al., 2001 for a discussion of drag reduction and its consequences. Elsewhere, the skin is secured in place by flat-head nylon bolts. Remove the bolts and lift the skin off the ribs to gain access to the interior. Installing or removing the drive motor, CTD, or ACM requires removal of the skin from the left side of the profiler.

During normal operation there is no need to remove the top faired end cap. The bottom faired end cap must be removed to reach the controller housing. This is a necessary operation for all deployments and for bench testing. To remove the bottom end cap first lay the profiler on its right side. Then unscrew and remove the socket head nylon cap screw that secures the end cap. The screw is reached through the 10 cm by 4 cm oval opening on the back of the profiler. The opening is located at the bottom of the seam where the two halves of the skin meet. The screw passes through the bottom rib of the frame and threads into the internal rib of the lower end cap assembly. With the screw removed, strike the front of the end cap sharply with your palm to slide the assembly aft and off its mounting posts. The four posts are 316 stainless steel. Reverse the procedure to reattach the end cap.

You may find it helpful to elevate the lower end of the profiler by a centimeter or two when removing or replacing the end cap. Make sure the prop is under a rib so that the load is not entirely supported by the skin. The end cap will remain attached to the frame by a short loop of rope. The rope is the primary lift point used during launch and recovery at sea. These operations are discussed below. It is not necessary to unscrew the flat-head nylon bolts that secure the edge of the faired end cap skin to the internal rib of that assembly. Removing the faired end cap exposes the lower end of the controller housing. See below for further information.

Cable Retainers

The cable retainers secure the profiler to the mooring cable. They are machined from blocks of UHMW and each is secured to the front plate with four socket head nylon cap screws. The retainers are strong enough to support the weight of the MMP when it is suspended in air and the free flooding skin is filled with water. The retainers will also sustain, within limits, the snap loads that may be experienced during launch and recovery.

Glass Spheres

The two glass spheres mounted in the frame together provide 44 lbs of buoyancy to balance the weight of the pressure housings and their contents. The spheres are manufactured by MRL from borosilicate glass with a 30.5 cm (12") outside diameter. The spheres contain no electronics or batteries that would require regular servicing by the operator. All spheres have been tested at MRL to 10360 psi (7000 meters).

The spheres should be visually inspected before and after each deployment to check for signs of fatigue caused by repeated pressure cycling. Fatigued spheres should be replaced to prevent failures during a deployment. The markings visible on the spheres when they are first received are normal and operators should become familiar with them. After each recovery, operators should visually check for the following signs of fatigue: (1) more than 3-5 cm^3 of glass dust in the interior of the sphere, (2) any large shards of glass in the interior, or (3) any interior or exterior spawls. If signs of fatigue are present the sphere should be replaced.

To remove the upper sphere the top faired end cap must be removed. To remove the fairing, unscrew the flat-head nylon bolts securing the edge of the end cap to the top rib. Once the end cap is released the sphere is free to roll. Exercise caution. To remove the lower sphere the port and starboard halves of the skin must both be removed and the upper portion of the frame must be disassembled. When replacing spheres be sure to align the equatorial seal with the slots cut into the supporting ribs. The proper orientation is shown in the line drawing above.

Pressure Housings, Cables, and the Drive Train

The controller, motor, CTD, and ACM housings are all machined from titanium and require little maintenance beyond fresh water rinsing after recovery (see below). However, the hardware associated with the housings is stainless steel and should be monitored for corrosion. Replace corroded hardware as necessary. Spare stainless steel hardware is included in the tool kit. The black jackets of the underwater cables are made from neoprene rubber. The clear, oil filled tube connecting the ACM sting and electronics is polyvinyl chloride, formulated for low hydrocarbon permeability. Excess cable length from each cable run should be gathered in the volume immediately above the bottom rib and forward of the controller housing.

Controller Housing

The controller housing contains the MMP controller electronics, the main lithium battery pack, the transponder electronics, and the alkaline transponder batteries.[1] These parts are mounted to the lower end cap of the housing as a single assembly. To remove the assembly and gain access to the electronics and batteries, unscrew the 6 socket head stainless steel cap screws that secure the end cap. A bar of UHMW stock or other hard plastic makes an effective and non-damaging torsional pry bar with which to free the end cap from the pressure cylinder once the screws are removed. The lower rib makes an effective fulcrum.

[1] The transponder is an optional component; transponder electronics and batteries may be absent.

All connections between the controller and the other components of the system pass through the lower end cap. The end cap bulkhead connectors are labeled as follows:

COM	Serial communications port to PC, cable in tool kit, dummy plug in place
CTD	CTD sensor communication port
ACM	ACM sensor communication port
XPR	Transponder
M	Drive motor
PR	Pressure relief valve

Two clamps secure the controller housing to the frame. The clamps are the aft portions of the two lowermost ribs of the frame. They are each secured in place by two socket head nylon cap screws. The screws are only accessible when the skin is removed. The housing will normally twist in place. The housing should be oriented with the communications port to the back (aft) and the transponder port to the front before replacing the faired end cap. If necessary, loosen and re-tighten the clamps to achieve this orientation.

The pressure relief port can be opened manually to equalize internal and external pressures before opening the housing. Simply screw an 8-32 bolt into the threaded hole in the end of the pressure plug and pull on that handle to open the valve. The relief valve will open automatically if a dangerously high internal pressure, caused by some form of battery out-gassing, develops. As with any underwater pressure housing containing batteries, be aware of this possibility and take appropriate precautions when opening the housing after recovery.

CTD

The CTD and ACM are connected to and powered from the controller housing. The CTD slides in and out through a fitted hole in the front plate. A pinch bracket secures it in place. The single cap screw that secures the CTD in the bracket can be reached through the small hole in the port side skin or by removing the port side skin. The CTD should be mounted so that the flow path through the white, toroidal, inductive conductivity cell is oriented vertically and so that the oil-filled pressure compensation bladder extends to port, away from the mooring cable.

The CTD communications and power cable should be run from the CTD to the CTD connector on the end cap of the controller housing through the central hole in the bottom rib of the frame. The CTD and ACM connectors are physically (and electrically) identical. The cables and connectors have been color coded to avoid confusion. Nothing will be physically damaged if the cables are accidentally switched, but the system will not be able to collect sensor data during a deployment. The system control program (SCP) will display warnings to the operator before a deployment if the cables are switched.

ACM

The ACM sting has four "fingers" extending at a 45º angle away from a central post. The fingers are labeled +X, +Y, -X, -Y. By convention, the sting should be mounted with the -Y finger up. When the base plate is in place and the four bolts have been loosely tightened, twist the sting and align it so that the +Y and -Y fingers lie on a vertical plane and the +X and -X fingers lie on a horizontal plane. Then tighten the bolts carefully. When the lock washers are flat, STOP TIGHTENING. The bolts are 316 stainless steel. The threaded hole is in UHMW. Over-tightening will quickly (and far more easily than you might expect) strip the threads. This may prevent or delay a timely deployment. See below for additional important sting mounting information.

The sting mounts on a hinged bracket (UHMW) through which the mooring cable runs. The mooring cable must be located on the centerline so that the profiler will align cleanly into the flow. The bracket allows the current sensor to be located on the centerline as well. An off center location would introduce a left-right bias in the flow measurement because the sting would not be symmetrically aligned with the streamlines of the flow around the body of the MMP. The sting extends well forward of the body of the MMP so that its measurement is made in relatively undisturbed flow.

Two socket head nylon cap screws secure the bracket. Release the screws and swing the sting out of the way when the MMP is being connected to or disconnected from the mooring cable. Be sure to re-secure the screws for the deployment. The hinge is positioned so that the sting will rest in position when the profiler is lying on its starboard side (port side up).

The ACM electronics housing contains compass and tilt sensors. It is important that the housing is properly aligned and secured within the frame of the MMP so that the sting relative path velocities measured by the sensor can be rotated into a Cartesian earth frame during post-processing.

The ACM housing is mounted in a clamp (UHMW) that is mounted to the port side angle brace of the frame.[2] To remove the housing first remove the port side skin. Then release the CTD and move it out of the way. Unscrew the two socket head nylon cap screws securing the ACM clamp to the port angle brace and remove the clamp and ACM housing together. Loosen the four, recessed, socket head nylon cap screws to release the housing from the clamp.

To reinstall the housing first locate the milled depression in the top face of the end cap. The depression may be hidden under a label or there may be a label with an arrow indicating its location or direction. The housing should be mounted so that the depression is towards the front of the profiler. Locate the mounting holes in the clamp to determine its orientation relative to the frame of the MMP. Place the housing in the clamp and twist it to orient the milled depression to what will be the front face of the clamp. Tighten the clamp and reinstall the clamp/housing assembly. A calibration procedure for the compass that will account for inaccuracies in this installation is discussed in Data Offload, Processing, and Interpretation.

The ACM communications and power cable should be run from the ACM electronics housing to the ACM connector on the end cap of the controller housing through the central hole in the bottom rib of the frame. Again, the CTD and ACM connectors are physically (and electrically) identical. The cables and connectors have been color coded to avoid confusion.

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[2] The reader may have noticed by now that the MMP is "left handed". For almost all maintenance and bench top operations the MMP should be placed on its right side with the left side up. Remove the port side skin to gain access to the interior. Removing the port skin exposes the cable runs and most of the hardware of interest. These items cannot be easily reached from the right side. Placing the profiler on its right side will also prevent the ACM sting from pivoting down, possibly causing damage to the fragile fingers, when the cap screws securing the hinged mounting bracket are released.

The oil filled cable connecting the ACM sting to the ACM electronics is fragile. Care must be taken to prevent damage to the coaxial wires inside the cable, the solder connections at the base of the sting, and the oil seal of the outer tube to the base. Only the manufacturer can repair damage to the cable. NEVER pull on the cable. NEVER introduce a tight bend in the cable.

When installing or removing the sting the cable must be threaded through a narrow slot in the hinged bracket. Do not force the portion of the cable immediately adjacent to the base plate of the sting through the slot. The wires are particularly susceptible to damage through repetitive strains in the vicinity of the solder joints at the base of the sting. Release enough cable from the interior of the profiler, removing the port side skin if necessary, so that it is a portion of the cable at least 15 cm (6") away from the base of the sting that passes through the slot. Squeeze the cable gently with two fingers, aligning the interior wires so that they do not cross over each other, and slide the cable through the slot.

After installing the cable and orienting and securing the sting, the cable should be secured to the hinged bracket with a plastic tie-wrap so that it cannot contact the mooring cable running through the bracket. There is a hole in the corner of the bracket through which the tie-wrap can be run. Be gentle. Do not bend the cable coming from the sting too tightly and try to avoid crimping the outer tube. Run the cable through the slot in the port side skin and along the machined grooves, port side forward, in the frame ribs and spacer posts. Excess cable can be coiled loosely in the volume above the ACM electronics.

Motor Housing and Drive Wheel

The motor is also connected to and powered from the controller housing. The DC brush motor and 46:1 gearbox run in air inside the housing. A cup shaped, high energy, rare earth magnet attached to the output shaft of the gearbox is magnetically coupled to a cylindrical, high energy, rare earth magnet outside the housing. The latter is jacketed in Hasteeloy, a corrosion resistant steel alloy (nickel-chromium-molybdenum), to protect it from the seawater to which it is exposed. The coupling can support more torque than the motor can provide. The available drive torque exceeds the torque that can be applied by the mooring cable without slip. The cylindrical magnet is connected to the shaft of the drive wheel.

The components of the drive wheel are machined from titanium and PBT (polybutylene terephthalate, a polyester). The portion of the drive surface in contact with the mooring cable is coated with urethane. The urethane has favorable wear properties and increases the level of torque that can be applied by the motor without slip. The practical endurance of the urethane is in excess of one million meters, but is not precisely known. Operators should inspect the urethane for visible wear after each deployment and have the drive wheel resurfaced or replaced by MRL when necessary.

The drive motor assembly is suspended from the frame in a UHMW bracket. The pivoting bracket has two rotational degrees of freedom, giving the wheel the ability to pass over small obstructions on the mooring cable. The drive wheel is pulled against the cable by a spring. Frictional coupling to the cable is sufficient to propel the MMP against a static load of several pounds (several thousand grams). The actual load limit depends on local environmental conditions and can be variable.

It is important that a minimum tension of 500 lbs is maintained in the mooring cable. When the tension drops the deviation of the cable path increases, allowing the spring to shorten. That reduces the frictional coupling between the drive wheel and reduces the lift capacity of the MMP. This can become important at the extreme ends of a profile where the differing compressibilities of the profiler and seawater make the MMP buoyant or heavy. The profiler is normally ballasted to be neutrally buoyant at the mid-point of the profile. See the discussion under Ballasting the MMP for further information.

It is worth mentioning here that profiling tends to keep the mooring clear of bio-fouling by periodically scouring the cable. However, drifting organic or man made detritus can get caught on the mooring; this is most likely at the time of launch. The design of the drive train makes it extremely resistant to fouling. Additionally, the drive and frictional coupling are robust enough to continue profiling when fouling does occur (see Morrison, et al., 2001).

Other Components of the Drive Train

Guide wheels for the cable are located next to each of the cable retainers. The wheels are machined from an internally lubricated thermoplastic polyester, which is dimensionally stable, provides strong resistance to wear, and has a low coefficient of friction. The guide wheels rotate freely on bearing races with polyamide-imide balls, which have high compressive strength and low rolling friction.

The mooring cable itself is a standard marine cable with a steel core and a polyethylene jacket. The diameter of the steel wire can range from 3/16" (4.76 mm) to 5/16" (7.94 mm). The corresponding outside diameter of the jacketed cable then ranges from 1/4" (6.35 mm) to 3/8" (9.53 mm). Smaller cables cannot support the 500 lbs minimum mooring tension that the system requires. Larger cables will not fit in the contoured drive surface of the drive wheel, significantly reducing the lift capacity of the profiler (see the discussion under Motor Housing and Drive Wheel). In cases where larger diameter wires are required to meet anticipated mooring loads, the standard drive wheel should be replaced with a custom wheel that has been machined to fit the heavier cable.

Transponder

The transponder is an optional component of the system. The transponder allows an operator to remotely verify system operation. By ranging on the transponder from the deploying vessel the operator can verify that the MMP is profiling on schedule before leaving the mooring station.

The transponder circuit boards are located inside the controller housing. The transponder is powered by a set of premium grade, 9 V, alkaline batteries, and draws no power from the main lithium battery pack of the MMP. Electrically, the two systems share only a common ground and a pair of digital I/O lines (see System Architecture). The transponder electronics have an on/off switch if the operator wishes to disable them (to stop the annoyingly loud pinging during bench testing, for example). The switch is located on a corner of the circuit board close to the end cap of the controller housing. The "ON" position is marked on the circuit board. The transponder can also be disabled by disconnecting all eight of the 9 V alkaline batteries. This should be done by disconnecting the two in-line connectors in the wiring harness, leaving the batteries in place. If the batteries are removed the ballast weights must be adjusted before deploying the profiler (see Ballasting the MMP).

The transponder's transducer assembly is mounted on the top rib of the frame, aft of the upper glass sphere. It does not require any maintenance beyond rinsing with fresh water after a deployment. The top faired end cap must be removed to gain access to the transducer. Such access is seldom necessary and is not recommended unless some repair operation, such as replacement of the upper sphere, makes it necessary. To remove the fairing, unscrew the flat-head nylon bolts securing the edge of the end cap to the top rib. Once the end cap is released the upper glass sphere is free to roll. Exercise caution.

The transducer assembly consists of a 316 stainless steel plate and band clamp, an oil filled neoprene boot containing the transducer, and an exposed silicon-bronze bolt. The transponder cable should be run through the holes in the top three ribs and over the gap in the fourth rib created by the upper mounting clamp for the controller housing. From this point run the cable under the port side frame post and through the large hole in the bottom rib to the controller end cap. Excess cable can be loosely coiled in the volume above the bottom rib.

Cleaning and Maintenance

Thoroughly and completely rinsing the MMP with fresh water immediately after recovery is the single most important maintenance procedure the operator can conduct to extend system life and prevent avoidable problems. Shipboard constraints on water usage may limit the operator to spraying the interior and exterior with a hose. With care and attention to o-ring seals in the lab, this will generally be sufficient. However, complete immersion in fresh water is preferable. Warm water, warm water with soap or mild detergent added, and some agitation and manual swabbing are appropriate ways to enhance the removal of salt and other substances. Common soaps and detergents will damage none of the materials from which the MMP is fabricated. When in doubt, consult the Manufacturer's Safety Data Sheet (MSDS) for incompatibilities. The table below lists the materials used.

Frame	ultra high molecular weight polyethylene (UHMW)
Skin	medium density polyethylene
Mounting posts	316 stainless steel
Housings	titanium
Spheres	borosilicate glass
Cable jackets	neoprene, polyvinyl chloride
Connectors	glass reinforced epoxy
Hardware	nylon, 316 stainless steel
Magnetic coupling	Hasteeloy (outer coating)
Drive wheel	urethane, PBT, titanium
Guide wheels	thermoplastic polyester
Bearings	polyamide-imide
Transducer	neoprene, 316 stainless steel, silicon-bronze

The concern with fresh water rinsing is not primarily corrosion prevention. With the exception of a few pieces of stainless steel hardware, none of the exposed materials is a corrosion risk. The concern is the formation and expansion of salt crystals as the seawater evaporates and leaves a salty residue. Crystal formation on o-rings or o-ring sealing surfaces, for example, can result in temporary, potentially catastrophic, leaks at the beginning of a subsequent deployment. The crystals do not dissolve immediately and so act like pieces of grit or sand that have not been removed from an o-ring. Other modes of damage are possible. The ambient pressure at the bottom of a normal MMP profile virtually guarantees that salt will have fully penetrated all crevices.

Several maintenance procedures, primarily visual and tactile inspections, are described in the preceding text and in the paragraphs below. Those procedures that require regular attention are (1) o-ring lubrication and inspection, (2) bulkhead and cable connector lubrication and inspection, (3) stainless steel hardware inspection, and (4) glass sphere inspection. "Regular attention", as used here, means "before every deployment, after every recovery, before every placement in storage, and after every return from storage". O-ring, connector, and hardware maintenance are described in greater detail below.

O-Rings

Both ends of the controller housing are sealed with face and radial o-rings. The radial o-ring is supported, on its low-pressure side, by a back-up ring. The back-up ring is oriented to present its concave side to the radial o-ring. The other three sides, seen in cross-section, are flat. The motor housing is also sealed with a radial o-ring and a back-up ring. Spare o-rings are included in the tool kit. Part numbers are given in the table below:

Controller	Face	2-256, BUNA-N, 70 durometer
	Radial	2-253, BUNA-N, 70 durometer
	Back-up	8-253, BUNA-N, 90 durometer
Motor	Radial	2-146, BUNA-N, 70 durometer
	Back-up	8-146, BUNA-N, 90 durometer

O-rings should be checked for damage, wear, and foreign material before and after every deployment. The inspection should be both visually and tactile. Fingers are more sensitive to the presence of bumps, grit, and hair than are eyes. Eyes will pick up the presence of small cracks if the o-ring is gently and lightly stretched. The o-rings should periodically be removed for detailed inspection and replaced if necessary. Take this opportunity to inspect and clean the o-ring grooves. Always check the position of the o-rings when sealing a pressure housing, making sure that they stay in position as the end cap is inserted into the cylinder.

A thin coating of o-ring lubricant should be applied to the o-rings when they are installed. The coating must be renewed regularly. MRL recommends the use of Parker O-Lube, a barium based grease made by Parker Seals, for use with pressure housing o-rings. O-Lube is environmentally safe and can be cleaned up with soap or mild detergent. Use the grease intelligently. The seal is not improved by quantity, but by light, even coverage.

A failure to properly maintain the o-rings will result in flooding of the housing and probable destruction of its contents. The combination of face and radial seals in a cylindrical housing was chosen because it is robust and forgiving. However, the seals cannot be neglected indefinitely by the operator without cost.

Connectors

The bulkhead connectors, with the exception of the connector on the motor housing, are fabricated from glass reinforced epoxy. The motor connector is neoprene. All of the connectors are threaded into their end caps and sealed with o-rings. These are long-term seals and do not require regular inspection as long as the connectors and end caps are thoroughly rinsed/soaked in fresh water after recovery.

The pins and bodies of the bulkhead connectors and the sockets and cowls of the cable connectors must be regularly inspected, cleaned, and greased to prevent leaks. The intrusion of seawater into a connector can rapidly lead to the destruction of a pin, through forced galvanic corrosion, with subsequent flooding of the interior of the pressure housing.

Connectors that are regularly connected and disconnected, such as those on the end cap of the controller housing, require regular maintenance. This is particularly true of the communications cable, bulkhead connector, and dummy plug. A thin coating of grease should be applied to all contact surfaces, including pins, sockets, cowls, and bodies. MRL recommends Dow-Corning 55, an o-ring lubricant, for this purpose. Silicon based dielectric pastes such as Dow-Corning 4 or Dow-Corning 5 are also suitable. All of these lubricants are environmentally safe and can be cleaned up with soap or mild detergent. Similar to the o-rings, the quality of the seal is enhanced by a thin, even coating, not the application of large quantities of lubricant.

Properly maintained connectors will commonly trap a small quantity of air as they are mated. The air can cause problems and should be removed before tightening the plastic locking shell. To remove the air, place the fingers of one hand around the top of the cowl and slide them towards the bulkhead connector while squeezing. An audible "burp" as the air escapes indicates success.

All of the cables and connectors are keyed to indicate the correct relative orientation. The "thumb bump" on the outside of the cable connector cowl should always be aligned with the thick pin (or socket) on the bulkhead connector. If the connectors are not properly aligned they can still, with difficulty, be forced together. To do so will, in general, permanently damage the socket that receives the thick pin. If the circuit is subsequently energized, the electronics, the peripheral component, or both may be damaged or destroyed. The operator ignores the connector alignment indicators at his or her peril.

Nylon and Stainless Steel Hardware

Nylon hardware is used at many points in the MMP because it is light and reasonably strong. Further, nylon hardware will not corrode and requires no maintenance beyond fresh water rinsing after recovery. However, nylon is not as robust as stainless steel, and particular care must be taken to avoid over-tightening nylon hardware. The threads are easily stripped and the heads of screws and bolts can, and occasionally do, twist off the shaft when excessive torque is applied. Fortunately, nylon is easily drilled out and there are spare screws and bolts in the tool kit. Operators should observe the simple rule: when it is firmly tight (or when the lock washer is flat), STOP TURNING! The extra quarter or half twist "just to be sure" that can be applied to metal hardware is not appropriate with nylon.

Two additional caveats pertain particularly to the MMP. First, nylon absorbs water when it is immersed. The nylon will swell slightly when this happens. This means screws and bolts will be tighter when the MMP is recovered than when it was launched. This is another reason to avoid over-tightening. Also, operators must exercise caution and patience removing nylon screws and bolts after recovery. The swollen screws and bolts will respond to a slow, steady application of torque. Do not force them. Second, the flat head bolts that secure the skin of the MMP will pull right through the skin if they are over-tightened. Exercise appropriate caution and patience. Do not over-tighten.

The socket head cap screws securing the controller and motor housing end caps are 316 stainless steel. They are more robust than the nylon hardware, but they should still not be over-tightened. Over-tightening will not improve the o-ring seal and it may twist the head off the shaft of the screw. Unlike nylon, stainless steel is not easily drilled out. There are spare screws in the tool kit.

A thin coating of non-metal, anti-seize, thread compound should be applied to the screws before they are threaded into the titanium pressure housing. Anti-seize compound prevents the formation of micro-welds, which make removing the screw difficult or impossible. This is a common problem when two similar metals are threaded together.[3] MRL uses and recommends Lub-O-Seal's NM-91 non-metal anti-seize thread compound for the MMP controller and motor housings. The compound is good for a number of threading cycles, but should eventually be renewed. A visual inspection before each deployment is recommended. A drop spread on the threads of the screw is sufficient. NM-91 is environmentally safe and can be cleaned up with soap or mild detergent.

The screws of the controller housing end cap should be tightened in a repetitive circular pattern, with no more than a half to a full turn of each screw after it catches the end cap before moving on to the next screw in the pattern. This procedure will keep the end cap aligned as the screws pull it into the pressure housing. Always visually check that wires are not caught between the end cap and the cylinder. Always check the o-rings with both fingers and eyes to make sure they are properly positioned and greased, that they are free of grit, hair, breaks, bumps, and creases, and that they stay in place as the end cap is pulled into the pressure housing.

Shipping and Storage

The Shipping Crate

The MMP shipping crate is a fitted, reusable, international freight container. The crate is intended for both shipping and storage of the profiler. It meets the requirements for transport by overland, ocean, or air freight carriers. You should regard it as part of the profiler system.

The lid of the crate is secured in place by several spring clamps and a number of marked screws. Remove the screws and clamps and lift the lid to reach the profiler. The crate includes a fitted support base with built-in skids for freight handling equipment. The interior is lined with 1" of high-density packing foam for added protection. A fitted cradle supports the body of the profiler and the sting of the ACM is packed in foam rubber or bubble wrap. There is room in the interior for the MMP, the tool kit, and a supply of spare parts.

Do not disassemble the profiler for shipping or storage. Leave the components of the MMP firmly secured to the frame. This is the best way to prevent damage during handling. The exceptions to this rule are the batteries, which are described below, and sting of the ACM. The sting should be unbolted from the hinged bracket before placing the MMP into the shipping crate. The sting will fit in the crate next to the top section of the profiler. Slide as much of the oil filled cable out from the interior of the profiler as is necessary. Surround the sting with ample padding to prevent shaking movement. Make sure that the fingers are not subjected to lateral mechanical stresses when the crate is closed.

MRL strongly recommends that you do not discard or destroy the shipping crate. It will enable you to safely and conveniently store and transport the profiler many times.

[3] The type of compound used depends on the two metals in question. For example, o-ring grease or Aqua-Lube can be used with stainless steel bolts and aluminum pressure housings. Make sure that any replacement cap screws used with the titanium housings of the MMP are 316 stainless steel. Contact MRL for additional spares if necessary.

Batteries

The alkaline batteries that power the transponder should, at a minimum, be disconnected during shipping. The individual batteries can be disconnected from their sockets or the two in-line connectors in the wiring harness can be opened. While disconnection is sufficient, MRL strongly recommends removing the batteries from the controller housing and transporting them in the tool kit. Wrap the batteries in non-conductive plastic or tape the contacts to prevent discharge.

We recommend shipping the batteries disconnected and outside the housing based on experience. We have, on numerous occasions, received equipment shipped to us with connected batteries. In several instances, long delays, accidents during shipping or problems in the electronics have fully drained the batteries during transport. This has resulted, on several occasions, in the release of hydrogen gas at high pressure into the sealed pressure housing. Fortunately, we take precautions opening any sealed housing. On a number of other occasions the discharged batteries have released their internal chemical components to the severe detriment of the electronics they formerly powered. Take the batteries out before shipping!

We would make the same recommendation for the lithium battery, however, legal restrictions associated with shipping lithium make that recommendation moot. See below for information about shipping the lithium battery pack.

Storage

If the MMP is to be stored unused for more than a month, first make sure that any data stored on the flash card have been properly archived. Then remove all batteries from the controller housing (main lithium battery pack, eight 9 V alkaline batteries). Check the o-rings, reassemble the housing, and perform any necessary maintenance procedures, including a fresh water rinse. Place the profiler in the shipping container. Storage facility temperatures between 0°C and 40°C are recommended. Temperatures outside this range will generally not cause damage, but the profiler should be allowed to return to the ocean normal range before testing and use. Damage to the profiler may result if temperatures drop below 0°C and water is still present in crevices or seals.

If the main battery is not fully discharged, cover the connector with insulating tape and store the battery in a cool environment. A refrigerator is not inappropriate; lower temperatures prolong shelf life, though the battery should not be frozen. The battery should never be exposed to temperatures in excess of 93°C. Keeping the battery within the 0°C and 40°C storage temperature range of the MMP is recommended. If the main battery is fully discharged it should be disposed of in accordance with local safety and environmental regulations.

Lithium Battery Pack

The MMP is powered by a high-capacity lithium battery pack.[4] Twenty-four double-D cells are assembled in two layers inside the pack. Electrically the pack is arranged in eight parallel stacks of three cells in series. The nominal delivered voltage is 10.8 V. A new battery will briefly deliver 11.6 V or more before dropping to a stable 10.8 V for most of its usable life. The nominal energy capacity of the battery is 240 Ahr. Field use indicates this is a mildly conservative value and can reasonably be used for the calculation of system endurance (see Morrison, et al., 2001).

It is important to note that shipping regulations, both US and international, prohibit transport, by any means, of the MMP with the main lithium battery installed in the pressure housing or otherwise contained in the MMP shipping crate. <u>The lithium battery must be shipped separately.</u> The quantity of lithium in the battery pack qualifies it as a Class 9 hazardous substance as defined by United States Department of Transportation Regulations under the heading Miscellaneous Hazardous Substances. The applicable international regulation is United Nations UN3090, which pertains to liquid cathode lithium batteries. Further local and national regulations may apply in countries outside the United States.

The battery must be shipped in an approved and properly marked container. The box in which it is shipped to you by MRL is such a container and can be re-used. That box is, in fact, the container in which the battery manufacturer shipped the battery to MRL. Contact MRL if you require assistance.

MMP Electronics

A line drawing of the MMP controller electronics is shown below. The controller is a three board stack mounted on one of the chassis plates that connect the controller housing end cap to the cage holding the main battery. The transponder electronics are mounted on the other chassis plate. The transponder batteries are mounted on the outside surfaces of the two plates.

The reader is encouraged to remove the end cap, battery, and electronics assembly from the controller housing for this discussion. You should locate each of the components and connectors identified in the drawing and accompanying text. Take standard electrostatic discharge (ESD) precautions when handling the MMP electronics. These include use of grounded wrist or ankle straps and grounded ESD mats. Handle boards by their edges, avoiding contact with the components. Never pass electronics directly to another person; you are almost certainly at different electrostatic potentials. Ground yourself by touching the ESD mat and place the electronics on the mat while maintaining contact. Then the other person can ground themselves and safely pick up the electronics.[5]

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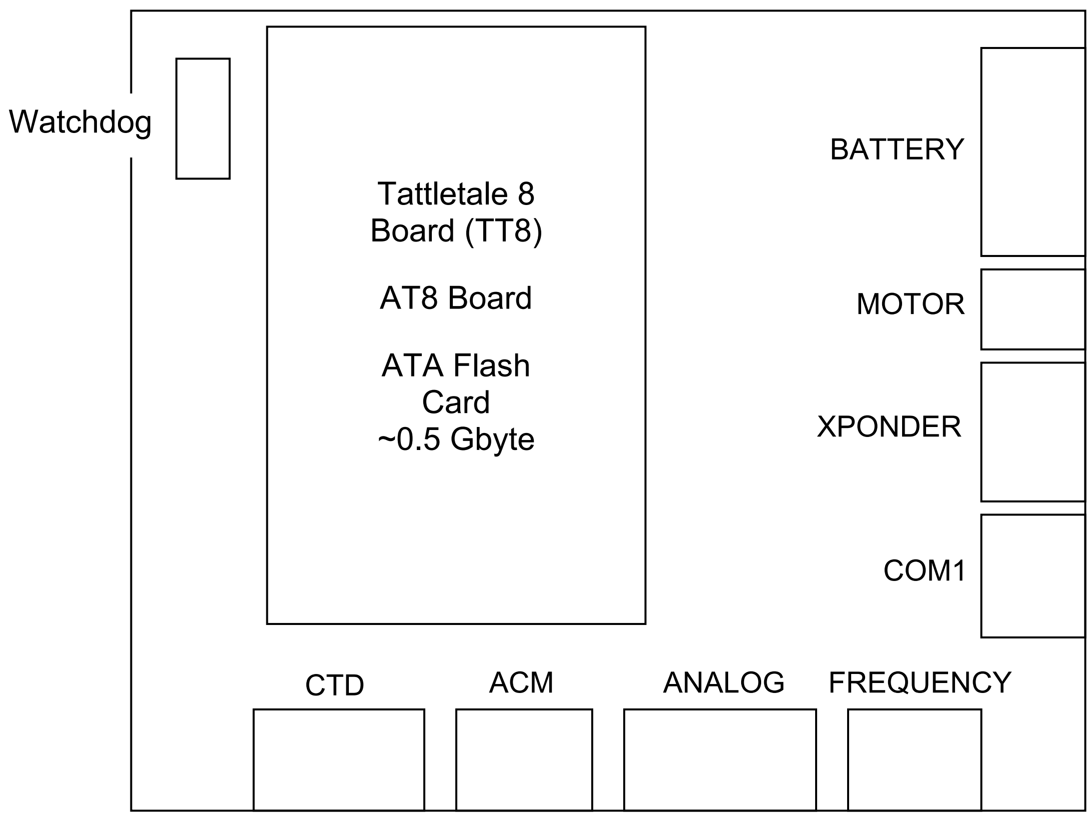
[4] The transponder is independently powered by a set of eight 9 V alkaline batteries. The two power sources share a common ground.

[5] Damage attributable to static discharge has not been a notable problem with the MMP at MRL and it may be reasonably argued that these procedures are overly cautious. Even we don't always use wrist straps, but we are very good about the other precautions. It has also been observed that the author of this manual is not an entirely reasonable individual on some topics. This is one of them. He is the one you will be calling for help if you let the smoke out of the electronics. He recommends these precautions. Even the wrist strap if the environment is dry. It's your call.

MMP Controller Electronics



The Controller Electronics Stack

The top circuit board in the controller stack is an AT8 (PERAT8V2I), a product of Persistor Instruments, Inc. (PII, www.persistor.com), Bourne, Massachusetts, USA. The AT8 is configured to support a full size flash card (PCMCIA ATA) and works with PII's PicoDOS software, which runs on the TT8 micro-controller described below, to provide the profiler with a robust, non-volatile, and DOS/Windows compatible file system. The capacity of the installed flash card is approximately 0.5 Gbyte.[6] To assure reliability, PII and MRL strongly recommend that you use only type SDP3B SanDisk FlashDisk PCMCIA ATA flash cards with the MMP. PII has indicated to us that other brands and SanDisk cards other than type SDP3B are not as reliable and/or require more power. There have been no problems with the SDP3B cards. MRL can procure appropriate cards for you or suggest a SanDisk distributor. The flash card provides non-volatile, solid-state storage for sensor and engineering data, deployment definition and status information, and the MMP's system control program (SCP).

The largely hidden middle board in the controller stack is a TattleTale 8 (TT8) micro-controller, a product of the Onset Computer Corporation (www.onsetcomp.com), Pocassett, Massachusetts, USA. The TT8 is a powerful, single board computer. It has a large and varied I/O capacity and supervises the operation of the MMP hardware under the direction of the SCP. The SCP was developed at MRL. Future revisions with enhanced deployment capabilities are planned and will be available at no charge to customers with earlier versions.

[6] 440 Mbyte is typical. However, as of October 2001, those cards were being phased out by manufacturers and replaced with 512 Mbyte cards. The standard sensor suite generates approximately 220 Mbyte of data per million meters of travel. The endurance limit of the profiler is currently 1 to 1.2 million meters.

The 10 cm × 12 cm (4.0" × 4.75") board at the bottom of the controller stack is the motherboard of the moored profiler. The motherboard was designed and built at MRL. It supports interface ports for peripheral components, a power distribution network, and an independent system watchdog circuit. The watchdog chip is shown in the line drawing. The super capacitor that provides the watchdog with a temporary (several days) independent power source is located on the underside of the motherboard. The function of the watchdog will be discussed at greater length in the System Architecture and User Interface sections of this manual.

Edge Connectors

Peripheral components like the motor and sensors connect to the controller through the black edge connectors indicated and labeled in the drawing. The connectors are also labeled on the motherboard. Each edge connector has a unique number of pins and is keyed to prevent accidental misconnection by the operator. The reader is encouraged to locate and identify these connectors on the motherboard now. You will observe that most have connectors from the wiring harness currently inserted. The harness connectors lock in position when they are fully inserted.

The wiring harness can be traced back by hand from the CTD, ACM, COM1, and MOTOR edge connectors to the corresponding bulkhead connectors on the end cap. The XPONDER (transponder) connector can be traced to the transponder electronics stack. The BATTERY connector can be traced to the main battery when it is connected. The ANALOG and FREQUENCY connectors are normally empty, but can be traced to additional instruments if the sensor suite has been expanded.

The CTD and ACM ports provide switched power and an RS-232 serial connection for those sensors. Power and communications are controlled by the TT8 under the direction of the SCP. COM1 is a three wire RS-232 port for communication with the operator's PC. The XPONDER connector includes a pair of logic level digital I/O lines and the common electrical ground shared by the MMP and transponder electronics.

MOTOR is the output of a standard H-switch and provides a directional drive voltage to the DC brush motor. The control logic and the TT8 can also pulse width modulate (PWM) the drive voltage to control motor speed. The drive circuit is designed in anticipation of the back EMF voltages that are generated when the motor is driven by the mooring during launch and recovery operations and during storms. The resulting electrical currents are absorbed through voltage limiting shunt components that can dissipate several watts. The motor and drive circuit are also untroubled by the occurrence of stall or stick-slip behavior. These may occur during launch and recovery operations or if the MMP encounters an obstruction during a profile. Operators do not need to worry about these sorts of events nor should they go to any length to prevent them.

The ANALOG and FREQUENCY connectors are provided for future expansion of the sensor suite. These ports are configured to accept a wide variety of oceanographic sensors with analog and frequency outputs. Switched power, digital I/O, and several types of serial interface (SPI, RS-232, RS-485) are also available on the connectors to support future expansion. Interface characteristics will be discussed further in System Architecture.

Although the connectors do lock when fully inserted, manually verifying that the connectors are engaged and locked before a deployment is a reasonable and recommended precaution. Operators should be aware that, over time, a thin layer of particles and oils will accumulate on the contact surfaces of the connectors. An oxide layer may also develop. Both will interfere with smooth electrical operation. The layers can be easily removed by "exercising" the connectors (several cycles of disconnecting and reinserting) or with commercially available cleaning sprays for electrical contacts. These sorts of problems normally take five or more years to develop, but the actual time depends on connector design, environmental conditions, general use patterns, and maintenance.

Connecting the Main Battery

Inserting the connector from the main battery into the BATTERY port on the motherboard will start the TT8 micro-controller and begin execution of the system control program. This is both the appropriate way and the only way to turn the system on and off. Operators should always try to return the user interface to the Main Menu (see User Interface below) before disconnecting the power. This is akin to running the shut down procedure on a PC before powering down in that it allows the system to protect the integrity of the file system and the hardware.

The operator should always have the PC booted, the communications software running, and the communications cable connected before inserting the battery connector and beginning execution of the SCP. The subsequent interaction of the operator and the system is described in the User Interface.

Ballasting the MMP

Accurate ballasting is absolutely essential for a successful deployment. The lift capacity of the MMP is limited by the strength of the coupling between the drive wheel and the mooring cable. Ballasting errors of a few pounds will trap the profiler against one of the stops for the duration of the deployment. Data will be returned by the system, but it will all be from a single depth.

Accurate ballasting requires precise measurements of the air weight of the MMP and the water weight of the MMP in water of some known density. Ballasting also requires knowledge of the effective compressibility of the profiler and the dependence of profiler density on temperature. With those four numbers available, the required weight of lead ballast can be calculated for a particular deployment if the density, pressure, and temperature of the water at the mid-point of the planned profile are known. (N.B. It is the *in situ* quantities that are required, not the potential density or the potential temperature.)

The compressibility of the MMP was originally estimated based on material constants. That estimate has been (and continues to be) refined using field data and is now reasonably well known. An empirical correction that accounts for the remaining uncertainty is part of the ballast calculation. The air and reference water weights of each profiler we manufacture are measured in our laboratory and provided to the customer on a ballast sheet at the time of delivery. If the configuration of the MMP is not changed, these values do not need to be measured again. MRL also calculates and attaches an appropriate quantity of lead ballast for the first planned deployment. The calculation is based on *in situ* density and pressure information supplied by the customer. The ballast sheet documents the measurements and illustrates the calculation.

A sample ballast sheet, with archival data from a profiler shipped in February of 2001, is shown below. While you may never need to make the air and water weight measurements, we have included a complete description here so that you will have a clear understanding of the process and also some knowledge of the accuracy requirements and known pitfalls should you ever need to make the measurements yourself.

Determining Air and Water Weights

The air weight should be measured on a scale with an accuracy of 1 gram (1 g). Electronic scales with this level of accuracy and a dynamic range that includes the 70 kg weight of the profiler are commercially available. If such a scale is not available to you, the profiler can be disassembled, the individual parts weighed, and the results added. As long as the accuracy requirement is met, there are no unexpected pitfalls in determining the air weight.

There are two serious pitfalls associated with measuring the water weight. The first problem is bubble formation on the exposed surfaces of the MMP. The bubbles form around microscopic irregularities in the skin of the MMP and are fed by the dissolved gases present in the water.[7] In our experience a continuous sheet of bubbles coats the MMP within a few minutes of immersion. The bubbles add a significant amount of buoyancy to the profiler and invalidate the measurement.

To prevent bubble formation, which can only take place within a meter or two of the surface, we suspend each profiler near the bottom of the 17 meter deep McLane test well. A length of nylon monofilament (fishing line, 40 lb test[8]) connects the MMP to a triple beam laboratory balance mounted above the well. The balance has an accuracy of approximately 0.1 g. The weight of the monofilament is entirely negligible. With this arrangement and the controlled conditions of our well we can make a very precise measurement of the reference water weight of each profiler.

Obviously a well or tank of sufficient depth is not commonly available. However, the bubble problem is real and significant and must be addressed any time a measurement of water weight is made. Working off a dock may be the only practical approach available to most operators. The uncontrolled motion of the water will complicate the measurement, but it can be done. Re-configured profilers can, of course, be shipped to MRL, where our personnel can make the measurement under controlled conditions.

The second problem is more subtle, but also more easily solved. The density of the MMP has a distinct temperature dependence. We commonly observe substantial changes in water weight, as measured by the triple beam balance, when a profiler is first immersed in our test well. A plot of these changes over a five hour period is shown below. The curve is a classic exponential response to a step change in temperature. In this case the water temperature was approximately 18°C and the air temperature, with which the MMP was originally in thermal equilibrium, was approximately 25°C. The ultimate change in weight was approximately 40 g (out of a total mass of ~70000 g) or 6 g/°C. The time constant for the process is approximately two hours.

To allow for complete temperature equilibration we leave profilers suspended at the bottom of the test well for a minimum of ten hours (4 to 5 time constants), generally overnight, before recording their water weight as measured with the triple beam balance.

[7] The bubbles that stream to the surface from nucleation points on the glass in a mug of beer, a flute of champagne, or some other carbonated beverage are a familiar example of the same phenomenon.
[8] We used 20 lb test until we temporarily misplaced a profiler while lowering it to the bottom of the well. The author of this manual, who is a certified research diver and a similarly certified colleague, recovered the profiler a few days later. There was no damage. Now we use 40 lb test.

Deployment (Neutral) Pressure: 4000 db	Ballast By: February 16, 2001
Deployment (Neutral) Temperature: 2.1956667 °C	Date: February 15, 2001
Deployment (Neutral) Salinity: 34.909333 pss	MMP S/N: ML00414-42
Deployment (Neutral) Density: 1.0459119 g/cc	MMP Electronics S/N: ____________
Deployment Site: _________Lat_________Lon	CTD S/N: ______________________
Deployment Date: ______________________	ACM S/N: ______________________
Recovery Date: ________________________	Transponder freq.: _______________ KHz

1. MMP air weight [Use scale with a 10 gram accuracy]	70135	g
2. Tare water weight (See note 1) [Use scale with a 1 gram accuracy]	1008	g
3. Hang the tare weight on the bottom of the MMP and place them in the ballast tank to obtain their total water weight. [Use scale with a 1 gram accuracy]	751	g
4. MMP water weight (item 3 – item 2)	-257	g
5. Ballast tank water temperature	18	°C
6. Water density from the attached table	0.998625	g/cc
7. MMP volume (item 1- item 4)/(item 6)	70488.92227	cc
8. MMP compressibility constant	0.300	cc/db
9. MMP volume change @ deployment pressure (item 8 * deployment pressure)	1200	cc
10. MMP volume @ deployment pressure (item 7 – item 9)	69288.92227	cc
11. MMP volume temperature correction constant	6.00	cc/°C

12. Temperature difference (item 5 – deployment temperature)	15.8043333	°C
13. MMP volume change @ deployment temperature (item 11 * item 12)	94.8259998	cc
14. MMP volume @ deployment temp & pressure (item 10 – item 13)	69194.09627	cc
15. Deployment density @ deployment pressure	1.0459119	g/cc
16. Calculated air weight so that the MMP is neutral at the deployment pressure. (item 14 * item 15)	72370.9287	g
17. Weight difference (item 16 – item 1)	2235.9287	g
18a. If an internal weight, a weight placed in a pressure housing, was used to ballast, the ballast air weight = (item 17) See note 2.		g
18b. If an external weight was used to ballast, the ballast water weight = (item 17) See note 2.	2236*	g

Note 1: Usually an external tare weight is required to completely submerge the MMP to obtain its water weight in the fresh water ballast tank. If one is required, enter its water weight in item 2, if no weight is required to completely submerge the MMP, enter 0 in item 2.

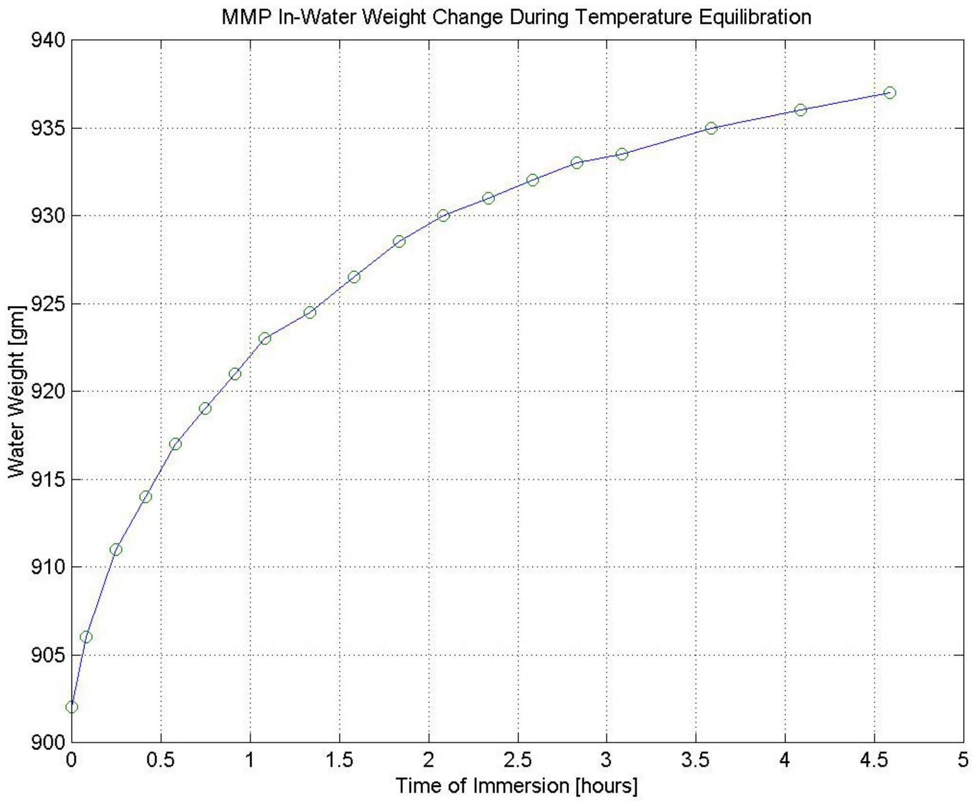
Note 2: If the answer is positive the weight must be added, and conversely, if the answer is negative the weight must be removed.

* Adjustment for uncertainty in the MMP compressibility constant (item 8):

Subtract 128 g

Final ballast: Add 2108 g of lead

Ballasted for lithium battery pack



Filling Out the Ballast Sheet[9]

We begin a ballast sheet by entering the *in situ* pressure, temperature, salinity, and density of water at the planned neutral depth for the deployment. That density may be available directly or it may be calculated, using an equation of state for seawater, from measurements of pressure, temperature, and salinity at the neutral depth. The neutral depth is generally the mid-point of the planned profile. The MMP is less compressible than seawater, so its buoyancy increases as it profiles down and decreases as it profiles up. To avoid exceeding the lift capacity of the profiler at the deep and shallow limits of travel, the aim of the ballast calculation is to make the MMP neutrally buoyant at the mid-point of the profile. Maintaining neutral buoyancy at the mid-point also reduces drive train loses, which increases mission endurance.

The remainder of the ballast sheet, Items 1 to 18, guides the operator through the ballast calculation. The reader should refer to the example ballast sheet during this discussion. Enter the measured air weight of the MMP in Item 1. The MMP is buoyant in fresh water (and seawater), so a lead tare weight is required to fully submerged it for the water weight measurement. A kilogram of lead is generally sufficient. Measure the water weight of the lead tare weight using the triple beam balance and record this in Item 2.

Measure the water weight of the profiler, with the tare weight attached. Have a care for the pitfalls outlined in the previous section. Record the result in Item 3. Subtract the water weight of the tare weight to get the uncorrected water weight of the MMP and record the result in Item 4. This will be a negative number because the profiler is positively buoyant.

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[9] The calculation is described here in full so that the process and the potential problems will be clear. However, an Excel spreadsheet, which performs the necessary calculations as data are entered by the operator, is provided with the software in the tool kit.

The *in situ* density of the reference water should be entered in Item 5. If fresh water is used as a reference, as is done in the MRL tank, the density depends only on temperature. Enter the temperature of the water (measured at the temperature equilibration depth of the MMP, sufficiently deep tanks do exhibit stratification) in Item 5 and the density, from the table provided with the ballast sheet, in Item 6. If the ballasting is done in seawater, measure the pressure, temperature, and salinity of the water (at the time and location of the MMP water weight measurement, the water masses near docks are not constants) and calculate the *in situ* density using an equation of state. Record the measurements and enter the density in Item 6.

Calculate the volume of the MMP. The formula is (Item 1 - Item 4) / Item 6. Physically, this is the mass of the water displaced by the profiler divided by the fluid density. Note that Item 4 is typically negative. For the values entered on the example ballast sheet the calculation is:

$$\frac{70135-(-257)g}{0.998625g/cc}=\frac{70135+257g}{0.998625g/cc}=70488.92227cc$$

The compressibility constant is provided in Item 8. Multiply the compressibility constant by the pressure at the neutral depth (Item 8 × neutral pressure) and enter the result in Item 9. This is the calculated volume change at the planned neutral depth. Subtract the volume change from the reference volume (Item 7 - Item 9) and record the pressure corrected volume in Item 10.

The constant characterizing the dependence of MMP volume (density) on temperature is given in Item 11. Calculate the temperature difference between the reference water and the temperature at the planned neutral depth (Item 5 - neutral temperature) and record the result in Item 12. Then calculate the volume change (temperature constant × temperature difference, Item 11 × Item 12) and record the result in Item 13. Finally, calculate the temperature (and pressure) corrected volume of the profiler, i.e., the volume at the neutral pressure and temperature (Item 10 - Item 13) and record the result in Item 14.

Enter the neutral density in Item 15. The air weight for which the MMP will be neutrally buoyant at the planned neutral depth, neutral volume × neutral density (Item 14 × Item 15), can now be calculated and entered in Item 16. The difference between the required air weight and the actual air weight (Item 16 - Item 1) is the weight of lead that must be attached as ballast for the profiler to be neutrally buoyant at the planned mid-point depth. Record the value in Item 17.

If the tare weight of lead used to sink the profiler for the water weight measurement had been placed inside the pressure housing, Item 17 would be the *air weight* of lead to add to the lead inside the pressure housing. (Item 17 may be negative, indicating that this weight should be removed from the lead in the housing.) Record the air weight, rounded to the nearest gram, as Item 18a. (See Note 1 on the ballast sheet. Internal lead would have increased the value in Item 1, the air weight of the MMP, and set Item 2, the water weight of the tare weight to zero. The rest of the procedure would be the same.)

MRL typically uses an external tare weight, as described in this example, so the value in Item 17, typically positive, is the *water weight* of lead that must be added to the profiler. The lead will be mounted externally. In this case, enter Item 17, rounded to the nearest gram, as Item 18b.

The final calculation is the empirical correction for the remaining uncertainty in the compressibility constant. Subtract 128 g from Item 18a or Item 18b. This weight is the quantity of lead to be added as ballast (removed if the quantity is negative). If an internal tare weight was used, weigh out the *air weight* of lead using the triple beam balance and install the lead inside the pressure housing. If, as in this example, an external tare weight was used, weigh out the *water weight* of lead using the triple beam balance and install the lead outside the pressure housing. Lead disks can be attached with socket head nylon cap screws that thread into holes machined into the bottom rib of the frame. Lead shot, used to trim the ballast, can be placed in a free flooding pouch that is tie-wrapped to the frame.

The ballast sheet calculations must be performed for each new deployment. As long as there has been no physical change in the configuration of the profiler, you will not have to make measurements other than to determine the air or water weight of the lead ballast. Note, however, that changes to the configuration are not limited to additions like autonomous, strap-on sensors. Removing the transponder batteries is a change for which you must account. Fortunately, all that is necessary is an adjustment of the total air weight of the MMP by the air weight of the missing batteries. Similarly, when the main battery pack or the transponder batteries are changed the weight difference (generally negligible, but you should check) should be determined (air weight) and entered in the calculation. Once such adjustments have been made, the calculation requires only that information about the *in situ* pressure, temperature, and density (or salinity) at the neutral depth of the deployment is available.

Launch and Recovery

We provide here a very general overview, with some specific guidance, of MMP launch and recovery operations. The discussion does not purport to be a course in mooring operations; it is a summary of necessary steps that experienced personnel can refer to and modify to fit particular circumstances. Experience and teamwork are absolute prerequisites for safe, successful mooring work. Fortunately, mooring deployment and recovery are regular occurrences on research vessels and the ship's crew, especially the bosun, will normally have considerable experience and expertise on which you can and should draw. Your own knowledge and experience, particularly with regard to the MMP, and the skill of other members of the science team, will also be invaluable. Moorings of any type require a team effort. MRL strongly recommends prior planning of these operations, with participation by all members of the launch and recovery team, before proceeding. This approach will enhance the safety of personnel and equipment and also the probability of success.

Launch

We will assume here a simple mooring with a subsurface float, a single, continuous length of jacketed cable, an acoustic release, and an anchor. Two physical stops with padded bumpers will be mounted on the mooring, some distance above and below the programmed depth limits of the profile. In more complex moorings there may be additional instruments above and/or below the physical stops. We will also assume that the ship has a rear A-frame, a crane, and a selection of winches, blocks, and capstans. Your team may need to modify the outline below to take advantage of available equipment.

First, verify system operability and program the MMP for the deployment as described in the User Interface. Then disconnect the communications cable, attach the dummy plug, and secure the bottom faired end cap. Remove the cable retainers and loosen the mounting of the ACM sting so that the MMP can be attached to the mooring cable. The MMP is ready.

Launch the subsurface float using the crane and begin streaming the mooring cable behind the ship using the winch and a block suspended from the A-frame. Pull cable that has passed through the block onto the deck and attach the top bumper at the intended depth. Stream additional cable and again pull cable that has passed through the block onto the deck.

Lay the cable in place along the front plate of the MMP, making sure the cable is oriented so that the top of the profiler is towards the subsurface float and the bottom of the profiler is towards the block. Secure the MMP to the cable with the cable retainers. Tighten all eight of the socket head nylon cap screws firmly. Pass the cable under the bracket on which the ACM sting is mounted and secure the bracket. Make sure the drive wheel properly engages the cable.

Using the crane and appropriate tag lines, lift the MMP using the loop of rope that extends out of the bottom faired end cap. The rope is installed in the profiler to support this mode of launch. The ends of the rope are secured to the frame of the MMP. Use a slip line or a release to attach the crane to the rope loop. Gradually allow cable that had been pulled onto the deck and attached to the MMP to return to the position it occupied while streaming. The MMP is now supported, upside-down, from the crane and the cable. Use the crane to slide the profiler down the cable and into the water. When the MMP is sufficiently immersed to avoid unnecessary snap loads, release it and recover the crane and tag lines.

Continue to stream cable, attaching the lower bumper at the planned location. Secure the end of the cable to the acoustic release and anchor. Deploy the anchor when the station is reached.

Recovery

Recovery will be a relatively standard operation. Trigger the release and capture one end of the mooring. We will assume initial capture of the subsurface float. Detach the float and run the cable through the A-frame block and onto the winch. When the upper bumper is reached, pull that section of cable onto the deck and remove the bumper. Continue to wind cable onto the winch.

The MMP will be on the tether somewhere between the bumpers. Where depends on the profiling schedule, ballasting accuracy, and whether the tension in the cable after release can sustain some degree of coupling with the drive wheel. The presence of flotation modules below the lower bumper may have a strong effect on coupling. However, the MMP is not buoyant in air and the drive wheel, even with strong coupling, will only sustain a few pounds. Continue to wind the mooring cable onto the winch and, in the absence of severe fouling or entanglement, the profiler must eventually fetch up against the bottom bumper. The bumper will sustain the full flooded weight of the MMP and can be used to lift the vehicle clear of the water. If you recover the bottom of the mooring first, the top bumper can be used to lift the MMP.

Once the MMP has been lifted clear, pull it onto the deck and release it from the tether. The drive motor may be running while you work. It can be safely ignored until you can connect a communications cable to the system and terminate the deployment. Always boot the PC and get the communications software running before connecting the communications cable. Always connect the cable to the PC first and to the MMP last. See the discussions in the User Interface and Operating Crosscut and TattleTerm chapters of the manual for more information.

Move the MMP to a safe location and perform a preliminary fresh water rinse. Focus on the end cap of the controller housing since you will be opening that soon to recover the data. Do not neglect a more thorough rinsing or immersion once the flash card has been recovered and the end cap has been re-installed. Don't forget to recover the rest of the mooring.

III. System Architecture

The system architecture of the McLane Moored Profiler is shown, in cartoon form, on the following page. It may help the reader to refer to this somewhat whimsical representation while reading the description below. Each rectangular box in the diagram can be identified with a component of the system. The arrows between the boxes characterize the interfaces that exist between the components. With the exception of the AT8 board and the flash card, which are the physical components of the file system, all communication and control between the Tattletale 8 and the peripheral components passes through the MMP motherboard.

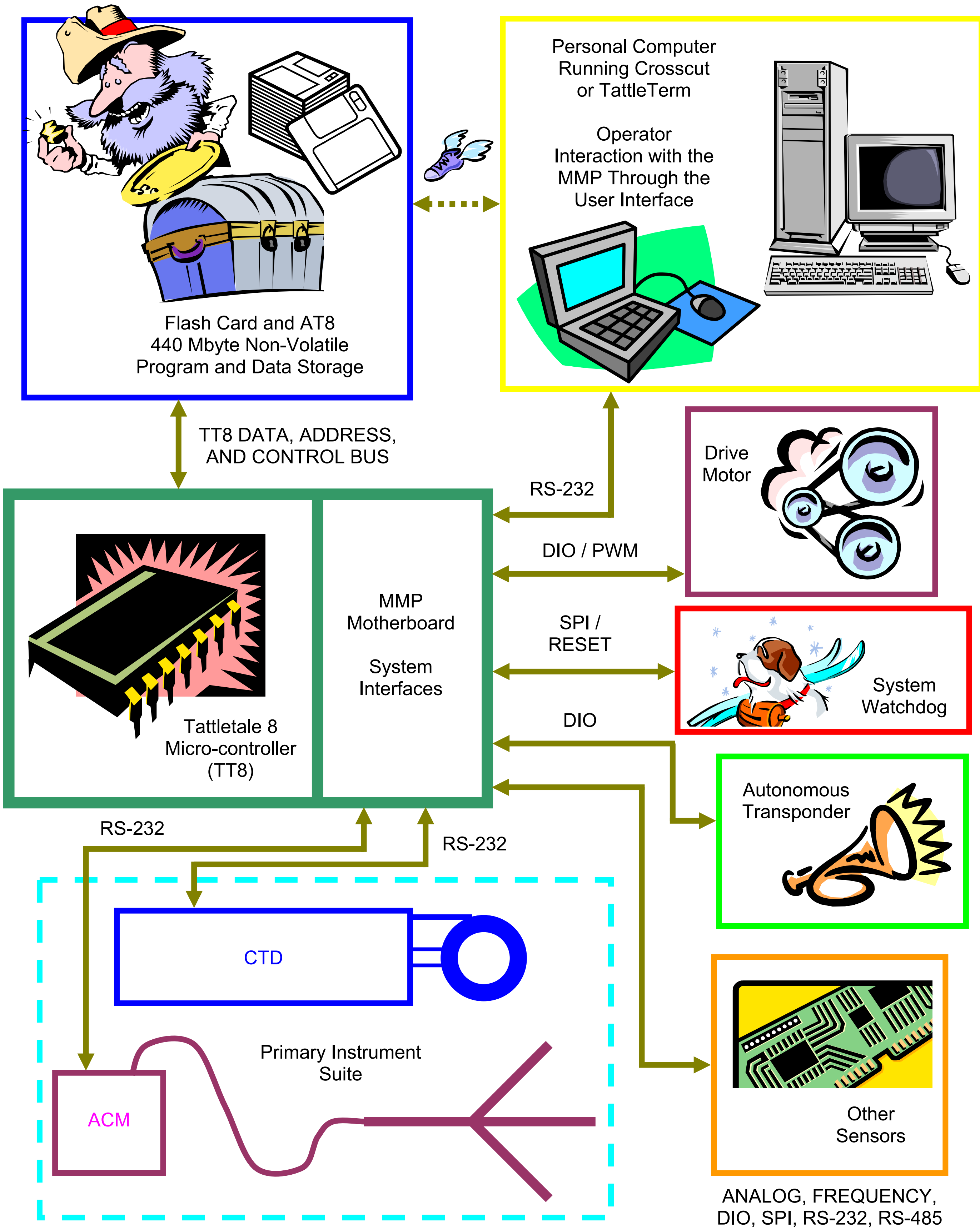
Working familiarity with some technical terms is assumed in the descriptions below. Full understanding of specific terms is not essential, however, achieving a general understanding of the concepts presented will make you a more effective operator. For clarity, we begin with a very brief description of a typical deployment. More detailed information will be presented in the discussion of the User Interface.

During a Deployment

After an operator programs the MMP and initiates the autonomous portion of a deployment, the profiler enters a low power state for a user-specified interval. During that time the launch of the profiler and the setting of the mooring can be completed. The system then conducts the first profile, which is denoted Profile 0. If it is not already there, Profile 0 takes the MMP to the bottom of the programmed range. Subsequent profiles are numbered 1, 2, 3, … and are conducted following the schedule programmed by the operator. Odd numbered profiles proceed from the bottom of the programmed range to the top of the programmed range. Even numbered profiles proceed from top to bottom.

Two minutes before the scheduled start time of each profile the system turns on the sensors and they begin logging data. Profiler motion starts at the scheduled start time. During the profile the sensors log data autonomously and the MMP records engineering and status information. Motion stops when the end of the programmed profiling range is detected. The sensors continue to log internally for two minutes. The system then stops the sensors and transfers their data to the flash card. The intervals of sensor logging before motion begins and after it ends provide data that can be used during post-processing to correct for sensor drift. Other conditions, an obstacle blocking the mooring cable for example, may be detected during a profile and may trigger behavioral changes. A profile is considered complete when the sensor and engineering files have been closed. The system enters the low power sleep state again and waits for the next scheduled profile.

The system will continue to conduct profiles in this manner until the deployment is terminated. Termination by the system will occur if the battery is fully drained or if the flash card or the file system become full. The deployment can also be manually terminated by the operator after recovery.


Flash Card and AT8
440 Mbyte Non-Volatile
Program and Data Storage
Personal Computer
Running Crosscut
or TattleTerm
Operator
Interaction with the
MMP Through the
User Interface
TT8 DATA, ADDRESS,
AND CONTROL BUS
RS-232
Drive
Motor
DIO / PWM
Tattletale 8
Micro-controller
(TT8)
MMP
Motherboard
System
Interfaces
SPI /
RESET
System
Watchdog
DIO
Autonomous
Transponder
RS-232
RS-232
CTD
Primary Instrument
Suite
ACM
Other
Sensors
ANALOG, FREQUENCY,
DIO, SPI, RS-232, RS-485

Tattletale 8 Micro-Controller

The Tattletale 8 (TT8) is the physical brain of the MMP. It is a powerful, single-board micro-controller with significant computational and I/O capabilities. The main processor is a Motorola 68332, a 68000 family CPU with multiple co-processors and I/O modules on a single IC. In addition to the 68332, the TT8 includes a PIC micro-controller serving as a boot manager and programmable real-time clock (RTC), 256 Kbytes of flash memory, 1 Mbyte of RAM, an 8 Kbyte EEPROM, two RS-232 serial communication ports, many flexibly programmable digital I/O channels, and a 12-bit, 8-channel, analog-to-digital converter. A TT8 manual with a complete description can be downloaded from the Onset Computer web site, www.onsetcomp.com.

Two programs, the TOM8 and PicoDOS, are stored in the non-volatile[10] flash memory. The TOM8 (Tiny Onset Monitor for the TT8) is a mini-monitor that oversees the loading and running of system control programs. PicoDOS is the TT8's software link to the AT8 and the flash card. PicoDOS commands called from the MMP SCP or through the PicoDOS operator interface provide access to and control of the file system. PicoDOS manuals can be downloaded from the PII web site, www.persistor.com.

The MMP SCP is, in effect, the operating system of the profiler. The code includes the user interface, communication and control routines for system components, and the logical structure that guides a deployment based on the deployment definition parameters supplied by the operator. Current versions of the SCP are too feature rich (too large) for the unused portion of the flash memory. For this reason the installed version of the code is stored on the flash card (non-volatile) and loaded into the RAM (volatile) whenever power is applied or the system is otherwise rebooted. The transfer of the code is automatic and requires only a small fraction of a second. The code executes in RAM, and has access to information stored in the flash memory, in the EEPROM, and on the flash card.

The EEPROM is used to store the serial number of each unit, the current odometer and trip meter readings, and a copy of the parameters defining a deployment. The odometer can be used to schedule and track major system maintenance procedures. The trip meter is a monitor of the remaining energy capacity of each battery. A second copy of the deployment definition parameters is stored on the flash card. This is done so that copies travel with both the system and the data. The parameters stored on the flash card are available during data offload, but are not essential to recovery of the sensor or engineering files (see below). The deployment definition parameters stored in the EEPROM preserve the last settings programmed by the operator. The system loads those parameters when power is reapplied, rather than using a set of default parameters supplied by MRL. This feature allows you to preset the MMP for a deployment before going to sea and reduces the risk of unintended changes during training and deployments. The stored parameters are also part of the independent system watchdog feature described below. Each of the copies is treated as a backup copy by the system if the other copy is unavailable.

[10] Non-volatile memory retains information when power is removed. Information stored in non-volatile memory must be erased or over-written to be lost. The flash memory, the EEPROM, and the flash card all provide non-volatile storage. Volatile memory loses stored information when power is removed. Only the RAM is volatile.

AT8 Board and Flash Card

The AT8 board is connected directly to the 110 pin address, data, and control bus of the TT8 (see figure). The flash card plugs into a PCMCIA connector on the AT8 board. The free end of the card is supported on machined nylon washers. The AT8 board and the flash card are the physical components of the MMP's file system. By design, the file system on the flash card is compatible with MS-DOS and MS-Windows. Any PC equipped with an internal or external PCMCIA port and running DOS or some version of Windows can read from and write to the flash card installed on the MMP.

The importance of this feature will be most apparent when archiving data after a deployment. An MMP equipped with a standard instrument suite will collect approximately 220 Mbytes of data during a million meter deployment. Those data are stored on the flash card in a mildly compressed binary form. Spooling that quantity of information, translated into ASCII text, through the 9600 baud communications port of the MMP to the hard disk of your PC will require only slightly less time than it took the MMP to conduct the profiles (several weeks). Transferring the data through the serial port in their binary form is possible, but the process requires repeated human interventions (or a reliable batch file) and only reduces the transfer time by a factor of two to four (a reduction to several days at best).

However, if the flash card itself is moved from the MMP to the PC, as shown by the "sneaker net" link in the figure, the binary data files can be transferred to your hard disk at a rate limited only by bus speed and disk write times. If your PC is more than two to three years old you may have time to get a cup of coffee after starting the transfer. If your PC is newer than that, don't bother getting up.[11] The use of PDP-N_NN.EXE[12], PC executable MRL software to process the binary data files, will be described in Data Offload, Processing, and Interpretation. The fast processor creates ASCII text files that can be read by commercially available numerical analysis and plotting software. It also has a number of useful options not included in the serial processor built into the MMP SCP. Serial transfer of the data is useful during training and bench testing, but we recommend moving the flash card to your PC and directly (and quickly) archiving the raw binary data after a deployment.

It is important to note here that the presence of an actual file system, similar to those found on desktop and laptop computers, imposes some operational requirements on the operator. As in any file system, files must be formally opened for read and write operations. They must also be formally closed to flush buffers and update the file allocation table (FAT). The latter operation protects the data and makes it accessible to the system in the future, during archiving and processing, for example. Just like the operating system on your PC, the MMP SCP performs these housekeeping tasks without troubling the operator. And, just like the operating system on your PC, if you disconnect power without running the shut down procedure you risk corrupting the file system and losing data. Modern PC operating systems include error recovery tools. The MMP does not. To protect the file system, the equivalent of shut down, returning the user interface to the Main Menu, should always be performed before removing power. The flash card should only be removed or installed when the system is not powered or when the "hot swap" utility is being run. More information about these procedures is provided in the description of the User Interface.

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[11] There is a touch of hyperbole in this statement, but only a touch. Moving the flash card to the PC will reduce archiving time by nearly three orders of magnitude, from days or weeks to seconds or minutes. See Data Offload, Processing, and Interpretation for a benchmark with data from a 935,000 meter deployment..

[12] PDP is an acronym for Profiler Data Processor. N_NN is the version number of the SCP running on the MMP when the data were collected. For example, PDP-2_08 is associated with Version MMP-2_08 of the SCP.

Files Stored On the Flash Card

During each profile of a deployment, the system creates and stores three data files on the flash card. Two of these are sensor files, one each for the CTD and the ACM. The data are stored as scaled integers to minimize storage requirements. Each of the three values in a CTD record requires 3 bytes (9 bytes/record). Each of the nine values in an ACM record requires 2 bytes (18 bytes/record). The quantities selected for measurement and storage are discussed below, in User Interface, and in Data Offload, Processing, and Interpretation. The scaling and offset values used to pack and unpack the binary data can be found in the sensor manuals in the tool kit. The binary data processors provided with the MMP normally take care of the translation.

The third data file contains engineering information and all of the time tags associated with a profile. The time tags include, for example, the start and stop times for sensor data and profiler motion. Each engineering record is a time tagged log of battery voltage, motor current, and ambient pressure. The engineering files also record profile termination conditions, encounters with obstructions on the mooring tether, and general status information. The information is stored in a coded binary form to reduce the storage requirement. The contents of the data files will be discussed at greater length in Data Offload, Processing, and Interpretation.

The engineering and sensor files are assigned names of the form XNNNNNNN.DAT, where X is an E, C, or A, identifying the file as engineering, CTD, or ACM data, and NNNNNNN is the profile number, padded with leading zeros (0000000, 0000001, 0000002, …, 0000414, …).

In the course of each deployment, the system also creates and stores three system files on the flash card. The first of these, DEPLOY.DAT, contains the flash card copy of the deployment definition parameters. PROFILES.DAT contains the current profile number. This file is updated with a new value each time the system starts a new profile. The profile count is also used by the independent system watchdog feature described below. The third system file, IRQ_XCPT.LOG, contains a time history of interrupt requests (IRQs) and other exceptions sent to or detected by the TT8 during the deployment. IRQs are generated periodically by the independent system watchdog and aperiodically by the transponder. Other logged exceptions include the creation time of the file, critical handler faults (low level problems detectable by the 68332 CPU, the critical handler places the system in a controlled low power state until it is rebooted by the watchdog), and unattended resets (a reboot by the watchdog after the 68332 CPU "crashes" and fails to acknowledge a watchdog IRQ).

The two remaining files stored on the flash card are AUTOEXEC.BAT and the system control program. AUTOEXEC.BAT is automatically executed by PicoDOS when power is applied to the system or a reboot is executed. The MMP's autoexec calls the SCP, triggering the transfer to RAM and subsequent execution of the program. The MMP SCP is named MMP-N_NN.RUN, where N_NN is the version number, e.g., MMP-2_08.RUN. If either of these files is inadvertently removed from the flash card the MMP will be inoperable. Backup copies are supplied with the MMP. You should archive them on your hard disk and bring copies on every deployment. The files can be emailed to you from MRL, even if you are out at sea. To install them, simply insert the flash card in your PC and copy the files to it using standard DOS or Windows commands. To avoid fragmentation of the file structure on the card, MRL advises reformatting the card before copying the files. Archive all data files before reformatting!

There is one important downside to the DOS/Windows compatibility of the file system. DOS and Windows limit the number of files that can exist in the root directory of a disk (or flash card). That limit is 4096 files for the 0.5 Gbyte flash cards installed in the MMP. For the file structure created by current versions of the SCP and described above, this means the maximum number of profiles an MMP can conduct during a single deployment is 1362. After that the file system is full, even if storage space remains on the flash card. Planned revisions to the SCP will change the file structure to eliminate this constraint.

MMP Motherboard

The interface circuits that translate the signals and commands passing between the TT8 and the peripheral components of the system are mounted on the motherboard. The system watchdog circuit and its independent power supply are also located there. The motherboard was designed at MRL and is built and tested here.

All of the interfaces include features to protect the system from electrical damage. The eight independent voltage taps of the main lithium battery pack are diode isolated on the motherboard. Each cell in the battery pack is internally fused for 3 A. There is an accessible, single-use, 2 A fuse in the common return of the battery pack. That fuse is physically attached to the pack. Self-resetting semiconductor "fuses" isolate the three branches of the power distribution network - (1) the TT8, AT8, and motherboard, (2) the sensor suite, and (3) the drive motor. The branch supplying the drive motor is designed to protect the rest of the power distribution network from the back EMF voltages that are generated when the motor is driven by the mooring. This may occur during launch and recovery operations. Wave induced mooring motions, particularly during storms, may also produce strong, transient, back EMFs. The generated electrical currents are absorbed through voltage limiting shunt components that can dissipate several watts.

Digital I/O (DIO) pins, serial communication lines, and analog channels are all protected from voltage surges by high/low pairs of shunt diodes.[13] A dedicated analog channel is used to monitor the voltage of the main lithium battery during deployments and when diagnostic tests are performed.

Other characteristics of the interfaces are indicated on the system architecture diagram and further information is provided in the discussions of the peripheral components below.

Personal Computer and Communications Software

All MMP operations, including system testing, deployment programming, and data recovery, are controlled through the SCP user interface. The operator enters instructions on the keyboard of a PC running terminal emulation software. The MMP executes the commands and responds with system status information and data that are displayed on the screen of the PC.

Laptop and desktop computers running MS-DOS or MS-Windows are the most common platforms, however, palmtops and PCs with other operating systems have been used successfully. While MRL does not endorse any particular hardware platform or operating system, our own experience is with laptop and desktop PCs running DOS and Windows. These are certainly our preferred environments.

[13] DIO lines can be used as either inputs or outputs. Some can be programmed for special, time dependent, input or output behaviors. In all cases they can have only two values, 0 V or 5 V, a Logic 0 or a Logic 1. Analog channels are used to measure analog voltages. The measurement is passed to the micro-processor in digital form.

The communications link between the MMP and your PC is a standard, 3-wire, full duplex, RS-232 connection passing primarily ASCII text bytes. In more familiar terms this is just the serial port, COM1 or COM2, of your PC. The communications cable and the terminal emulation software you will need are included in the tool kit. Two terminal programs, Crosscut and TattleTerm, are also provided. Crosscut is a DOS program and will also operate under some versions of Windows. TattleTerm is a Windows program and will operate under all versions of Windows that we have tested. Instructions for installing and operating these emulators can be found at the end of this manual in Operating Crosscut and TattleTerm. We do recommend and endorse the use of Crosscut and TattleTerm.

Drive Motor

The drive motor control interface is composed of three DIO lines. One of the lines can be programmed to output a pulse train with a variable duty cycle. A dedicated analog channel is used to measure motor current during deployments and when diagnostic tests are performed. Current is steered through the DC brush motor with a standard FET H-switch. A logic network controlled by the DIO lines drives the switch. Unregulated battery voltage is applied directly to the motor through the H-switch to minimize losses that would reduce the endurance of the system. At the nominal battery voltage of 10.8 V the profiling speed of the MMP is 25 cm/s. The current drain at this speed varies depending on environmental conditions. A reasonable working figure is 140 mA. A more complete discussion of motor current can be found in Morrison, et al., 2001.

One of the DIO lines is used to set the motor direction for upward or downward profiling. The second line enables the motor or disables it and sets the brake. The brake is set electronically by grounding both terminals of the motor through the lower legs of the H-switch. The brake is sufficiently strong to support several pounds of positive or negative buoyancy. The third DIO line is programmable. In one state it permits an enabled motor to free wheel. The motor is not driven by the battery in this condition and offers no resistance (other than friction) to external torque. The motor is automatically set to free wheel during launch to reduce slip related wear of the drive wheel. The other state of this line drives an enabled motor in the selected direction. This is the state used for profiling.

The MMP presents an unacceptably high load to the motor if an attempt is made to accelerate too rapidly. Any sudden transition in the voltage applied across the motor will produce a large spike in motor current and torque and may cause the drive wheel to slip against the cable. The applied voltage should be increased slowly from 0 V to the full voltage of the battery. This will gradually increase the speed of the MMP from 0 cm/s to the full profiling speed, which is nominally 25 cm/s. Based on testing in the MRL test well, the applied motor voltage is ramped up linearly over a 30 second period to start each profile. Pulse width modulation (PWM) is used to accomplish this without sacrificing efficiency in the drive train. The programmable DIO pin is set to produce a 20 KHz pulse train and the drive voltage is varied by changing the duty cycle from 0 % at the beginning of the ramp to 100 % at its end. It is the reactance of the motor inductance and a parallel capacitor that filter the pulse train and produce a smooth average drive voltage from the pulse train. Once the duty cycle reaches 100 % the pulse train is turned off to reduce processor overhead and the DIO pin is simply set to the run state.

At some cost in mission endurance, PWM could be used to control profiling speed. A reduced speed might, for example, be necessary if a sensor with a slow response time or a long sampling interval was added to the instrument suite. This capability is not currently implemented.

Independent Watchdog

The watchdog circuit normally receives power from the main lithium battery. However, it also has an independent back-up power supply in the form of a "super cap", a large capacity capacitor that functions like a rechargeable battery. The watchdog will continue to function, even in the event of a power supply interruption, and there is no need to periodically replace a small wafer battery. The super cap, once fully charged, can keep the watchdog active for several days in the absence of power from the main lithium battery. All components of the watchdog are mounted on the motherboard.

The heart of the watchdog circuit is a DS1306 real-time clock chip. The operation of this chip is largely autonomous. The TT8 and the DS1306 communicate through a SPI (Serial Peripheral Interface) port and an IRQ (interrupt request) line. Whenever the operator sets the RTC (real-time clock) of the TT8, the RTC of the DS1306 is automatically set by the system. To avoid confusion, the watchdog clock is referred to as the WDC and RTC is reserved to denote the real-time clock of the TT8. Both the RTC and the WDC are accurate to approximately 1 second per day (1 minute per month). In addition to maintaining an independent real-time clock, the DS1306 steers a small current ($\leq$1 mA) into the super capacitor whenever the main lithium battery is connected.[14] The trickle of charge assures that the independent power supply will be ready if needed.

The other portion of the watchdog circuit is a hardware counter. The counter is driven by a 32.768 KHz square wave generated by the DS1306. Once reset to zero by the TT8, the counter will "roll over" after 4096 seconds, about 68 minutes. The roll over triggers a "one-shot" pulse on the master clear line of the TT8. The pulse is the equivalent of a hardware reset and forces the TT8 to reboot. Master clear is functionally similar to that button on the front of your PC that you have to push when the computer is fully crashed and unresponsive to all keystroke combinations.

The normal operation of the watchdog is quite straightforward. When power is first applied to the MMP, the SCP performs a number of initialization procedures. Among these tasks, the watchdog counter is reset to zero and the DS1306 is programmed to send an interrupt request to the TT8 at one minute after the hour during every hour of operation. When the TT8 receives a watchdog IRQ, which occurs every 60 minutes at one minute after the hour, the TT8 acknowledges and clears the request by communicating with the DS1306 through the SPI. Then the TT8 resets the 68 minute counter to zero, logs the IRQ if a deployment is in progress, and goes on with whatever operation was being conducted when the interrupt was received. These actions indicate the TT8 is smoothly running the SCP. As long as the TT8 is operating properly, the counter never rolls over and the TT8 is never rebooted.

In the (unlikely) event of a processor crash, however, the operation of the watchdog circuit triggers the Unattended Reset, Autonomous Operation (URAO) feature of the system control program. URAO autonomously resets the system, loads the correct time from the DS1306, recovers the deployment parameters programmed by the operator, and restarts the deployment already in progress. URAO also functions in the event of a transient loss of the main power supply. URAO will be described at greater length in the discussion of the User Interface. It is sufficient to state here that the URAO feature includes multiple fail-safes and a layered set of options for parameter recovery.

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[14] The initial current into an uncharged capacitor is limited to approximately 1 mA. As the voltage across the capacitor increases from zero the current will decrease. The overall current drain of the watchdog circuit is small compared to the maximum charging current.

The operation of a watchdog prompted recovery is also quite straightforward. Assume that during a deployment or some other unattended period, the TT8 "crashes"; it is no longer running the system control program or it has been put to sleep by the critical handler after a detectable fault. The watchdog continues to operate autonomously and sends a scheduled IRQ to the TT8. The unresponsive TT8 ignores the interrupt and, in consequence, the counter, which has counted 60 minutes of its 68 minute period, is not reset. Approximately eight minutes later the counter rolls over and triggers a TT8 master clear. The system reinitializes, detects the absence of an operator (see User Interface), and starts the URAO feature.

You will probably never need the system watchdog, but it can be nice to know that it is there, watching, just in case.

Transponder

The transponder is an optional component of the system. When installed, it allows personnel on a research vessel to verify that the system is profiling as scheduled. This is accomplished with a transponder deck unit that can measure the range to the MMP as it changes over time. The intent is simply to give the operator a sense of confidence that all is well before the vessel leaves the site of the deployment. Note that there is an "on/off" switch on the transponder electronics boards. It is located on the corner of the top board near the end cap of the controller pressure housing. The switch must be in the ON position for the transponder to function.

The transponder is largely autonomous, pinging in response to external acoustic signals that fall in a 0.5 KHz band centered on 9.5 KHz.[15] If a deck unit is not available, you can usually trigger a ping in the laboratory or on deck by jingling a set of keys or banging a pair of wrenches together near the transducer. This is one particularly simple way to test that the transponder is working, though it cannot be used to measure range. The transponder is driven by its own electronics and powered by eight 9 V alkaline batteries. All eight of the batteries must be installed for the transponder to function. It draws no power from the main lithium battery. Its average current drain is 3 mA, which will exhaust the alkaline batteries in approximately one year.

The two systems share a common electrical ground and two DIO signal lines. One signal is a TT8 IRQ activated by the transponder to indicate when it has pinged. The MMP logs these interrupts during a deployment, but not otherwise. The other signal is a command from the TT8 to ping. This combination of logic signals could, in theory, be used to establish low bandwidth communications between the MMP and a research vessel. For example, a time coded set of pings could be defined as a command to the profiler to terminate the deployment, go to the bottom stop, signal its arrival there, and await recovery. However, there are currently no plans to implement a communications link of this nature.

[15] A 6 switch DIP on the transponder electronics board is used to set the receive and transmit frequency bands. Each band is 0.5 KHz wide and identified by its center frequency. 9.5 KHz is the default receive frequency. The transponder can be set to receive at 13.0 KHz instead by changing the state of switch 5 from CLOSED (Logic 0) to OPEN (Logic 1). Switches 1 (LSB) to 4 (MSB) control the transmit frequency: 0000 selects 7.5 KHz, 0001 selects 8.0 KHz, …, 1111 selects 15.0 KHz. To meet the power output specification of the transponder the transmit frequency should only be changed within one of three frequency bands: 7.5 KHz - 8.5 KHz, 9.0 KHz - 11.0 KHz, or 11.5 KHz - 15.0 KHz. Switch 6 has no function in the transponder's MMP implementation and should be left OPEN.

Other Sensors

The MMP was originally conceived as an instrument system for use in investigations of physical oceanographic processes. As such, the primary instrument suite is a CTD and an ACM. The profiler's utility as an instrument platform for biogeochemical studies of the ocean was recognized early on, however, and the electronics were designed from the beginning to support an expanded suite of instruments. MRL will work with a customer to integrate a new sensor or new sensors into the system.

Many biogeochemical sensors are direct reading instruments without the autonomous internal logging capability of the CTD and the ACM. In a typical implementation the output of such an instrument is digitized each time a record of engineering parameters is assembled and the measurement is added to the engineering record. The operator selects that update rate when programming the deployment definition parameters (see User Interface). Sensors with greater autonomy might be added to the system in a manner similar to the CTD. In all cases the addition of new instruments requires significant hardware and software changes to the profiler. The integration can only be performed by MRL.

Five analog-to-digital (A/D) channels are available on the motherboard's ANALOG connector. Each channel can accept a 0.0 V to 4.096 V input and digitize it to 12-bit (1 mV) accuracy. The 4.096 V limitation is a characteristic of the TT8's A/D converter. Unfortunately, analog sensors with a 0 V to 5 V output are the norm. Fortunately, voltages greater than 4.096 V will not damage the MMP electronics, however, the output of the A/D conversion will be 4.096 V. In these cases the sensor output can be scaled on the MMP motherboard to fall into the allowed range. The system's analog ground and a reference voltage generated by the A/D are both accessible on the connector.

Two DIO channels (0 V and 5 V) are available on the motherboard's FREQUENCY connector. Both channels can be programmed as counters to accommodate sensors with frequency outputs (e.g., quartz pressure transducers). They can also serve as simple logic inputs. Alternatively, the channels can be configured as outputs and used to control sensor parameters such as gain.

Three types of interface are available to support sensors equipped for serial communications: one 3-wire, full duplex, RS-232 port, one 3-wire, half duplex, RS-485 serial bus port, and one Serial Peripheral Interface (SPI) port.

Finally, two independently switched sources of power are available from the main lithium battery pack. The supply voltage is nominally 10.8 V. An unswitched source of battery power, for sensors that must be continuously powered, is also available.

Primary Instrument Suite

The primary instrument suite is comprised of two sensors, a CTD and an ACM. Currently, only the Falmouth Scientific, Inc. (FSI) EMCTD and 2D-ACM have been integrated into the MMP system. Each is loaded with a firmware version that is unique to the MMP. Manuals for both instruments can be found on a CD in the tool kit. Planned revisions of the MMP's SCP and hardware will eventually offer customers the option of choosing from a limited selection of CTDs and ACMs produced by other manufacturers.

The TT8 communicates with each of the sensors through a dedicated RS-232 serial port. As described at the beginning of this chapter, the instruments are turned on and start logging internally at the beginning of each profile. When the profile is completed, logging is stopped and the data are transferred to the flash card. These steps are directed by the SCP.

The CTD logs one measurement each of conductivity, temperature, and depth in each record (standard settings, see below) and acquires records at a nominal rate of 1.85 Hz. Each datum is stored as a scaled integer in three bytes. There are, therefore, nine bytes in a CTD record and the CTD can log records internally for approximately 8.75 hours before filling its 512 Kbyte data memory. The measured current drain of the CTD is 12.5 mA while logging internally (profiling) and 30 mA while moving data onto the flash card. The duration of the data transfer is 10% - 15% of the elapsed profile time.

The ACM logs a 2-axis tilt measurement, a 3-axis compass measurement, and a 4-axis velocity measurement in each record (standard settings, see below). Each datum is stored as a scaled integer in two bytes with eighteen bytes in a record. ACM records are also acquired at a nominal rate of 1.85 Hz and can be logged internally for approximately 8.75 hours before filling the ACM's 1 Mbyte data memory. The measured current drain of the ACM is 25 mA while logging internally and 40 mA while moving data onto the flash card. The sensors do not log time tags with their measurements; all time tags are recorded in the engineering files.

The overall data acquisition rate for the primary instrument suite is approximately 50 bytes/second. At a profiling rate of 25 cm/s the acquisition rate is 200 bytes/meter or 200 Mbytes per million meters of travel. The acquisition of engineering data is an incremental increase on this that brings the total to roughly 220 Mbytes per million meters.

During a profile the system queries the CTD for real-time depth (pressure) measurements. The information is used to determine when the end of a profile has been reached or an obstruction has been encountered. These algorithms will be described in greater detail in the discussion of the User Interface. The SCP is structured so that it can continue to conduct a deployment if one or both of the primary sensors is damaged or otherwise fails to communicate.

Standard settings for deployment on the MMP exist for both the CTD and the ACM. The logged quantities described above are the most important aspect of the standard settings, which will be described in detail in the discussion of the User Interface. MRL strongly recommends that you use the standard settings for all MMP deployments. However, the SCP will, at the discretion of the operator, support deployments with non-standard settings. The ACM in particular can be programmed to log other quantities in each record.

While the SCP can support a deployment with non-standard settings, the on-board offload utility and the high-speed profiler data processor cannot. Processing binary data files collected with non-standard sensor settings is the responsibility of the operator. The SCP can automatically verify standard sensor settings at the beginning of a deployment or allow the operator to manually program the sensors. Again, we recommend that you exercise the latter option with caution. Verify proper system operation with the new settings in advance of a deployment by running a complete trial deployment in the lab. Some combinations of non-standard settings will prevent the collection of any sensor data during a deployment.

IV. User Interface

This chapter describes operator interaction with the McLane Moored Profiler through the user interface of the system control program (SCP). A large number of example screen displays are included. The displays were captured using Crosscut while interacting with an MMP running Version 2.08 of the SCP. The displays are annotated for greater clarity. We strongly encourage you to read this chapter while interacting with an MMP through the user interface. Trying the examples will help to familiarize you with MMP operation. We suggest that you review the material in Operating Crosscut and TattleTerm, which describes the operation of the terminal emulators used to communicate with the MMP, before proceeding. The section describing Connecting to a PC is particularly important.

The Power-up Sequence

Power is applied to the MMP by connecting the main lithium battery pack to the BATTERY connector on the motherboard. When power is applied, the micro-controller automatically loads the system control program into the 1 Mbyte RAM of the TT8 and begins execution.

The first steps in the power-up sequence are initialization routines that place the TT8 and the AT8 in a default state and prepare them for MMP operation.[16] Once initialization is complete, the system will display a welcome message and begin a 30 second countdown, during which the operator will normally assert control of the system by typing [CTRL]-[C] (hold down the Control key and press 'c'). If the operator fails to assert control the SCP triggers the Unattended Reset, Autonomous Operation (URAO) feature and attempts to restart the deployment that is, presumably, in progress. URAO will be described more fully later in this chapter.

After the operator asserts control, the system initializes and activates the watchdog circuit. A warning will be displayed if a problem is detected and the operator will be instructed to enter 'w' or 'W' at the Main Menu to trigger watchdog initialization and activation manually. The system then determines the storage capacity of the flash card and the number of data files that can be accommodated by the file system.[17] Following watchdog initialization, the system prompts the operator to set the real-time clock (RTC) of the TT8 and then automatically synchronizes the watchdog clock (WDC) to the RTC. The current values of the profiling odometer and trip meter are displayed and the operator is given an opportunity to reset the trip meter to zero. The trip meter is used to monitor the remaining energy capacity of the battery. Normally the operator will reset the trip meter when a new battery is installed.

[16] Explicit in the initialization is verification that the AT8 and the flash card are present and functioning. Obviously, since they are the repository of the SCP, they are present and functioning if program execution begins. However, the checks are inherent in the initialization routines. Significantly for the MMP, the verification is used to enable or disable further use of the flash card. This software lockout prevents flash card operations that can crash the Motorola 68332 CPU if executed in the absence of supporting hardware. If, for example, the flash card is removed and not replaced during a "hot swap", the system will detect the absence and disable flash card operations.

[17] Recall that the flash card is DOS compatible and that DOS places limits on the number of files that can exist in the root directory of the file system. That limit is 4096 files for the 0.5 Gbyte flash cards installed in the MMP. For the file structure created by current versions of the SCP and described above, this means the maximum number of profiles an MMP can conduct during a single deployment is 1362. After that the file system is full, even if storage space remains on the flash card. Planned revisions to the SCP will change the file structure to mitigate the constraint on the number of profiles.

Finally, the system loads the current deployment definition parameters from the EEPROM. The parameters are recorded in the EEPROM and on the flash card whenever the operator begins a deployment. Non-volatile storage of this information allows the operator to program the parameters for a deployment well in advance of the actual launch, even before embarking on the research vessel. This is an important and convenient feature of the design. In particular, it greatly reduces the risk of launching a profiler with a set of factory default or incorrectly entered parameters that are a poor match to the needs of a particular investigation. The stored parameters are also used by the URAO utility to restart a deployment.

Recovery of the stored parameters completes the power-up sequence. A normal sequence, as it would appear on the screen of a PC running Crosscut, is shown below.

```
MMP-2_08



 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.

 28 seconds                                                ← countdown timer,
                                                              [CTRL]-[C] asserts
 Independent system watchdog successfully initialized.        operator control
 Watchdog alarm IRQ has been activated.

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

 439.443 Mbyte flash card installed
 439.263 Mbyte currently free

 File system can accommodate  4089 data files
 Deployment can include up to 1362 profiles


 Clock reads 01/01/1970 00:00:00
 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 [01/01/1970 00:00:03] ? 1 26 02 17 9 55 ← operator types the
                                                              date and time,
 Clock reads 01/26/2002 17:09:55                              [ENTER] sets RTC
 Change time & date (Yes/No) [N] ?

 Setting watchdog clock . . . done.                        ← system sets WDC

 Profiling odometer
   Total profiling distance:          0 meters             ← system odometer
   Battery trip meter:                0 meters             ← battery trip meter

 Reset trip meter (new battery) (Yes/No) [N] ?             ← default leaves trip meter
                                                              unchanged
```

The MMP Main Menu will be displayed once initialization is complete. The operator initiates all further system operations from the Main Menu.

Setting the Clock

It is not necessary to set the RTC during the power-up sequence. The RTC can be set at any time from the Main Menu (see below). The operator is also prompted to check and set the clock when starting a deployment. However, we have observed that setting the clock accurately reduces the incidence of operator error. It should also be noted that not setting the clock before starting a deployment could have severe consequences. Therefore, we strongly recommend that you cultivate the habit of setting the clock during the power-up sequence.

How can an unset clock compromise a deployment? The RTC cannot run when the power is disconnected. When power is applied, the RTC is reset to January 1, 1970, 00:00:00, the ANSI C time reference, and begins a steady count.[18] During a deployment, profiles are scheduled with reference to a date and time programmed by the operator. That date will, presumably, be later than the year 2001 (since this text is being written in early 2002). If the RTC is not set to the current time and the profile schedule is, the MMP will wait for more than 30 years to start the deployment. We strongly recommend that you cultivate the habit of setting the clock during the power-up sequence.

The example above shows how to set the RTC. The date and time should be entered using the US convention of month followed by day followed by year: MM/DD/YY HH:MM:SS. Years can be entered using 1, 2, 3, or 4 digits (99 or 1999 for 1999 and 1, 01, 101, or 2001 for 2001). Years between 1970 and 2038 are allowed. Spaces, as used in the example, are acceptable delimiters between values, however slashes and colons can also be used. Leading zeros are not required, but are acceptable. The RTC is actually set to the entered date and time when the operator presses [ENTER] after typing the six date and time values. Typically the operator will type a time that is 5 to 10 seconds in the future, and then press [ENTER] as the external clock used for reference reaches that time.

The Profiling Odometer

The profiling odometer provides the operator with an estimate of the profiler's cumulative, lifetime, travel distance. The odometer can be used to schedule and track major system maintenance procedures. The trip meter is a reasonably accurate "gas gauge" for the battery. Both the odometer and the trip meter are incremented automatically during a deployment. The trip meter can be reset at the discretion of the operator, but not the odometer.

The profiling endurance of a standard lithium battery pack is 1 to 1.2 million meters. Subtracting the trip meter from 1 million meters provides an estimate of the remaining profiling capacity of the battery. Obviously, it is important for the operator to reset the trip meter, or otherwise record and track the value, when a new battery is installed. The odometer and the trip meter can each accumulate more than 2 billion meters before they "roll over". (The actual limit is $2^{31}-1 = 2147483647$ meters.)

Note that the odometer and trip meter are not used by the system to constrain the duration of a deployment. The MMP monitors the battery voltage during a deployment and will trigger a graceful shut down if the battery becomes exhausted. The odometer and trip meter are provided as a convenience and reminder for the operator. The calculation of the profiling distance added to the odometer and trip meter at the end of each profile is described at the end of this chapter in Profiling Odometer.

[18] The clock continues to advance as long as power is present. The operator is free to set the clock to any arbitrary date and time in the allowed range and the count simply continues from the new value. The allowed range is 1970 to 2038.

Re-Booting the TT8

The power-up sequence will not be repeated unless the system is re-booted. A "cold" re-boot can be accomplished by disconnecting the power and then reconnecting it after 5 to 10 seconds. The delay allows capacitors in the system to fully discharge. If the RTC does not reset to 01/01/1970 00:00:00 you did not wait long enough before reconnecting. A "warm" re-boot can be executed by exiting the system control program to the TT8 monitor (TOM8) and then re-starting the program manually (see Exiting to the Monitor). The RTC is not reset by a warm re-boot.

Points to Note

Responding to Prompts

Character case does not, in general, matter. Upper and lower case alphabetic characters used in response to various prompts are equivalent. The exception is the password required to exit to the monitor. Passwords are case sensitive. Many prompts have default answers that can be selected simply by pressing [ENTER]. The default answer, if there is one, will be displayed at the end of the prompt in square brackets. An example is the default "no" response to the prompt for setting the RTC during the power-up sequence.

Prompts for numerical values will only accept numbers that fall within a displayed range. The displayed upper and lower bounds are included in the acceptable range. When an out of range or otherwise unacceptable entry is made the system will re-prompt the operator. Numerical prompts discriminate between integer and floating-point values in the sense that floating-point values will be truncated or otherwise altered or rejected when an integer value is sought. Integer values are, or course, acceptable when a floating-point value is anticipated as long as the integer is inside the displayed range. It will generally be clear from the context and the displayed range when a floating-point value is expected.

Similarly, prompts for alphanumeric input, such as those following a menu display, will only accept characters from a restricted list, the visible (and hidden) menu options. Unrecognized characters will simply cause the system to re-prompt the operator.

Logging Interactions with the MMP

We recommend that you log all of your interactions with the MMP. Logging or "file capture" is described in Operating Crosscut and TattleTerm. Logging is essential if data from the flash card are to be recovered by spooling them through the communication port using the on-board data offload utility. However, a complete record of your session programming the system for a deployment can be invaluable during (and often before) data analysis. We strongly recommend this use of the file capture utility of the communications program. Record your interactions.

[CTRL]-[C]

The key combination you will find most useful when running the MMP is [CTRL]-[C] (hold down the Control key and press 'c'). [CTRL]-[C] will gracefully terminate whatever operation the system is conducting and return to the Main Menu. Several [CTRL]-[C]s will be necessary in some cases. There may be other, less drastic, options, but [CTRL]-[C] will always work, and, as long as terminating the current operation is not a problem for the operator, [CTRL]-[C] is a benign action that will cleanly terminate the active process before returning to the Main Menu.

For example, [CTRL]-[C] is the only correct way to manually terminate a deployment when the profiler is recovered. After a [CTRL]-[C] is received during a deployment the system will complete any critical steps, such as terminal data storage operations, and return to the Main Menu. Thus the "graceful termination" characterization. Those critical operations are generally completed within a small fraction of a second. The system will display a notice if more time is required.

[CTRL]-[C] will not harm the hardware in any way. [CTRL]-[C] will exit cleanly from a prompt during parameter entry without altering the variable. [CTRL]-[C] is the only way to manually wake the system from the low power sleep condition (three [CTRL]-[C]s are required). When in doubt, [CTRL]-[C] will take you to the Main Menu where you can take control of system operation.

Powering-down

To turn the profiler off, simply disconnect the main lithium battery pack. As a general rule, remove power only after stopping whatever operation the system is performing ([CTRL]-[C]) and returning to the Main Menu. Powering down while an operation is in progress is not in any way detrimental to the hardware, however, it does put active data files at some risk and may skip the recording of any deployment definition changes that have been made. For these reasons it is especially important that you never remove power to stop a deployment. Always use [CTRL]-[C] first. This is akin to running "shut down" on a PC before switching it off; it allows the processor to protect the file system and exit cleanly.

Dates

Observant readers will note that the RTC dates in the example displays vary over a period of several months. MMP manuals are not written in a day.

The Main Menu - Operating the MMP

The Main Menu is the operational control nexus of the MMP user interface. The operator initiates all system operations from the Main Menu. This section of the manual describes each of the visible (and hidden) Main Menu options. The MMP Main Menu is shown below. To select an option press the appropriate alphanumeric character key followed by [ENTER].

```
         McLane Research Laboratories, USA
              McLane Moored Profiler
       Version: mmp-2_08.c   S/N: ML00414-42

        ╔══════════════════════════════════╗
        ║            Main Menu             ║
        ╚══════════════════════════════════╝
              Mon Jan 28 13:46:19 2002


       <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  ?
```

<1> Set Time

The Set Time option allows the operator to set the RTC. The system automatically sets the WDC whenever the operator sets the RTC. The date and time should be entered using the US convention of month followed by day followed by year: MM/DD/YY HH:MM:SS. Years can be entered using 1, 2, 3, or 4 digits (99 or 1999 for 1999 and 1, 01, 101, or 2001 for 2001). Years between 1970 and 2038 are allowed. Spaces are acceptable delimiters between values, however, slashes and colons can also be used. Leading zeros are allowed, but are not required.

The RTC is set to the entered date and time (and then continues running) when the operator presses [ENTER] after typing the six date and time values. It is pressing [ENTER] that should be synchronized to some reference. This is most easily accomplished by typing a time that is 5 to 10 seconds in the future and then pressing [ENTER] as the external clock used for reference reaches that time. The time of exit from the RTC routine does not affect the clock.

```
         Selection  ? 1                                      ← press '1'  followed by
                                                                [ENTER]
Clock reads 01/28/2002 15:17:24
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 [01/28/2002 15:17:26] ? 1 28 02 15 18 5 ← operator types the
                                                                date and time,
Clock reads 01/28/102  15:18:05                                 [ENTER] sets RTC
Change time & date (Yes/No) [N] ?                            ← exit RTC routine

Setting watchdog clock . . . done.                           ← WDC synchronized
```

The accuracy of the RTC is approximately 1 minute per month, comparable to the accuracy of a quartz wristwatch. There are variations from one unit to the next and there is some dependence on temperature. A working estimate of temperature dependent clock error is 2.5 seconds per day at 25°C, 0.0 seconds per day at 20°C, and 2.7 seconds per day at 0°C.

<2> Diagnostics

Diagnostics is a scrolling display of system status information. The display includes the real-time clock, the watchdog clock, the battery voltage to tenths of a volt, and the motor current in milliamps (mA). The latter quantity will typically be zero to a few mA; the motor is not running during Diagnostics. A non-zero value below 10-12 mA indicates a small offset voltage in the hardware and can be ignored or subtracted from motor current readings taken when the motor is running. The nominal voltage of the lithium battery pack is 10.8 V. 11.6 V or more is typical with a new battery, but this will drop to the nominal value after some use and remain stable there for most of the battery's usable life.

An example Diagnostics display is shown below. 'X', 'x', or [CTRL]-[C] will exit from Diagnostics and return to the Main Menu. The scrolling can be toggled on and off without leaving Diagnostics by pressing any other alphanumeric key.

```
      Selection  ? 2

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

RTC: 01/28/2002 15:52:54   WDC: 01/28/2002 15:52:53   10.9 Vb      0 mA
RTC: 01/28/2002 15:52:55   WDC: 01/28/2002 15:52:54   10.9 Vb      0 mA
RTC: 01/28/2002 15:52:56   WDC: 01/28/2002 15:52:55   10.9 Vb      0 mA
```

The scrolling display provides the operator with both explicit and implicit information about system status. The steady advance of both clocks indicates that they are working. It is not necessary that the clocks are precisely synchronized. A one second offset is typical shortly after the system sets the WDC. An accurate and advancing WDC also indicates that the TT8 SPI bus, a critical communications link used by the 68332 CPU to communicate with the watchdog and other devices, is functioning.

The battery voltage provides some information about the battery. A reading above 11 V, for example, indicates a very fresh battery. After the initial high readings, the battery voltage will remain near 10.8 V until ~90% of the available energy in the battery has been used. The voltage then drops rapidly to ~7.8 V and remains near that level while most of the remaining available energy is used. As the battery nears complete exhaustion (99+% of the available energy extracted), the voltage falls rapidly to zero unless the current drain is drastically reduced. The MMP uses a threshold of 7.5 V to detect battery exhaustion.

In brief, a reading below 10 V indicates that at least 90% of the 240 Ahr capacity of the battery has been used. Such a battery should generally not be used for a deployment, but it has significant utility as a power source during bench testing and operator training. A reading below 7.5 V indicates that essentially all of the available energy in the battery has been used and that the battery should be disposed of in accordance with applicable safety regulations for lithium batteries. These two voltages are used to trigger operator warning messages.

If the output of the lithium battery is below 10.0 V, a caution message suggesting replacement of the battery before deploying the system will be displayed during the exit from Diagnostics.

```
Battery voltage is abnormally low.  Check/replace
main battery pack before deploying system.


Press any key to continue.
```

If the output of the lithium battery drops below 7.5 V, a warning message and a single system status line will be displayed. Diagnostics will automatically terminate and the user interface will return to the Main Menu.

```
Main battery is extremely low and should be replaced
before running diagnostics.

RTC: 01/28/2002 16:35:46   WDC: 01/28/2002 16:35:46    6.8 Vb      0 mA


Battery voltage is abnormally low.  Check/replace
main battery pack before deploying system.


Press any key to continue.
```

A battery reading near 10.8 V can only tell the operator that the battery is somewhere in the middle of its usable life. The simplest gauge of remaining battery capacity is the cumulative profiling distance, as estimated by the profiling trip meter or as calculated from the data. 1 to 1.2 million meters is the approximate endurance limit of the MMP.[19]

Reasonable battery and motor current values when running Diagnostics demonstrate that the sensing circuits on the motherboard and the analog-to-digital converter chip on the TT8 are working. Like the advancing WDC, reasonable values also show that the SPI bus is operating.

Diagnostics should be used to make a fast, preliminary assessment of system status. Other Main Menu options, described below, provide additional tools that allow the operator to make a more detailed and comprehensive assessment of system operability.

<3> Flash Card Ops

Flash Card Ops gives the user access to the files on the flash card through a DOS-like interface called PicoDOS. The Flash Card Operations menu is shown below. Where necessary, instructions or supplementary information are displayed on the screen when a selection is made. Note that the Flash Card Operations menu allows the operator to delete or corrupt data files and the system control program. Exercise appropriate caution.

---

[19] The limit has been estimated based on results from a short deployment (Morrison, et al., 2001) and has also been demonstrated by a summer 2001 deployment during which 1008 approximately one thousand meter profiles were completed before battery exhaustion triggered a graceful shut down. The total travel distance was ~935,000 meters. Additionally, during a year long 2001-2002 deployment an MMP profiled ~960,000 meters.

Option 1 measures the total capacity of and remaining free space on the flash card. It also calculates the number of files permitted by the file system and the resulting limit on the number of profiles that can be conducted during a single deployment. This is the same subroutine run during the power-up sequence.

```
        ╔══════════════════════════════════╗
        ║      Flash Card Operations       ║
        ╚══════════════════════════════════╝

       <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 / 100 Mbytes) . . . done.

 439.329 Mbyte flash card installed
 439.124 Mbyte currently free

 File system can accommodate  4089 data files
 Deployment can include up to 1362 profiles


 Press any key to continue.
```

Option 2 is equivalent to a "dir" command in DOS. At a minimum, the flash card should contain MMP-N_NN.RUN, the system control program, and AUTOEXEC.BAT, the batch file that calls the SCP when power is applied to the MMP. The additional files in the example below contain the deployment definition parameters (DEPLOY.DAT), the current profile count (PROFILES.DAT), and the log of interrupt requests and other exceptions (IRQ_XCPT.LOG). All three are binary files normally processed by the on-board offload utility or the high-speed binary data processor. Other files that might be present are the engineering, CTD, and ACM files from a deployment.

```
Directory of A:
MMP-2_08.RUN        166,202 01-29-02 22:08
AUTOEXEC.BAT             10 01-29-02 22:08
DEPLOY.DAT               80 01-29-02 22:08
PROFILES.DAT              4 01-29-02 22:08
IRQ_XCPT.LOG              6 01-29-02 22:08

     439,123,968 bytes free


 Press any key to continue.
```

Option 3 displays the profile count in hexadecimal notation. In the example below, the profile count stands at $019E_{hex}$ (414_{dec}), indicating that 415 profiles, numbered 0 through 414, have been conducted and are stored on the flash card.

```
LOCATION  CONTENTS
00000000  0000 019E

 Press any key to continue.
```

Option 4 can be thought of as DOS's "del *.*" command. However, the operation carried out is actually "format", the same as Option 6. Pay attention to the displayed warning. If the SCP and/or the AUTOEXEC.BAT file are deleted, the MMP cannot be deployed. The files must be restored from the archival backups, which should be stored on your PC. The PC must also be able to read and write full size flash cards (PCMCIA ATA).

```
 This utility will delete all files on the flash
 card, INCLUDING THE SYSTEM CONTROL CODE if it is
 present.

 Do you wish to continue (Yes/No) [N] ?          ← may we suggest the default?
```

Option 5 allows the operator to remove or install a flash card without disconnecting system power ("hot swap"). The system displays instructions and then sets the card socket for a safe exchange. When the exchange is complete, the SCP checks that a card is present. The card capacity routine (Option 1) is run if a card is detected. If no card is detected, the SCP locks out all flash card operations except flash card exchange, allowing eventual insertion of a card.

```
 This utility permits a flash card exchange
 without disconnecting the battery.  Hit any
 key TWICE after the exchange.  The utility
 is reasonably robust, however, if the system     exchange card after ellipsis
 crashes, simply follow the instructions or       is displayed and system pauses,
 disconnect the battery, wait 10 seconds, and     press [ENTER] twice when
 reconnect the battery.                           card exchange is complete.
                                                    ↓
Ready for card change (CS2), hit any key to continue ... Card Installed


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

 439.329 Mbyte flash card installed
 439.124 Mbyte currently free

 File system can accommodate  4089 data files
 Deployment can include up to 1362 profiles


 Press any key to continue.
```

Option 6 formats the flash card. This utility can be used to insure that new cards are compatible with PicoDOS. To do this, boot the MMP with a system card containing the SCP and AUTOEXEC.BAT. Run the card exchange option and insert the card to be formatted. Run format. Then remount the system card using hot swap a second time.

As with the delete option, pay attention to the displayed warning. If the SCP and/or the AUTOEXEC.BAT file are deleted, the MMP cannot be deployed. The files must be restored from the archival backups that should be stored on your PC. Your PC must be able to read and write full size flash cards (PCMCIA ATA).

```
This utility insures flash card compatibility,
however, running format will erase all files
currently stored on the card, INCLUDING THE
SYSTEM CONTROL CODE if it is present.

Do you wish to continue (Yes/No) [N] ?
```

Finally, Option 7 provides full access to PicoDOS. While this may be useful to some users, we suggest that you exercise caution and restraint. It is possible to corrupt or delete data and program files using this portion of the interface. It is also possible to alter the system in a way that compromises proper operation. In particular, it is possible to change the boot procedure or delete the system control program or AUTOEXEC.BAT. We suggest that you do not use the Command Line Interface if you are not thoroughly familiar with the TT8 and with PicoDOS. Make sure you have an archival copy of the SCP and AUTOEXEC.BAT on your PC.

```
=====  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,        ← Observe the caution
           halt, damage, or hide the system
           program resident in flash memory.

 <?>-<ENTER> for list of commands                   ← a '?' redisplays the command list
 <CTRL>-<C> to exit                                 ← returns to Flash Card Ops menu

 Enter command >>                                   ← command line prompt
```

Option M of the Flash Card Operations menu returns the user interface to the Main Menu. ([CTRL]-[C] will also return to the Main Menu.) Note that all flash card operations (except the card exchange option) are disabled by the system if a flash card and/or the supporting hardware are not detected during the power-up sequence. Flash card operations are also disabled if a flash card and/or the supporting hardware are not detected during the exit from the card exchange option.

An Operational Note

The flash card provides reliable, non-volatile storage of the system control and autoexec programs (and the data). The programs cannot spontaneously evaporate, but they can be erased by an operator command. Flash Card Ops gives you access to those commands and, as we all know, accidents happen. As a precaution, always maintain archival backups of the SCP and AUTOEXEC.BAT on a PCMCIA ATA capable PC and be sure that PC is available to the MMP in the lab and out at sea. If disaster strikes, MRL can email the programs to you, even out at sea. It requires some negotiation with the satellite people, but it can be done. Supplying a PC in an emergency is a lot harder.[20] Don't leave the dock without it.

<4> Sleep

The MMP draws 180 to 200 mA of current from the battery while profiling (Morrison, et al., 2001). Of that total, ~150 mA goes to the drive motor and most of the balance is used to power the primary sensor suite. The TT8 is a small fraction of the total load, typically <1%, during a profile. However, the TT8 remains powered between profiles, and those periods can be long enough for the cumulative effect of a small drain, a few milliamps, to be a significant factor in the energy budget of a deployment. This is the reason for Low Power Sleep (LPS).

When performing active tasks or calculations, the TT8 draws from 5 to 20 mA. Examples are 14 mA while communicating with a sensor, 18 mA while providing a pulse width modulated signal to the motor, and 20 mA when transmitting text to a PC. While waiting for input from the operator, the drain is typically only 2 mA. This is the state when the user interface has presented the operator with a menu or other prompt. In LPS, however, the TT8 draws a total current of only 0.5 mA (500 µA).

During a deployment, and even during a profile, the SCP will place the TT8 in LPS whenever the schedule makes a transition possible. The TT8 wakes from LPS based on an alarm signal from the RTC or when commanded to wake-up by an operator. The alarm signal is set by the SCP based on the programmed schedule. The SCP will also place the TT8 in LPS and await recovery after it terminates a deployment. The system will end a deployment if the battery falls below 7.5 V, if the flash card is full, or if the maximum number of data files has been reached. When under the control of an operator, the system will transition to LPS whenever it has waited more than 20 minutes for input from the user. Just before the system transitions to LPS it will display the current time and indicate that it is sleeping. During LPS the system will temporarily awaken every 20 minutes to check system status and then return to LPS. During the check the current time and the "Sleeping . . . " message will be repeated.

[20] We once air dropped a TT8 electronics stack to a customer at sea (they had an accident on deck, the hardware did not survive, its an instructive story). There are pictures of the drop, dubbed "Operation Buffalo Chip", on our web site in the "at-sea" gallery (www.mclanelabs.com/gallery.html). We do not recommend this approach for PC replacement, but this, too, can be done.

To wake-up the system from LPS send three [CTRL]-[C]s. A prompt with a blinking '?' will be displayed after the second [CTRL]-[C]. You need to enter the third [CTRL]-[C] inside a 3 second window while the '?' is blinking or else repeat the entire sequence. The first two [CTRL]-[C]s can actually be almost any two keystrokes. The third keystroke must be [CTRL]-[C].

The Low Power Sleep option of the Main Menu forces a transition to LPS, allowing power conservation at the discretion of the operator. When the TT8 enters Low Power Sleep, it will display the current time and then indicate that it is sleeping. An example is shown below.

```
<01/30/2002 15:58:51> Sleeping . . .            ← 2 keystrokes starts wake-up

Enter <CTRL-C> now to wake up?                  ← send [CTRL]-[C] to finish wake-up
```

<5> Bench Test

The MMP Bench Tests are a suite of utilities that allow the operator to assess the operability and performance of each of the peripheral components of the system. These utilities are also useful for training and operator familiarization. The Bench Tests menu is shown below.

```
                Bench Tests
           Fri Feb  1 13:35:55 2002


 <1> CTD Communications     <6> Motor Operation
 <2> CTD Pressure           <7> Brake set.  Change?
 <3> CTD Average Pressure   <8> Ping Transponder
 <4> ACM Communications     <9> Test System Watchdog
 <5> ACM Tilt and Compass   <M> Main Menu

        Selection  ?
```

<1> CTD Communications

Option 1 is a "pass-through" communications channel to the CTD. It is roughly equivalent to connecting the CTD directly to the serial port of your PC and communicating with it using the CTD's command set (described in the CTD manual). The important visible difference from a direct connection is that the Bench Tests utility echoes your commands, entered at the keyboard, to the screen of the PC. The CTD by itself does not.

Depending on how deeply involved you wish to become with the CTD, you may need to read and understand the CTD manual, a copy of which is provided on a CD in the tool kit. If you have questions, MRL will attempt to address them. It may be necessary to forward some questions to the sensor manufacturer. We do recommend a quick perusal of the CTD manual for all operators.

For normal use with the MMP, you will only need to know a few CTD commands. The most important of these is simply [ENTER] or [CARRIAGE RETURN], which triggers the CTD to send a single scan of data when it is in "run mode", the state in which it powers-up and logs data.[21] An example is shown below.

```
          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.

                                ← operator presses [ENTER]
13.7847, 21.7239,  0.2079       ← CTD responds with 1 scan of conductivity, temperature, pressure

                                ← operator presses [ENTER] again
13.7841, 21.7325,  0.4280       ← CTD responds with another scan

                                ← operator presses [ENTER] a third time
13.7845, 21.7330,  0.4481       ← CTD responds with a third scan

                                ← operator sends [CTRL]-[C]

 TX channel closed.             ← SCP puts CTD in "open mode", shuts down communication
 RX channel closed.                channels, and . . .

 Shutting down power to CTD.    ← . . . shuts down CTD.

 Press any key to continue.
```

The first number in each scan is conductivity in mmho/cm. Next is temperature in °C and finally pressure in dbar. For this example the CTD was sitting in air on the bench with a 100 Ω resistor looped through the inductive conductivity cell. The CTD output makes sense for those test conditions, however, this obviously does not qualify as a calibration quality test. Sensors should be fully calibrated at a properly equipped facility before and after deployments. The results of those calibrations allow investigators to account for sensor drift during post-processing of the data. The sensor manufacturer operates such a facility. However, if you can provide an environment of known characteristics for the sensor, this test can provide a quick verification of CTD function and accuracy.

[21] During a profile, while the CTD is logging autonomously, the TT8 periodically sends a carriage return over the serial communications link to the CTD. The CTD responds with the most recent scan of data. The SCP parses the response string to extract the pressure and uses that information to determine when a profile is complete.

In addition to run mode, the CTD can be placed in "cal mode" or "open mode". Cal mode is used during sensor calibration. You will seldom, if ever, need to run cal mode. We refer you to the CTD manual for further information about calibration. It is in open mode that most CTD commands are active. To place the CTD in open mode type ***O[ENTER] (that's a letter 'O', either upper or lowercase, not a zero). In open mode the response to [ENTER] is "Open Mode".

`***O`	← open mode command followed by [ENTER]
	← [ENTER]
`Open Mode`	← CTD responds

CTD Shut Down Caution

[CTRL]-[C] at anytime, regardless of the current operational mode of the CTD, will terminate the communication session and power-down the sensor. ([CTRL]-[C] is a command to the SCP, not to the CTD, so it is not "passed-through".) Read the next paragraph before you try this.

One of the idiosyncratic, and very annoying, behaviors of earlier models of this CTD was that it could lose its calibration constants if it was shut down in run mode during the narrow window in time of a memory access. While rare, this did happen.[22] According to the manufacturer, this cannot happen with the current model of the CTD. We remain unconvinced. As a precaution, we recommend placing the CTD (and the ACM) in open mode before turning the sensor off. Versions 2.08 and later of the SCP do this automatically when the operator sends [CTRL]-[C] to terminate the session.[23] If you are operating the MMP with SCP Version 2.07 or earlier you must place the CTD in open mode manually before terminating the session. We also recommend that you upgrade to Version 2.08 or later.

Standard CTD Settings for Use with the MMP

As previously discussed, there are standard CTD settings for use with the MMP. The system will check for these settings at the discretion of the operator before beginning a deployment. The system will not automatically program the standard settings, however. Using Option 1 of the Bench Tests, the CTD pass-through utility, the operator can verify and program the standard settings (or non-standard settings) before a deployment. The procedure is summarized below. When there is a → in one of the steps, the text to the left is what the operator types and the text to the right is the CTD's expected (standard settings) response. The operator can use either upper or lower case characters.

[22] The colloquial phrase for these occurrences was "the sensor lost its mind again". Fortunately, the default coefficients that replace the lost constants make data recovery during post-processing possible. The correct constants can be re-entered manually from the calibration sheet provided with each unit by the manufacturer. See the CTD manual for further information.

[23] Versions 2.08 and later of the SCP automatically place the CTD and the ACM in open mode before any automatic or operator commanded sensor shut down. In earlier versions of the SCP, the sensors were normally in open mode before shut down during a deployment. The modifications in Version 2.08 and later make the mode explicit during a deployment. The Version 2.08 modifications also make the transition automatic for exit from all of the Bench Tests utilities.

1) Establish communications using Option 1 of the Bench Tests menu.
2) Place the CTD in open mode (***O)
3) [ENTER] → Open Mode
4) ROP[ENTER] → 1335 (or some other serial number)
   Scale is OFF
   Address Operation is OFF
   Auto is ON
5) If the response to ROP, Read Operational Parameters, varies from the expected one, enter commands from the list below to correct the deviations:
   - SCALE=OFF[ENTER] will clear scale
   - CAOP[ENTER] will clear address operation
   - AUTO=ON[ENTER] will set auto
6) If you have made corrections, use the ROP command to verify the changes.
7) When the settings have been verified the command ***E[ENTER] will store them in the CTD EEPROM.
8) Wait a few seconds for the CTD to send a carriage return to the screen, indicating that the storage operation is complete.
9) [ENTER] → Open Mode
10) [CTRL]-[C] to terminate the session and shut down the CTD.
11) If you made corrections, re-establish communications and verify that the settings are now correct on power-up.

A sample interaction, verifying standard CTD settings, is shown below.

```
 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.

***O                             ← open mode command followed by [ENTER]

                                 ← [ENTER]
Open Mode                        ← CTD responds
ROP                              ← ROP[ENTER], operator query for operational parameters
1335                             ← CTD responds with correct standard settings
Scale is OFF
Address Operation is OFF
Auto is ON
***E                             ← ***E[ENTER], operator commands non-volatile storage
                                    of the parameters
                                 ← CTD sends CARRIAGE RETURN when storage is complete
                                 ← operator sends [CTRL]-[C] to terminate session
 TX channel closed.              ← SCP commands "open mode" as a precaution, shuts down
 RX channel closed.              ← communication channels, and . . .

 Shutting down power to CTD.     ← . . . shuts down CTD.

 Press any key to continue.
```

Non-standard CTD settings will affect system operation during a deployment. Caution and a trial deployment on the bench are strongly advised if you chose to deploy an MMP with other than the standard CTD settings.

<2> CTD Pressure

Bench Tests Options 2 and 3 test the ability of the system to extract pressure information from the CTD. The pressure measurements of the CTD are primary inputs to the SCP routines that guide and control each profile.

Bench Tests Option 2 powers-up the CTD, queries it for a scan of data using the carriage return run mode command, parses the response to extract the pressure, displays the result, and shuts down the CTD. An example is shown below.

`This option tests one of the CTD communication routines. It does not allow time to properly warm-up the sensor; the returned value is not accurate.`	← This warning is more germane to an earlier version of the CTD. The current version is essentially accurate immediately after power is applied.
`Applying power to CTD . . . ready.`	
`Pressure =    +0.700 dbar`	← the returned pressure
`Press any key to continue.`	

Versions 2.08 and later of the SCP place the CTD in open mode before shutting it down. Earlier versions of the SCP shut down the CTD in run mode. This will occasionally cause a problem. We recommend that you upgrade to the current version of the SCP and that you refrain from using this Bench Tests option until you have installed the upgrade.

<3> CTD Average Pressure

Bench Tests Option 3 queries the operator for the number of pressure values to average. It then powers-up the CTD, queries it for the requested number of scans using the carriage return run mode command, parses the responses to extract the pressure, displays the results, calculates and displays the average, and shuts down the CTD. An example is shown below.

```
This option tests one of the CTD communication
routines.  It does not allow time to properly
warm-up the sensor; the returned values are
not necessarily accurate.

Enter number of measurements for average (1 to 5000) ? 10   ← operator requests 10
                                                               measurements
Applying power to CTD . . . ready.

+1.661 dbars                                                 ← first of 10 measurements
+1.315 dbars
+1.135 dbars
+0.658 dbars
+0.485 dbars
+0.654 dbars
+0.951 dbars
+1.023 dbars
+0.969 dbars
+0.807 dbars                                                 ← last of 10 measurements

Average pressure =    +0.966 dbar                            ← average pressure

Press any key to continue.
```

This utility can be used to acquire a time series of the power-up response of the CTD pressure transducer. Earlier (high-power) versions of the CTD exhibited a systematic power-up transient of several minutes duration due to self-heating. The current low power version of the CTD has no significant self-heating transient.

Versions 2.08 and later of the SCP place the CTD in open mode before shutting it down. Earlier versions of the SCP shut down the CTD in run mode. This will occasionally cause a problem. We recommend that you upgrade to the current version of the SCP and that you refrain from using this Bench Tests option until you have installed the upgrade.

<4> ACM Communications

Option 4 is a "pass-through" communications channel to the ACM. It is roughly equivalent to connecting the ACM directly to the serial port of your PC and communicating with it using the ACM's command set (described in the ACM manual). The important visible difference from a direct connection is that the Bench Tests utility echoes your commands, entered at the keyboard, to the screen of the PC. The ACM by itself does not.

Depending on how deeply involved you wish to become with the ACM, you may need to read and understand the ACM manual, a copy of which is provided on a CD in the tool kit. If you have questions, MRL will attempt to address them. It may be necessary to forward some questions to the sensor manufacturer. We do recommend a quick perusal of the ACM manual for all operators.

For normal use with the MMP, you will only need to know a few ACM commands. The most important of these is simply [ENTER] or [CARRIAGE RETURN], which triggers the ACM to send a single scan of data when it is in "run mode", the state in which it powers-up and logs data. An example is shown below.

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

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

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

                                          ← operator presses [ENTER], ACM responds with 1 scan of data
  0.16,    0.98,  0.3651,  0.0013, -0.9310,    2.54,   -2.77,   -4.20,   -1.16

                                          ← operator presses [ENTER] again, ACM responds with another scan
  0.16,    0.92,  0.3654,  0.0024, -0.9309,    2.59,   -2.77,   -4.23,   -1.13

                                          ← operator presses [ENTER] a third time, ACM responds with a third scan
  0.13,    1.06,  0.3653,  0.0014, -0.9309,    2.55,   -2.77,   -4.17,   -1.13

                                                ← operator sends [CTRL]-[C]

TX channel closed.                              ← SCP puts ACM in "open mode", shuts down communication
RX channel closed.                                 channels, and . . .

Shutting down power to ACM.                     ← . . . shuts down ACM.

Press any key to continue.
```

For this example the ACM electronics sat in air on the bench with the direction mark pointed approximately toward local magnetic north. Recall that the direction mark is oriented towards the front of the profiler, aligning it with the sting, when the ACM housing is mounted in the frame of the MMP. The sting was immersed in a bucket of reasonably still water placed on the floor. The ACM output makes sense for those test conditions, however, this obviously does not qualify as a calibration quality test. Sensors should be fully calibrated at a properly equipped facility before and after deployments. The results of those calibrations allow investigators to account for sensor drift during post-processing of the data. The sensor manufacturer operates such a facility. However, if you can provide an environment of known characteristics for the sensor, this test can provide a quick verification of ACM function and accuracy.

The Cartesian co-ordinate frame of the MMP is defined to have the +x-axis pointing forward, the direction in which the sting of the ACM points. The +y-axis points to port, the left side of the profiler. The +z-axis points up, completing a right-handed Cartesian system (see Morrison, et al., 2001). The first two numbers in each ACM scan are TX and TY, the tilt angles of the x- and y-axes about the y- and x-axes. When the ACM pressure housing, which contains the tilt and compass modules, is properly oriented in the profiler, TX is the pitch angle and TY is the roll angle. TX measures rotation about the y-axis and is positive when the ACM sting tips up, that is when the profiler tips backwards. (Note that this is backwards with respect to the usual "right-hand rule" for rotations - thumb of right hand points in the positive direction along the axis of rotation, fingers of right hand indicated the positive direction of rotation.) Similarly, TY measures rotation about the x-axis and is positive when the profiler tips to starboard. (Note that this rotation is consistent with the "right-hand rule".) The units of tilt are degrees. Full scale for both pitch and roll is ±45°. Tilt values near zero indicate that the profiler is vertical.

The next three numbers in each ACM scan are HX, HY, and HZ, the three components of the local magnetic field as measured by the compass. Each component is normalized by the strength of the magnetic field vector. Thus, for example,

$$HX = \frac{hx}{\sqrt{hx^2 + hy^2 + hz^2}}$$

where hx, hy, and hz are the measured components of magnetic flux along each axis of the compass. HY and HZ are determined similarly. Note that for the normalized values it is necessarily true that $HX^2 + HY^2 + HZ^2 = 1$. The normalized values are also, by definition, the direction cosines of the magnetic field in the frame of the MMP.

By convention we define magnetic flux to be maximally positive along an axis of the compass when the magnetic field vector is parallel to that axis. The magnetic flux is maximally negative along an axis of the compass when the magnetic field vector is anti-parallel to that axis. The magnetic flux is zero along an axis of the compass when the magnetic field vector is perpendicular to that axis. Using this convention we have:

$$HZ = \sin\varphi$$

where φ is the angle of the magnetic field vector measured from the horizontal. φ is positive if the field vector points above the horizontal and negative if it points below. We also have

$$\frac{HX}{\sqrt{HX^2 + HY^2}} = HX_{Horizontal} = \sin\theta_H$$

$$\frac{HY}{\sqrt{HX^2 + HY^2}} = HY_{Horizontal} = \cos\theta_H$$

and

$$\frac{HX_{Horizontal}}{HY_{Horizontal}} = \tan\theta_H$$

where θ_H is the angle of the horizontal component of the magnetic field vector measured clockwise from the positive y-axis. Defined in this way, θ_H is also the heading of the sting in "mathematical" compass coordinates:

When the sting is pointing:	θ_H is:
North	+90°
East	0°
South	-90°
West	180°

Consider an example. The magnetic flux vector in the vicinity of the McLane Research Laboratories points towards the magnetic north pole (no surprise there!) and downward at an angle that is ~70° below the horizontal. The table below shows measured values for HX, HY, and HZ for various magnetic pointing directions of the sting. Calculated values of φ, and θ_H are also included.

Sting Direction		HX	HY	HZ	φ	θ_H
N	90°	0.3645	0.0008	-0.9312	-68.6°	82.8°
NE	45°	0.2383	0.2321	-0.9430	-70.6°	37.7°
E	0°	-0.0246	0.2914	-0.9563	-73.0°	-7.4°
SE	-45°	-0.2508	0.1515	-0.9561	-73.0°	-53.7°
S	-90°	-0.3212	-0.1064	-0.9410	-70.2°	-101.2°
SW	-135°	-0.1979	-0.3218	-0.9259	-67.8°	-143.1°
W	180°	0.0511	-0.3652	-0.9295	-68.4°	174.7°
NW	135°	0.2817	-0.2563	-0.9246	-67.6°	130.4°

To collect the measurements in the table, the housing was aligned to magnetic north using a hand compass. Alignment to the other cardinal points was done by eye with reference to marks on the bench. Variations in φ are caused by the small tilt of the bench surface and compass calibration errors. Similarly, the variations in θ_H from the expected heading are caused by imperfect manual alignment and by compass calibration errors. The calibration errors, which may be as large as 10° to 20°, can be compensated for during post-processing using field data and measurements collected during a "spin test". The spin test data are collected by rotating the profiler on its base and aligning the sting to the eight cardinal points of the compass in sequence. This compass calibration procedure will be described in the discussion of Data Offload, Processing, and Interpretation. The heading calculations described above could then be applied to the corrected data without the need for horizontal normalization, which is included in the calibration. We would simply have:

$$\sin\theta_H = HX_{Corrected}$$

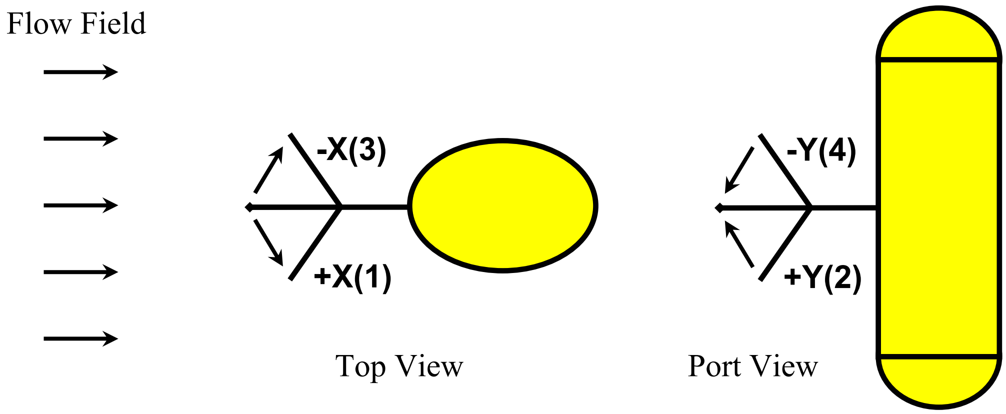
$$\cos\theta_H = HY_{Corrected}$$

$$\tan\theta_H = \frac{HX_{Corrected}}{HY_{Corrected}}$$

The final four numbers in each ACM scan are the velocities along the acoustic axes of the sting. The units are cm/s. The fingers of the sting are labeled +X, +Y, -X, and -Y. The first velocity in a scan is from the +X path, the second is from +Y, the third is from -X, and the fourth velocity is from the -Y path. By convention, the sting is mounted on the MMP with the -Y finger up. This places the +Y finger down, the +X finger to port, and the -X finger to starboard.

For the X fingers, velocity is defined to be positive for flow along the acoustic path from the central post of the sting towards the finger. For the Y fingers, velocity is defined to be positive for flow along the acoustic path from the finger towards the central post. With the sting pointed into the flow, the raw X-path velocities will be positive and the raw Y-path velocities will be negative. The angle between the acoustic paths and the central post is 45°.

These definitions and relationships are summarized in the schematic below. The arrows indicate the direction of positive flow along each acoustic path. The parenthetical values indicate the order in which the measurements appear in the scan. Translating the tilt, compass, and path velocity measurements into velocities in a Cartesian earth frame will be described during the discussion of Data Offload, Processing, and Interpretation.



Note that it is necessary to store the four path velocities and the compass and tilt information, not a Cartesian earth or MMP frame velocity vector. The contribution of profiler motion to the velocity measured by the ACM cannot be removed from such a vector during post-processing, so the ability of the ACM to perform the calculation should not be used. The ocean velocity field through which the MMP moves can only be mapped if all nine ACM measurements and an independent measure of profiling speed are available. The CTD provides that last piece of information in the form of the pressure rate, the change of depth with time.

In addition to run mode, the ACM can be placed in "cal mode" or "open mode". Cal mode is used during sensor calibration. You will seldom, if ever, need to run cal mode. We refer you to the ACM manual for further information about calibration. It is in open mode that most ACM commands are active. To place the ACM in open mode type ***O[ENTER] (that's a letter 'O', either upper or lowercase, not a zero). In open mode the response to [ENTER] is "OPEN MODE".

`***O`	← open mode command followed by [ENTER]
	← [ENTER]
`OPEN MODE`	← ACM responds

ACM Shut Down Caution

[CTRL]-[C] at anytime, regardless of the current operational mode of the ACM, will terminate the communication session and power-down the sensor. ([CTRL]-[C] is a command to the SCP, not to the ACM, so it is not "passed-through".) Read the next paragraph before you try this.

One of the idiosyncratic, and very annoying, behaviors of earlier models of this ACM was that it could lose its calibration constants if it was shut down in run mode during the narrow window in time of a memory access. While rare, this did happen.[24] According to the manufacturer, this cannot happen with the current model of the ACM. We remain unconvinced. As a precaution, we recommend placing the ACM (and the CTD) in open mode before turning the sensor off. Versions 2.08 and later of the SCP do this automatically when the operator sends [CTRL]-[C] to terminate the session.[25] If you are operating the MMP with SCP Version 2.07 or earlier you must place the ACM in open mode manually before terminating the session. We also recommend that you upgrade to Version 2.08 or later.

Standard ACM Settings for Use with the MMP

As previously discussed, there are standard ACM settings for use with the MMP. The system will check for these settings at the discretion of the operator before beginning a deployment. The system will not automatically program the standard settings, however. Using Option 4 of the Bench Tests, the ACM pass-through utility, the operator can verify and program the standard settings (or non-standard settings) before a deployment. The procedure is summarized below. When there is a → in one of the steps, the text to the left is what the operator types and the text to the right is the ACM's expected (standard settings) response. The operator can use either upper or lower case characters.

1) Establish communications using Option 4 of the Bench Tests menu.
2) Place the ACM in open mode (***O)
3) [ENTER] → OPEN MODE
4) RDM[ENTER] →
   TX=ON, TY=ON, HX=ON, HY=ON, HZ=ON, VPATH=ON, 18
5) The response to RDM (Read Data Message) indicates which features are to be logged (tilt, compass, path velocities). The number at the end is the number of bytes per scan in the compressed binary format. If other features are enabled, they can be disabled by typing NAME=OFF[ENTER], e.g., ATIME=OFF[ENTER] or STEMP=OFF[ENTER]. If any of the expected features are disabled they can be enabled by typing NAME=ON[ENTER], e.g., HZ=ON[ENTER] or VPATH=ON[ENTER]. NAME[ENTER] by itself will display the status of that particular feature.
6) ROP[ENTER] → continuous clear
   address op clear
   Logging Ops Set
   RLD checksum output cleared

[24] The colloquial phrase for these occurrences was "the sensor lost its mind again". Fortunately, the default coefficients that replace the lost constants make data recovery during post-processing possible. The correct constants can be re-entered manually from the calibration sheet provided with each unit by the manufacturer. See the ACM manual for further information.

[25] Versions 2.08 and later of the SCP automatically place the CTD and the ACM in open mode before any automatic or operator commanded sensor shut down. In earlier versions of the SCP, the sensors were normally in open mode before shut down during a deployment. The modifications in Version 2.08 and later make the mode explicit during a deployment. The Version 2.08 modifications also make the transition automatic for exit from all of the Bench Tests utilities.

7) If the response to ROP, Read Operational Parameters, varies from the expected one, enter commands from the list below to correct the deviations:
   - CCOP[ENTER] clears continuous
   - CAOP[ENTER] will clear address operation
   - SLOG[ENTER] sets logging ops
   - the operator cannot control the checksum output
8) TILT[ENTER] → TILT = on
9) COMP[ENTER] → COMP = on
10) NRML[ENTER] → NRML = on
11) If any of the last three responses varies from the expected value: TILT=ON[ENTER] enables tilt, COMP=ON[ENTER] enables the compass, and NRML=ON[ENTER] sets compass normalization.
12) AVGI[ENTER] → Averaging Interval Time = 00:15
    Enter interval (mm:ss):
13) If the averaging interval is 00:15 you can respond with [ENTER] or 00:15[ENTER]. If the averaging interval is not 00:15 your response should be 00:15[ENTER]. (Averaging is not actually being used by the ACM, but a zero value will cause the ACM to behave differently when it first begins logging. The non-zero value 00:15 is essentially arbitrary. You should use it because this is the value that the SCP has been programmed to expect.)
14) If you have made corrections, run the commands again to verify the changes.
15) When the settings have been verified the command ***E[ENTER] will store them in the ACM EEPROM.
16) Wait a few seconds for the ACM to send a carriage return to the screen, indicating that the storage operation is complete.
17) [ENTER] → OPEN MODE
18) [CTRL]-[C] to terminate the session and shut down the ACM.
19) If you made corrections, re-establish communications and verify that the settings are now correct on power-up.

A sample interaction, verifying standard ACM settings, is shown below.

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

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

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

***O                                ← open mode command followed by [ENTER

                                    ← [ENTER]
OPEN MODE                           ← ACM responds
RDM                                 ← RDM[ENTER], operator query for data message
TX = ON, TY = ON, HX = ON, HY = ON, HZ = ON, VPATH = ON, 18 ← ACM responds with
                                                          correct standard settings
ROP                                 ← ROP[ENTER], operator query for operational parameters
continuous clear                    ← ACM responds with correct standard settings

address op clear


Logging Ops Set
RLD checksum output cleared
```

```
TILT                                  ← operator checks tilt, compass, and averaging settings
TILT = on                             ← ACM responds with correct standard settings

COMP
COMP = on

NRML
NRML = on

AVGI
Averaging Interval Time = 00:15
Enter interval (mm:ss):

***E                                  ← ***E[ENTER], operator commands non-volatile storage
                                         of the parameters
                                      ← ACM sends CARRIAGE RETURN when storage is complete
                                      ← operator sends [CTRL]-[C] to terminate session
 TX channel closed.                   ← SCP commands "open mode" as a precaution, shuts down
 RX channel closed.                   ← communication channels, and . . .

 Shutting down power to ACM.          ← . . . shuts down ACM.

 Press any key to continue.
```

Non-standard ACM settings will affect system operation during a deployment. Caution and a trial deployment on the bench are strongly advised if you chose to deploy an MMP with other than the standard ACM settings.

<5> ACM Tilt and Compass

Bench Tests Option 5 provides a scrolling display of ACM tilt and compass information. This option powers-up the ACM and then periodically queries the sensor for a scan of data using the carriage return run mode command. The program parses the response to extract tilt and compass measurements, displays the result, and repeats the cycle until interrupted by the operator. An example is shown below.

```
This option displays the ACM tilt (TX and TY)
and compass (HX, HY, and HZ) outputs for use
while mounting the ACM pressure housing.

<CTRL>-<C> to terminate display.

Applying power to ACM . . . ready.


  TX      TY       HX       HY       HZ

+00.51  +01.12  +0.3460  -0.0051  -0.9382      ← Scrolling display
+00.45  +01.31  +0.3464  -0.0038  -0.9381
+00.47  +01.16  +0.3467  -0.0025  -0.9380
+00.45  +01.26  +0.3470  -0.0018  -0.9379
+00.40  +01.27  +0.3473  -0.0017  -0.9378
+00.45  +01.18  +0.3470  -0.0017  -0.9379
+00.39  +01.30  +0.3470  -0.0030  -0.9378
+00.44  +01.21  +0.3468  -0.0035  -0.9379
+00.47  +01.26  +0.3465  -0.0031  -0.9380
+00.45  +01.30  +0.3459  -0.0047  -0.9383
+00.43  +01.23  +0.3468  -0.0044  -0.9379
                                               ← [CTRL]-[C] to terminate scrolling
Press any key to continue.
```

The scrolling display provides the operator with a hands free data steam during a "spin test". A spin test is conducted to generate compass calibration corrections for use during post-processing. The scrolling display can be logged using the file capture utility of Crosscut or TattleTerm.

Versions 2.08 and later of the SCP place the ACM in open mode before shutting it down. Earlier versions of the SCP shut down the ACM in run mode. This will occasionally cause a problem. We recommend that you upgrade to the current version of the SCP and that you refrain from using this Bench Tests option until you have installed the upgrade.

<6> Motor Operation

Bench Tests Option 6 is used to test the drive motor. The operator can control the direction of rotation, up or down the mooring cable, and the duration of the velocity ramp. We recommend that you visually verify that the motor is spinning in the proper direction when you conduct this test. A ramp duration of 30 seconds is recommended if the motor is loaded when it starts turning (as it would be starting a profile in the water). When operating unloaded on the bench a duration of a few seconds is amply sufficient. A scrolling display of date and time, motor current, and battery voltage is provided once the motor reaches full speed. The operator can stop the motor abruptly (as it would be stopped during a profile) or with a velocity down ramp. The motor is automatically disabled and the brake set once the motor is stopped. An example is shown below.

```
Motor direction (Up/Down)       [U] ?                ← the default direction is up
Enter ramp duration [sec] (2 to 60) ? 5              ← the motor sat on the bench, in air
                                                          and initially unloaded
Beginning start ramp.                                ← PWM velocity ramp begins


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

02/09/2002 18:35:03   37 mA   10.5 V                 ← scrolling display begins
02/09/2002 18:35:04   37 mA   10.5 V
02/09/2002 18:35:05   37 mA   10.4 V
02/09/2002 18:35:06   37 mA   10.5 V
02/09/2002 18:35:07   37 mA   10.4 V
02/09/2002 18:35:08   49 mA   10.4 V                 ← a load is applied . . .
02/09/2002 18:35:09  111 mA   10.4 V
02/09/2002 18:35:10  120 mA   10.4 V
02/09/2002 18:35:11  119 mA   10.4 V
02/09/2002 18:35:12  126 mA   10.3 V
02/09/2002 18:35:13   64 mA   10.5 V                 ← . . . and removed
02/09/2002 18:35:14   37 mA   10.4 V
02/09/2002 18:35:15   37 mA   10.5 V
02/09/2002 18:35:16   37 mA   10.4 V
02/09/2002 18:35:17   36 mA   10.5 V
02/09/2002 18:35:18   36 mA   10.5 V                 ← [CTRL]-[C] stops the motor

Motor disabled.  Brake set.

Press any key to continue.
```

The load applied while the motor was spinning was the author's finger pressing against the drive wheel.[26] We invite you to give this a try. Begin gently and don't catch your finger between the wheel and the anti-fouling shroud.[27] Motor currents of 35 to 40 mA are typical when the motor is unloaded. Currents of 120 to 130 mA are common during a profile in the MRL test tank where hydrodynamic drag becomes a factor. In the ocean, where horizontal forcing by the ocean velocity field increases drive train friction, motor currents of 140 to 200 mA and more have been recorded (Morrison, et al., 2001).

<7> Brake/Free Wheel Toggle

Recall from the description of the drive motor in the discussion of System Architecture that the motor can free wheel or the brake can be set. Option 7 toggles the motor between those two states. The motor will spin freely if free wheel is set and will strongly resist external torques if the brake is set. Again, we invite you to give this a try (including poking at the wheel in both states). An example is shown below. Note that the current state is shown by the menu item.

[26] To the best of my recollection it was my right index finger, but almost any finger will do.
[27] Or, as we say in academia, instruct a graduate student to begin gently, advising them to keep their fingers away from the anti-fouling shroud.

```
        Bench Tests
     Sat Feb  9 18:35:21 2002


  <1> CTD Communications     <6> Motor Operation
  <2> CTD Pressure           <7> Brake set.  Change?             ← brake set
  <3> CTD Average Pressure   <8> Ping Transponder
  <4> ACM Communications     <9> Test System Watchdog
  <5> ACM Tilt and Compass   <M> Main Menu

         Selection  ? 7                                          ← Option 7

Enable Free Wheel (Yes/No) [Y] ?                                 ← default sets
                                                                    free wheel
        Bench Tests
     Sat Feb  9 18:35:24 2002


  <1> CTD Communications     <6> Motor Operation
  <2> CTD Pressure           <7> Free Wheel enabled.  Change?    ← free wheeling
  <3> CTD Average Pressure   <8> Ping Transponder
  <4> ACM Communications     <9> Test System Watchdog
  <5> ACM Tilt and Compass   <M> Main Menu

         Selection  ? 7                                          ← Option 7 again

Set BRAKE (Yes/No) [Y] ?                                         ← default sets
                                                                    brake
```

<8> Ping Transponder

Bench Tests Option 8 is used to verify that the transponder is on and functioning. Recall that the transponder has an independent power supply and an off switch; even if this optional system component is installed, it may have been manually disabled. When this option is selected the SCP commands transponder pings at three second intervals, displaying a time tag on the screen for each ping. Three seconds is marginally longer than the transponder's minimum cycle time.

```
Transponder will ping at 3 second intervals
until terminated by a <CTRL>-<C>.

 02/09/2002 18:35:30                  ← scrolling time tags indicate when each
 02/09/2002 18:35:33                     ping command was sent
 02/09/2002 18:35:36
```

The 9 V batteries powering the transponder have sufficient capacity for a one year deployment under normal conditions. The most significant part of the transponder power budget is the 3 mA continuous quiescent current drain while listening for a signal, not the high power, short duration transmissions made in response. Many times repeated ping commands will, however, have a significant effect. We suggest that you make it a practice to terminate this option with alacrity.

Note that this utility tests only the transmit circuitry of the transponder. The receive circuitry and the ability of the unit to function as a transponder can be tested with a deck unit or by jingling keys near the transducer to simulate an acoustic signal. Either approach will trigger a response ping, confirming that the unit is functioning. We recommend that you make this a regular part of system testing.[28]

<9> Test System Watchdog

Recall that the system watchdog circuit is composed of the DS1306 chip, which sends periodic interrupt requests to the TT8, and a hardware counter, which can restart the TT8 if the IRQ from the DS1306 is not acknowledged. Both portions of the watchdog circuit can be tested using Bench Tests Option 9. The test menu is shown below.

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

  Selection  ?
```

The Watchdog IRQ test temporarily resets the DS1306 clock, the WDC, so that it believes the time is 2 seconds before the regularly scheduled watchdog IRQ. The watchdog sends the IRQ when the 2 seconds have expired, the TT8 detects the interrupt and acknowledges it, and the system, including the WDC, is returned to normal. Failures are detected and reported to the operator. An example is shown below.

```
Initializing . . . done.                              ← WDC reset

Waiting for IRQ (2 seconds) . . . IRQ detected.       ← IRQ sent and detected

Watchdog IRQ test complete.                           ← system restored to normal
Watchdog is functioning normally.                        operating condition
```

The Watchdog RESET test reprograms the watchdog IRQ pin on the TT8 so that interrupts from the DS1306 will be ignored. It then resets the hardware counter to zero and transitions to low power sleep. The counter re-boots the TT8 after 68 minutes (4096 seconds). The test will "time out" after 70 minutes if there is no reset and can be stopped manually at anytime with a [CTRL]-[C]. This is necessarily a long test, but you should conduct it occasionally. An example of an operator terminated test is shown below.

[28] Jingling keys or banging wrenches together is a convenient and legitimate test of transponder function. Note, however, that the keys and wrenches produce a relatively broad band signal. The deck unit transmits a signal in the receive band. Ultimately, testing with a deck unit should be undertaken, if only because it is the deck unit that will be used to query the transponder when it is in the water.

```
This test verifies operation of the watchdog          ← on-line explanation of test
system RESET.  If successful, the system will
be RESET and operation will proceed as it does
when power is first applied to the system.
The RESET will not occur until an interval of
68 minutes and 16 seconds (4096 seconds) has
passed.  The test will time out after 70 minutes
if the RESET hardware fails.  The operator can
cancel the test at any time by entering three or
more <CTRL>-<C>s.

Proceed with test (Yes/No) [N] ? y                    ← operator chooses to proceed

Current time:   02/09/2002 18:36:05                   ←test timing information
Expected RESET: 02/09/2002 19:44:21
Time out:       02/09/2002 19:46:05

<02/09/2002 18:36:07> Sleeping . . .                  ← system enters LPS

Enter <CTRL-C> now to wake up?                        ← awakened by operator before
                                                         completion of the test
02/09/2002 18:36:09                                   ← system restored to normal
Watchdog RESET test terminated by
operator before completion.
```

URAO

We conclude this section with an example in which the Watchdog RESET test was allowed to take its course and in which, after the re-boot, the operator did not assert control. This is a demonstration of the URAO feature (Unattended Reset, Autonomous Operation) mentioned in previous chapters. The example shows portions of the layered approached to system recovery which makes the system robust. The system automatically programmed and started a deployment without operator guidance. Only the SCP and the autoexec program were on the flash card. No deployment was in progress and no deployment parameters had previously been programmed and stored. The SCP worked from a default set of parameters, programmed into the system for just such an emergency, and reconstructed the other information it needed by searching through the file system. The MMP is designed to carry on, no matter what.

```
This test verifies operation of the watchdog
system RESET.  If successful, the system will
be RESET and operation will proceed as it does
when power is first applied to the system.
The RESET will not occur until an interval of
68 minutes and 16 seconds (4096 seconds) has
passed.  The test will time out after 70 minutes
if the RESET hardware fails.  The operator can
cancel the test at any time by entering three or
more <CTRL>-<C>s.

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

Current time:   02/10/2002 15:38:37
Expected RESET: 02/10/2002 16:46:53
Time out:       02/10/2002 16:48:37

<02/10/2002 15:38:38> Sleeping . . .        ← system checks status every 20 minutes
                                               during low power sleep
```

```
<02/10/2002 15:58:38> Sleeping . . .
                                          ← watchdog IRQ ignored at 1 minute after
                                             the hour
<02/10/2002 16:18:38> Sleeping . . .


<02/10/2002 16:38:38> Sleeping . . .

MMP-2_08                                  ← watchdog RESETS TT8 and restarts the
                                             SCP, the power-up sequence
                                             begins

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.


 0 seconds                                ← counter is allowed to expire

   >>> A system RESET has occurred <<<    ← autonomous recovery begins

    Unattended Deployment Preparation     ← steps in the recovery are displayed on
       routine has been activated.           the screen as they occur

Setting system clock from watchdog . . . done.

Examining the flash card . . . initialization successful.

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

439.443 Mbyte flash card installed
439.263 Mbyte currently free

File system can accommodate  4091 data files
Deployment can include up to 1362 profiles


Logging the unattended reset . . . done.

Recovering the profile count . . .

Can't open file PROFILES.DAT.
File may not exist or file system may have failed.

Second attempt . . .

Can't open file PROFILES.DAT after two attempts.
File may not exist or file system may have failed.

Could not recover profile count.          ← the reconstruction is performed by searching
Reconstructing . . . done.                   the file system with a simple bisection
                                             algorithm for existing engineering files
Recovering deployment parameters . . .

Performing final initialization . . . done.

Unattended deployment preparations complete.
Continuing deployment.

02/10/2002 16:47:33
```

```
Initializing CTD logging pointers . . .      ← the initialization conversations with the CTD
                                                and the ACM were edited out (they would
                                                otherwise increase the length of this
Initializing ACM logging pointers . . .         example by several pages)


02/10/2002 16:47:53

Continuing 120 second sensor warm-up.
Initial dive to bottom stop will begin at  02/10/2002 16:49:33.


<02/10/2002 16:47:54> Sleeping . . .


02/10/2002 16:49:33

Can't open file PROFILES.DAT

Attempting to create file PROFILES.DAT       ← the file is initialized with the reconstructed
                                                value of the profile count (no profiles
Opening file E0000000.dat for storage of        had been conducted, so 0 is the
profile 0 engineering data.                     correct value)

Beginning profile 0                          ← profile begins with PWM velocity ramp,
                                                note that the system correctly
                                                reconstructed the profile count
Terminated by operator.                      ← author terminates the example with several
Motor disabled.  Brake set.                     [CTRL]-[C]s before ramp is completed

Storing data from last profile.              ← system terminates the profile gracefully,
Please wait.                                    taking care of the file system first

<CTRL>-<C>s will abort the storage
procedure and flush the data from
the last profile.

5 second pause for operator entry.

Closing engineering data file . . . done.

Deployment complete.
Please recover me.
```

It may be tempting to view URAO as a "throw and go" feature, allowing operators to pre-program the MMP and then, at a later date, simply connect the battery and launch the profiler without further operator interaction. While this would work, we do not recommend it. When URAO is triggered, it assumes that the MMP is already in the water and that the mooring is already deployed. Profiling typically starts less than 3 minutes after the battery is connected or about 71 minutes after the Watchdog RESET test is begun. The former is not enough time to launch a mooring. The latter may be, but only in a limited set of circumstances. While MMP hardware and software are able to handle such a situation with aplomb, this is not the intent of the feature.

This completes the description of the MMP Bench Tests. MRL recommends a full system assessment, using the Bench Tests options, before every deployment. We also recommend the Bench Tests for operator training and system familiarization.

<6> Deploy Profiler

Main Menu Option 6, Deploy Profiler, has three distinct functions. It provides the interface through which the operator enters the parameters that define a deployment, it can be used interactively during deployment planning, and it conducts the programmed deployment.

Once the deployment definition information is entered and stored in the EEPROM (and on the flash card), the operator may choose to return to the Main Menu without starting the deployment. The parameters are secure in non-volatile storage and will be loaded the next time the system is powered-up. The parameters also remain in RAM if the battery is not disconnected and will be unchanged when the Deploy Profiler option is selected again. Note, however, that exiting from the Deploy Profiler option and returning to the Main Menu terminates the deployment. The SCP is not a multitasking operating system and does not keep multiple processes running concurrently.

Before continuing it will be useful to review the selection below, During a Deployment, which is taken verbatim from the discussion in System Architecture.

During a Deployment

After an operator programs the MMP and initiates the autonomous portion of a deployment, the profiler enters a low power state for a user-specified interval. During that time the launch of the profiler and the setting of the mooring can be completed. The system then conducts the first profile, which is denoted Profile 0. If it is not already there, Profile 0 takes the MMP to the bottom of the programmed range. Subsequent profiles are numbered 1, 2, 3, … and are conducted following the schedule programmed by the operator. Odd numbered profiles proceed from the bottom of the programmed range to the top of the programmed range. Even numbered profiles proceed from top to bottom.

Two minutes before the scheduled start time of each profile the system turns on the sensors and they begin logging data. Profiler motion starts at the scheduled start time. During the profile the sensors log data autonomously and the MMP records engineering and status information. Motion stops when the end of the programmed profiling range is detected. The sensors continue to log internally for two minutes. The system then stops the sensors and transfers their data to the flash card. The intervals of sensor logging before motion begins and after it ends provide data that can be used during post-processing to correct for sensor drift. Other conditions, an obstacle blocking the mooring cable for example, may be detected during a profile and may trigger behavioral changes. A profile is considered complete when the sensor and engineering files have been closed. The system enters the low power sleep state again and waits for the next scheduled profile.

The system will continue to conduct profiles in this manner until the deployment is terminated. Termination by the system will occur if the battery is fully drained or if the flash card or the file system become full. The deployment can also be manually terminated by the operator after recovery.

Deployment Initialization

When Deploy Profiler is selected the SCP conducts a deployment initialization procedure to confirm that the MMP is ready to deploy. The checks are not exhaustive. We recommend that you first exercise the system using the tools in Bench Tests.

The system first checks that the file system (PicoDOS, the AT8, and the flash card) has been successfully initialized. A warning and instructions will be displayed if there is a problem and the SCP will terminate the deployment. Next, the operator is prompted to set the RTC. Setting the clock can be skipped if it is already properly set. The prompt is included primarily as a reminder to the operator that the clock must be accurate if the deployment is to be successful. Recall that at power-up the RTC is initialized to January 1, 1970, more than 30 years before the start time of the deployment. The system will try to wait that long if the clock is not set. Once the operator confirms the clock setting the system synchronizes the watchdog clock. If a watchdog problem is detected a warning and instructions will be displayed and the SCP will terminate the deployment.

Next, the system displays the profiling odometer and trip meter, giving the operator an opportunity to reset the latter. The display is included to remind the operator to replace the main lithium battery if the remaining energy capacity is insufficient for the planned deployment. A profiling endurance of 1 to 1.2 million meters can be assumed for a standard lithium battery pack. The trip meter should be reset when a fresh battery is installed.

The final check in the deployment initialization sequence is verification of the CTD and ACM settings. The operator may select automated or manual verification or may choose to skip the sensor check. The latter option should not be exercised if the operator intends to start a deployment. The ability to skip the checks is useful when the CTD or the ACM is not available for a bench test or the operator only wishes to review existing deployment parameters. Skipping the checks is also convenient during deployment planning, an interactive and iterative process that uses the parameter range and consistency checks built into the SCP to test the feasibility of proposed profiling schedules.

Automated verification conducts conversations with the CTD and the ACM to establish that the standard settings have been programmed into the sensor EEPROMs. The commands used and the expected responses are exactly those described in Bench Tests in the sections Standard CTD Settings for Use with the MMP and Standard ACM Settings for Use with the MMP (you are encouraged to make a comparison). The system does not correct the settings when an unexpected response is received. This is a task for the operator. If a sensor problem is detected, a warning and instructions will be displayed and the SCP will terminate the deployment.

Manual verification establishes pass-through communications channels to the sensors and allows the operator to verify, and change if desired, the settings of the CTD and the ACM. This feature is included to give operators greater flexibility in conducting a deployment. Note that the selected sensor settings are entirely the responsibility of the operator if this mode of verification is chosen. Importantly, if non-standard settings are programmed, the operator becomes responsible for processing the binary data in the sensor files. The McLane on-board offload utility and the high-speed profiler data processor will only work with binary files created using the standard sensor settings.[29] More importantly, there are some combinations of non-standard settings that will make data collection during a deployment impossible. If you choose to use non-standard settings, run a trial deployment in the lab before you go to sea and verify that the system will function as expected.

[29] Custom unpackers, for those customers who require them, can be contracted for through MRL.

An example of the initialization sequence is shown below. In this case the operator selected automated verification of standard CTD and ACM settings.

```
        McLane Research Laboratories, USA
             McLane Moored Profiler
      Version: mmp-2_08.c   S/N: ML00414-42

                     Main Menu
             Wed Feb 13 18:12:02 2002


      <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                        ← operator selects Deploy Profiler from
                                                 the Main Menu

 Clock reads 02/13/2002 18:12:04
 Change time & date (Yes/No) [N] ?            ← prompt to set RTC, operator's response
                                                 indicates current RTC time is correct
 Setting watchdog clock . . . done.           ← system synchronizes WDC

 Profiling odometer
   Total profiling distance:          0 meters      ← system odometer
   Battery trip meter:                0 meters      ← battery trip meter

 Reset trip meter (new battery) (Yes/No) [N] ?      ← no reset required


 Verification of CTD and ACM settings         ← verification of sensor settings

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

  Selection  ? a                              ← operator selects automated verification


 Automated verification of CTD and ACM settings.

 Applying power to CTD . . .                  ← system powers up the CTD
 Starting verification . . .

 Sending command  ***O                        ← CTD conversation begins, the conversation
                                                 is a series of commands and responses,
                                                 the system parses the responses to verify
Open Mode                                        that they match the expected responses


 Expected response received.
 Proceeding to next command.
```

```
 Sending command  ROP

1335
Scale is OFF
Address Operation is OFF
Auto is ON


 Expected response received.

 Standard CTD settings verified.

 Applying power to ACM . . .
 Starting verification . . .

 Sending command  ***O


OPEN MODE


 Expected response received.
 Proceeding to next command.

 Sending command  ROP

continuous clear

address op clear


Logging Ops Set
RLD checksum output cleared


 Expected response received.
 Proceeding to next command.

 Sending command  RDM

TX = ON, TY = ON, HX = ON, HY = ON, HZ = ON, VPATH = ON, 18



 Expected response received.
 Proceeding to next command.

 Sending command  TILT

TILT = on



 Expected response received.
 Proceeding to next command.
```

← standard CTD settings verified

← system powers up the ACM

← ACM conversation begins, the conversation a series of commands and responses, the system parses the responses to verify that they match the expected responses

```
 Sending command  COMP

COMP = on


 Expected response received.
 Proceeding to next command.

 Sending command  NRML

NRML = on


 Expected response received.
 Proceeding to next command.

 Sending command  AVGI

Averaging Interval Time = 00:15
Enter interval (mm:ss):

 Expected response received.
 Proceeding to next command.

 Sending command



 Expected response received.

 Standard ACM settings verified.              ← standard ACM settings verified


 Sensors initialized and ready for deployment. ← sensors initialized and ready to go

 Press any key to continue.
```

Programming a Deployment

When deployment initialization is complete the Deployment Menu, shown below, will be displayed. The menu is re-displayed each time changes are made by the operator. This is the interface through which the operator programs the deployment parameters. It is the deployment parameters that guide and control the conduct of the deployment. With respect to the scientific goals of an investigation, this is the single most important portion of the MMP user interface. It is critical that the operator and the investigator (if they are not one and the same) understand and are comfortable with each of the parameters. We strongly encourage you to experiment with these options while you read this section of the manual. You can't hurt the profiler and you will learn more about the system.

```
Start    1| Countdown delay        =     06:00:00 [HH:MM:SS]

Schedule 2| Pair start interval    = 000 06:00:00 [DDD HH:MM:SS]
         3| Reference date/time    =   02/18/2002 00:00:00
         4| Burst interval         = 007 00:00:00 [DDD HH:MM:SS]
         5| Pairs per burst        =           12
         6| Paired profiles              Enabled

Stops    7| Shallow pressure       =        500.0 [dbar]
         8| Deep pressure          =       2500.0 [dbar]
         9| Shallow error          =        100.0 [dbar]
         A| Deep error             =         50.0 [dbar]
         B| Profile time limit     =     02:46:40 [HH:MM:SS]
         C| Stop check interval    =           30 [sec]

         D| Done

         Selection  ?
```

Each of the deployment parameters is described in one of the boxes below. A "quick reference" summary can be found in the next section. A laminated version of the quick reference, suitable for deck use, is provided with the profiler. To change a parameter, type the associated number or letter from the menu followed by [ENTER]. When you make a selection a prompt or series of prompts for the parameter will be displayed. An example appears below. Each parameter has an allowed range, which is displayed on screen as part of the prompt and also in the written descriptions below.

The parameters are divided by general function into three groups: Start, Schedule, and Stops. The Start parameters, which can be either a countdown delay or an absolute date and time, control the start time of Profile 0, the first profile of the deployment. Recall that the MMP uses Profile 0 to locate the bottom stop. However it is set, the start delay is intended to give the operator and the deck team time to launch the profiler and set the mooring before profiling begins.

<u>Countdown delay</u>: A countdown delay is specified in hours, minutes, and seconds. It can be set as small as 00:00:00 and as large as 24:00:00. The countdown timer begins decrementing after the system pings the transponder at the start of a deployment. The ping marks the end of the 30 second interval during which the communications cable is normally disconnected before launch. That interval begins after flash card initialization. There will be more information about these procedures later in this section. For now it is sufficient to say that the countdown begins 1 to 2 minutes after the operator commits to a deployment. Profile 0 begins when the countdown reaches zero. Allowed range: 0 seconds to 24 hours in 1 second increments

To specify the deployment delay as a scheduled start time rather than a countdown delay, select Option 1 and choose scheduled at the prompt as shown in the example below.

```
         Selection  ? 1

(S)cheduled start or (C)ountdown delay [C] ? s

Current time:    02/17/2002 15:13:39
Enter date as MM DD YY HH MM SS
Enter year 2001 as 1, 01, 101, or 2001

Enter scheduled start date and time:   [02/17/2002 15:13:40] ? 2 17 02 21 0 0

Start    1| Scheduled start        =   02/17/2002 21:00:00

Schedule 2| Pair start interval    = 000 06:00:00 [DDD HH:MM:SS]
         3| Reference date/time    =   02/18/2002 00:00:00
         4| Burst interval         = 007 00:00:00 [DDD HH:MM:SS]
         5| Pairs per burst        =           12
         6| Paired profiles              Enabled

Stops    7| Shallow pressure       =        500.0 [dbar]
         8| Deep pressure          =       2500.0 [dbar]
         9| Shallow error          =        100.0 [dbar]
         A| Deep error             =         50.0 [dbar]
         B| Profile time limit     =     02:46:40 [HH:MM:SS]
         C| Stop check interval    =           30 [sec]

         D| Done

         Selection  ?
```

Scheduled start: A scheduled start is specified as an absolute date and time. Profile 0 begins when the RTC reaches the specified time. A scheduled start time must be at least 10 minutes in the future at the time the operator makes the entry. It must still be at least 10 minutes in the future when the operator selects Option D. (Option D indicates to the system that deployment programming is complete.) If either requirement is not met a warning will be displayed and the operator will be prompted to change the start time. An example entry is shown above.

Allowed range: Years 1970 to 2038 in 1 second increments and at least 10 minutes in the future as measured by the RTC.

The Schedule parameters control the timing of profiles. Profiles can be scheduled singly or in up-down pairs. The profiles or pairs of profiles can be scheduled at regular intervals or in bursts. Burst profiling is conducted with regular intervals between bursts and (shorter) regular intervals between starts within a burst.

Profile start interval/Pair start interval: The interval between profiles or pairs of profiles. The interval is measured between the start of profiling motion of sequential profiles or pairs of profiles. If the interval is less than the time required to complete a profile or pair of profiles, profiles or pairs will be skipped to prevent asynchronous profiling. This feature is a result of the reference time algorithm described below.

The exception to this rule is continuous profiling, which is selected by setting the start interval to 0. During continuous profiling each profile begins as soon as the previous profile is complete. There is no delay between profiles. Continuous profiling is asynchronous. It will provide the densest sampling possible with the MMP.

Allowed range: 0 seconds to 366 days in 1 second increments

Reference date/time: The initial reference time for the deployment. All subsequent profiles are referenced to this time. At the end of each profile or pair of profiles, including Profile 0, the system compares the reference time to the RTC. If the reference time is in the future, no change is made. If the reference time is in the past, it is iteratively incremented by the start interval until a time in the future is reached. That time becomes the new reference. If the start interval is consistent with (longer than) the time it takes to actually complete a profile or pair of profiles, then a single increment will typically be sufficient. Profile or pair motion starts on this sequence of reference times.

Consider, for example, the parameters in the deployment menus above. If Profile 0 is completed before 02/18/2002 00:00:00, then Profile 1 will begin at 02/18/2002 00:00:00. If, however, Profile 0 is completed at 02/18/2002 00:30:00, the reference time will be incremented once by the 6 hour start interval and Profile 1 will begin at 02/18/2002 06:00:00. Profile 2 will follow immediately because paired profiles is enabled. Assuming that first pair is completed in less than 6 hours, Profile 3 will begin at 02/18/2002 12:00:00. This will continue every 6 hours until the 12 pairs of the first burst are completed. If each pair requires more than 6 hours to complete, 8 hours for example, the pairs will start every 12 hours. The burst will still consist of 12 pairs, but it will take 6 days instead of 3 days to complete them.

Note that it is perfectly acceptable to set the reference time to some moment well in the past. This might be done to establish a common reference for an ongoing series of deployments or to make synchronization to tidal signals easier. The reference time can also be set well into the future, though this will mean a long wait for Profile 1. Most typically, the reference time is set a few hours or days in the future, after Profile 0 is expected to be completed, and is the time at which the investigator wishes Profile 1 (and Burst 1) to begin.

Note that the reference time is not used to schedule profiles if continuous profiling is selected. In particular, Profile 1 will begin immediately after Profile 0 is completed if the start interval is zero. This is also true for burst timing when the burst interval is set to zero.

Allowed range: Years 1970 to 2038 in 1 second increments

Burst interval: The interval between bursts of profiles or pairs of profiles. Burst sampling is used to balance the need for relatively high frequency profiling (to avoid aliasing the tidal signal, for example) with the finite endurance of the profiler and the need for long time series.

The behavior of the burst interval is similar to the behavior of the profile/pair start interval. Continuous bursts are selected by setting the burst interval to 0. When bursts are continuous, each burst starts as soon as the previous burst is complete. This behavior is independent of the profile schedule within each burst, which may be either continuous or timed by a non-zero profile/pair start interval. When bursts are continuous they are asynchronous. Even if the profiles within a burst are scheduled, that schedule is re-referenced with each new burst to the start of that burst; each burst starts asynchronously when the last profile of the previous burst is complete. That last is a subtle but important point if you are concerned with profile timing. The first profile or pair in the next burst occurs immediately, not after the balance of the programmed profile or pair start interval expires, even though the profiles or pairs within the burst are evenly spaced.

The timing of the first burst with respect to the initial reference time requires explanation. If the reference time is in the future when Profile 0 is completed, then Profile 1 and the first burst will begin at the initial reference time. This is how a deployment is normally programmed. If the initial reference time is in the past when Profile 0 is completed, the reference time is iteratively incremented by the (shorter) profile/pair interval, rather than the (longer) burst interval, to establish a new reference. Profile 1 and the first burst will begin at the new reference time. However, subsequent bursts are referenced by burst interval increments to the originally programmed reference time. Simply stated, this means that if the initial reference time is in the past, the first burst begins asynchronously but relatively quickly and subsequent bursts synchronously follow the programmed schedule.

Allowed range: 0 seconds to 366 days in 1 second increments

Profiles per burst/ Pairs per burst: The number of profiles or pairs of profiles in a burst. Setting this parameter to 1 disables burst profiling. When burst profiling is disabled the profiling schedule is determined by the profile start interval alone.

Consider the example provided by the deployment parameters above. For simplicity, assume the scheduling is consistent and that Profile 1 begins at the initial reference time. Then, every 6 hours, at 0000, 0600, 1200, and 1800, the MMP will start a pair of profiles. It will do this until the burst of 12 pairs has been completed. This will take 3 days. There will be no further profiling for 4 days, the balance of the 7 day burst interval. The pattern will then repeat with another burst of 12 pairs over 3 days, beginning at 0000, 7 days after the previous burst began.

Note that the MMP will continue a burst until it has completed all of the profiles or pairs of profiles in the burst. If this requires longer than the burst interval then the next burst (or bursts) will be skipped. Consider again the example deployment parameters above. If each pair of profiles actually required 7 hours to complete, then every other pair would be skipped. Pairs would start every 12 hours and the burst of 12 pairs would last 6 days rather than 3 days. Bursts would still start every 7 days. However, if each pair of profiles required 13 hours to complete, then pairs would start every 18 hours. The burst of 12 pairs would last 9 days and bursts would start every 14 days. Every other burst would be skipped.

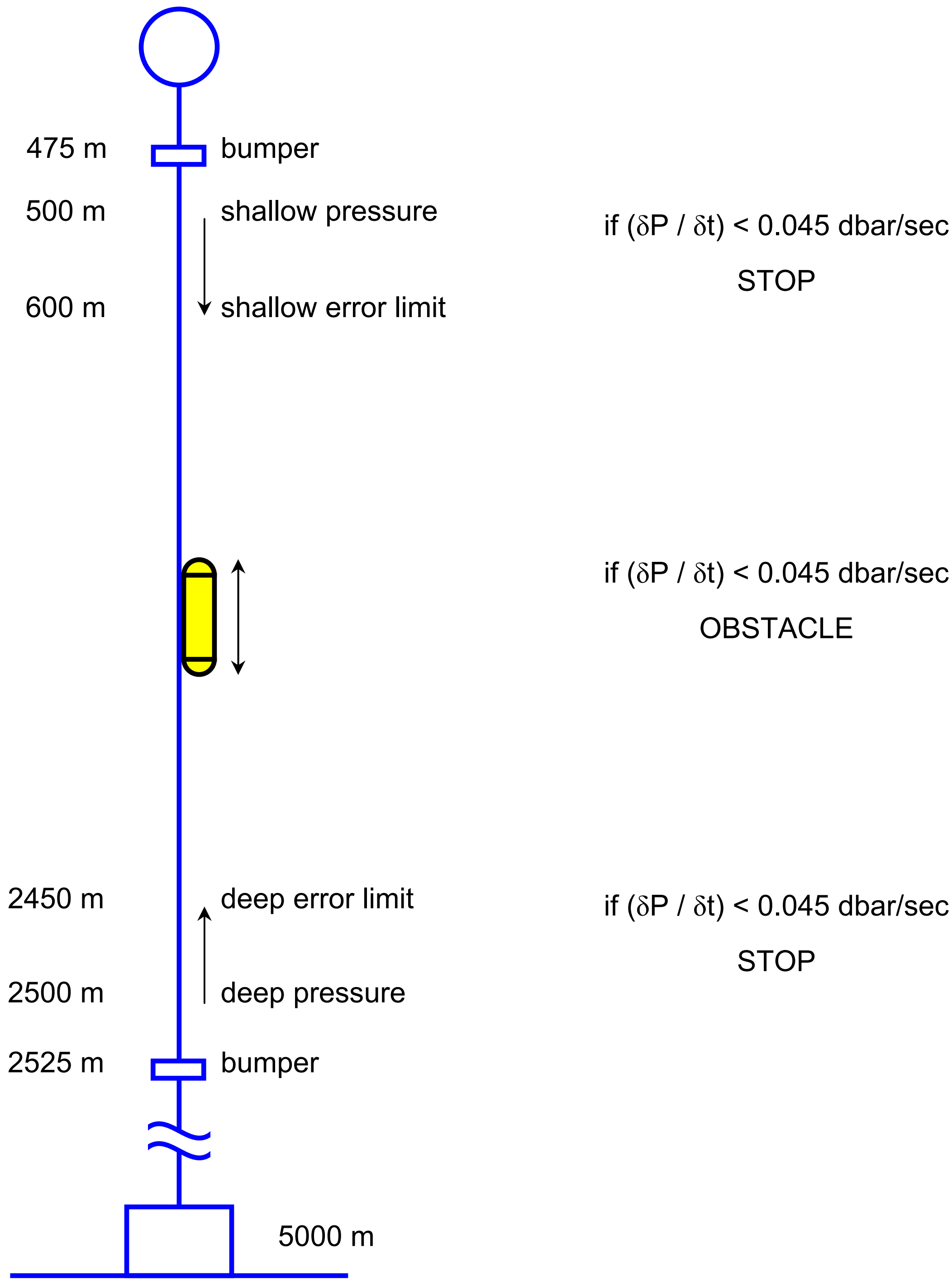
Allowed range: 1 - 1000 profiles or pairs of profiles

Paired profiles: Enables or disables paired profiles. When paired profiles are enabled, the deployment is scheduled in up-down pairs. The down profile is begun as soon as the up profile, inclusive of data storage, is completed. The start interval is the time between the start of motion for sequential up profiles. When paired profiles are disabled the system conducts the deployment in single profiles and the start interval is the time between the start of motion for sequential profiles.

Allowed range: Enabled/Disabled

The Stops parameters define the limits of each profile and guide the system in their detection. The MMP depends primarily on pressure measurements made by the CTD to detect the end of a profile. However, system status and elapsed profiling time are also monitored. This layered detection approach allows profiling to continue independent of the CTD. The reader may wish to refer to the accompanying schematic drawing of an MMP mooring. The schematic has been drawn to match the stops parameters in the example above.

The shallow and deep pressure limits or "stops" are ambient pressure levels, measured in dbars, between which the operator intends the MMP to travel. They are determined based on the needs of the investigation and with knowledge of the planned configuration of the mooring. When the ambient pressure becomes less than the shallow pressure stop on an upward profile or greater than the deep pressure stop on a downward profile, the system stops profiling. The sensors continue to log for two minutes before the system stops logging and moves the sensor data to the flash card. Ambient pressure is determined by querying the CTD. The shallow and deep pressure stops are the primary inputs the system uses to detect the end of a profile. If all goes as planned and nothing unexpected happens, every profile will be terminated based on the pressure stops. In the example above, the MMP will profile between 500 dbar and 2500 dbar, a profiling distance of approximately 2000 meters. Of course, studying the ocean is never that straightforward, thus the layered approach to stop detection.



- MMP Mooring Schematic -
Not to scale. For convenience, the depth in meters and the pressure in decibars have been equated. It is, of course, *in situ* pressure, not depth, that is available to the MMP during a profile.

Shallow pressure: The intended "top" of the profiling range. The system stops profiling on an upward profile when the ambient pressure becomes less than the shallow pressure limit. The sensors continue to log for two minutes before the system stops logging and moves the sensor data to the flash card. Ambient pressure is determined by querying the CTD. The shallow pressure limit is ignored during downward profiles.

In the example above the shallow pressure limit is set to 500 dbar. When setting the shallow pressure be aware that the allowed range depends on the current value of the deep pressure. If you wish to program a deeper range it may be necessary to change the deep pressure first.

It is important to take explicit note of the fact that the pressure stops are pressures, not depths. The measurements available to the MMP during a profile are of *in situ* pressure, not depth in meters. Unfortunately, physical locations on the mooring are commonly referenced in meters from the anchor or the topmost flotation. The near equivalence of meters and decibars is convenient, but variable and imprecise. The profiler does not integrate state variables over the depth of the water column to construct a mapping between the two frames of reference. That conversion is the responsibility of the operator.

Allowed range: 0.0 dbar to Deep pressure

Deep pressure: The intended "bottom" of the profiling range. The system stops profiling on a downward profile when the ambient pressure becomes greater than the deep pressure limit. The sensors continue to log for two minutes before the system stops logging and moves the sensor data to the flash card. Ambient pressure is determined by querying the CTD. The deep pressure limit is ignored during upward profiles.

In the example above the deep pressure limit is set to 2500 dbar. When setting the deep pressure be aware that the allowed range depends on the current value of the shallow pressure. If you wish to program a more shallow range it may be necessary to change the shallow pressure first.

It is important to take explicit note of the fact that the pressure stops are pressures, not depths. The measurements available to the MMP during a profile are of *in situ* pressure, not depth in meters. Unfortunately, physical locations on the mooring are commonly referenced in meters from the anchor or the topmost flotation. The near equivalence of meters and decibars is convenient, but variable and imprecise. The profiler does not integrate state variables over the depth of the water column to construct a mapping between the two frames of reference. That conversion is the responsibility of the operator.

Allowed range: Shallow pressure to 6000.0 dbar

When deploying the mooring, padded physical stops, or "bumpers", are secured to the mooring cable above and below the range defined by the pressure stops. The bumpers are typically placed 5 meters to 50 meters outside the range defined by the pressure stops. The actual placement depends on the anticipated dynamics of the mooring and on the placement of other mooring components. In the mooring schematic they have been placed 25 meters above the shallow pressure stop and 25 meters below the deep pressure stop. The bumpers prevent the profiler from straying off the portion of the mooring reserved for it. This is important because flotation and other instrumentation may occupy other parts of the mooring. Repeated collisions due to profiler motion or current and wave induced mooring motion are not in the best interests of either the MMP or those other mooring components. Additionally, the deep end of the mooring may extend below the 6000 meter depth limit of the MMP.

The pressure measurements acquired through CTD queries during a profile are each associated with an RTC time tag and stored in the engineering data file (along with the battery voltage and the motor current). The time and pressure information is used to dynamically calculate the pressure rate, $\delta P/\delta t$. The calculation is only performed over intervals, δt, of at least 3 minutes (180 seconds) duration.[30] This is done to filter out the effects of wave generated mooring motions (see Morrison, et al., 2001 and below for further discussion).

The pressure rate is used to detect obstacles on the mooring cable. An obstacle is a mooring component or some form of fouling that stops or severely hinders the profiling motion of the MMP. The nominal profiling speed of the MMP is 0.25 dbar/s (25 cm/s). When the pressure rate, averaged over at least 3 minutes, falls below a threshold of 0.045 dbar/s (4.5 cm/s), the SCP declares a pressure rate of zero. The pressure rate threshold and the minimum δt were determined empirically during a series of field trials and deployments over several years and cannot be changed by the operator. Experience has shown that a smaller δt or a higher threshold, either of which might be regarded as adequate based on the noise level of the CTD pressure measurement and the nominal profiling speed of the MMP, will lead to many false detections of a zero pressure rate. Those "false positives" are caused by wave induced mooring motions that modulate the otherwise steady progress of the profiler.

What is done after a zero pressure rate declaration depends on the MMP's location (depth), the current profiling direction, and the shallow or deep error programmed by the operator. In the mid-water region beyond the shallow and deep error windows a zero pressure rate is interpreted as an obstacle caused by fouling of the mooring cable. The mid-water obstacle ramming behavior is triggered in an effort to clear the cable and get past the obstruction. The system first backs away from the obstacle for one full 30 second velocity ramp. The profiler then moves forward again, starting with a 30 second velocity ramp and then continuing at the nominal profiling speed. If the ramming behavior is successful the MMP will simply continue the profile. If the obstruction is still in place then, 3 minutes or more later, another zero pressure rate will be detected and the "back off and ram" behavior will be repeated. Ramming is limited to a maximum of five occurrences during any one profile. A sixth detection terminates the profile. The sensors continue to log for two minutes before the system stops logging and moves the sensor data to the flash card. The detections do not have to be at or near the same depth. Each restart is logged in the engineering data file.

[30] This means the calculation is not performed for at least the first 3 minutes and 30 seconds of a profile. The CTD is not queried for the pressure during the 30 second velocity ramp. The earliest possible pressure measurement is acquired right after the ramp is completed and the first pressure associated with a suitably large δt is acquired no less than 3 minutes later. The pressure measurements and time tags are kept in rolling, indexed buffers so that the mooring motion filtering requirement of the calculation can be verified and met at each possible subsequent iteration. Failed pressure acquisitions are flagged and not used in the calculation.

The obstacle ramming behavior is limited to five repetitions because there are battery energy and drive train wear costs associated with the 15 minutes or more of drive wheel slip on the cable that are required to make five detections. Additional repetitions at this time are unlikely to be successful and only add to the energy and wear costs. Also, each restart adds to the elapsed time and the finite capacity of sensor memory puts a hard time limit on each profile. The obstacle ramming behavior exists at all because it can be successful, thereby improving the sampling coverage of a deployment. Five repetitions are a reasonable but essentially arbitrary balance between the costs and the potential gains. The profiler will try again during subsequent profiles. Ramming can be disabled at the discretion of the operator by extending the shallow and deep errors to cover the full extent of the profiling range. The shallow and deep errors and the behavior triggered by a zero pressure rate detection inside the error windows are discussed below.

Shallow error: Defines a window beginning below (deeper than) the shallow pressure stop and extending upwards without limit. If the system detects a zero pressure rate while inside the shallow error window on an upward profile, the "obstacle" is assumed to be the shallow bumper and the system stops profiling. The sensors continue to log for two minutes before the system stops logging and moves the sensor data to the flash card. The mid-water obstacle ramming behavior is not triggered. The shallow error is ignored on downward profiles.

The shallow error allows the operator to compensate for current forced mooring dynamics and for uncertainty in the actual depth of the bottom. As the mooring leans over in a current, the shallow bumper may be pulled below the shallow pressure stop. The same thing may happen if the bottom is deeper than expected. In these cases the obstacle ramming behavior would be futile. It would also waste battery energy and cause needless wear of the drive train. It is desirable to avoid both losses. The shallow error is programmed based on calculations of the mooring's dynamic behavior in a range of anticipated currents and knowledge of the possible depth error. Inside that window a zero pressure rate is interpreted as the shallow bumper, not fouling of the mooring cable, and the ramming behavior is not triggered. The profile terminates as if the shallow pressure stop has been detected. In the example above the shallow error is set to 100 dbar.

The mid-water obstacle ramming behavior can be disabled during upward profiles by extending the shallow error window below (deeper than) the deep pressure stop.

Allowed range: 0.0 dbar to 6000.0 dbar

Deep error: Defines a window beginning above (more shallow than) the deep pressure stop and extending downwards without limit. If the system detects a zero pressure rate while inside the deep error window on a downward profile, the "obstacle" is assumed to be the deep bumper and the system stops profiling. The sensors continue to log for two minutes before the system stops logging and moves the sensor data to the flash card. The mid-water obstacle ramming behavior is not triggered. The deep error is ignored on upward profiles.

The deep error allows the operator to compensate for current forced mooring dynamics and for uncertainty in the actual depth of the bottom. If the currents assumed in calculations of mooring dynamics are weaker than anticipated or if the bottom is shallower than expected, the deep bumper may rise above the deep pressure stop. In these cases the obstacle ramming behavior would be futile. It would also waste battery energy and cause needless wear of the drive train. It is desirable to avoid both losses. The deep error is programmed based on calculations of the mooring's dynamic behavior in a range of anticipated currents and knowledge of the possible depth error. Inside that window a zero pressure rate is interpreted as the deep bumper, not fouling of the mooring cable, and the ramming behavior is not triggered. The profile terminates as if the deep pressure stop has been detected. In the example above the deep error is set to 50 dbar.

The mid-water obstacle ramming behavior can be disabled during downward profiles by extending the deep error window above (more shallow than) the shallow pressure stop.

Allowed range: 0.0 dbar to 6000.0 dbar

The profile time limit is the final layer for stop detection. When the system is unable to detect a pressure or pressure rate based stop (and the battery voltage and motor current are within their prescribed limits), the profile is terminated based on elapsed travel time.

Profile time limit: The maximum time allowed for profiler motion. If the time limit expires while the MMP is profiling, the system halts profiler motion. The sensors continue to log for two minutes before the SCP stops logging and moves the sensor data to the flash card. The time limit applies only to the period of profiler motion during a single profile. It does not include the sensor logging intervals that occur before motion starts and after it ends or the time required to move data from the sensors to the flash card.

Whenever the operator changes the shallow pressure or the deep pressure, the SCP calculates the time that will be required to cover that distance. It pads that value by 25% and sets the profile time limit to the result:

profile time limit = 1.25 × (deep pressure - shallow pressure) / nominal profiling speed

The padding is intended to insure that the time limit remains long enough when the main lithium battery nears exhaustion. The nominal voltage of lithium batteries drops at that point, reducing the profiling speed. The calculation and display of a suggested profile time limit are performed as a convenience to the operator. The operator is free to accept or manually change the suggested time limit. A manual change may be necessary to meet some mission requirement of the investigation. The use of an alternative alkaline battery pack (lower voltage, different output time history, and slower average profiling speed) would also require a manual change to the time limit. Or the operator may simply wish to round off the estimate to the nearest hour or quarter hour. Note that any subsequent changes to the shallow or deep pressures will automatically update the profile time limit, overwriting the manual change. The operator's time limit must then be re-entered.

The time limit has an absolute maximum value of 8 hours. The internal memory capacity and the data rate of the CTD and the ACM limit logging to approximately 8.5 hours.[31] At a nominal speed of 25 cm/s, the MMP can profile the maximum excursion of 6000 meters in ~6.7 hours. The time limit is dynamically incremented during a profile whenever the mid-water obstacle ramming behavior is triggered. The increment includes the duration of the two additional velocity ramps, the zero pressure rate interval, δt, and the stop check interval (see below). The time limit is reset to 8 hours whenever an increment raises the time limit above the absolute maximum.

When everything goes as expected during a deployment the profile time limit is largely superfluous. The operator may, for example, assume that the only problem will be slower than expected average profiling speeds due to environmental forcing or imperfect ballasting or eventual battery exhaustion. Based on that assumption, setting the time limit to 8 hours gives the system the maximum amount of time to reach the stop on each profile and the operator can anticipate that each profile will be terminated based on pressure or pressure rate. However, if there are problems acquiring pressure measurements, this approach will also mean the maximum amount of time grinding uselessly against the physical stop and wasting a large portion of the energy in the battery. The only guidance we can provide here is to note that the system is robust; problems are rare and the hardware and software are designed to handle problems when they do occur. We suggest using the time limit calculated by the system, perhaps manually rounded up to the next larger quarter or half hour. In the example above we would (probably) set the time limit to 03:00:00.

Allowed range: 10 seconds to 8 hours in 1 second increments

[31] The CTD produces 9 byte records at ~1.85 Hz and has ~0.5 Mbyte of available internal storage. The ACM produces 18 byte records at ~1.85 Hz and has ~1.0 Mbyte of available internal storage.

The stop check interval is the last deployment definition parameter.

> Stop check interval: Controls how often during profile motion the system checks to see if it has reached the stop. The checks include examination of the ambient pressure, the pressure rate, and the elapsed time, as described above. The checks also include examination of the battery voltage and the motor current. In between checks the TT8 enters low power sleep.
>
> Infrequent checks, 30 to 60 second intervals, save a small amount of power because the TT8 is able to spend a larger portion of the profile in low power sleep. Infrequent checks are appropriate for relatively long profiles, those that are hundreds to thousands of meters in length. Infrequent checks also allow the system to overshoot the pressure stops to a greater degree and, potentially, spend time grinding against the physical stops while the TT8 sleeps, waiting for the next stop check. More frequent checks, 5 to 15 second intervals, have a small power consumption cost associated with them, but also reduce overshoot and grinding. Frequent checks are appropriate for relatively short profiles, those that are tens to hundreds of meters in length.
>
> Motor currents above 1500 mA indicate a catastrophic circuit failure and are grounds for immediate termination of profiler motion. This is "never going to happen", but we just don't like to take chances. High motor currents cause the system to restart a profile up to five times, similar to the repetitive attempts to pass an obstacle. High motor currents are not grounds for termination of the deployment.
>
> The output voltage of the main lithium battery is nominally 10.8 V until ~90% of the available energy in the battery has been used. The voltage then drops rapidly to ~7.8 V and remains at that level while most of the remaining available energy is used. As the battery nears complete exhaustion (99+% of the available energy extracted), the voltage falls rapidly to zero unless the current drain is drastically reduced. The MMP uses a threshold of 7.5 V to detect battery exhaustion and terminate the deployment. To avoid a premature or erroneous termination of the deployment, the battery voltage is averaged over five clean measurements obtained during sequential stop checks.
>
> (N.B.: The 7.5 V threshold was originally chosen based on the measured drain curves of single lithium cells. It has since been demonstrated in a million meter deployment that a 7.5 V threshold cleanly triggers deployment termination just below the beginning of the battery's final drop from 7.8 V.)
>
> Allowed range: 1 second to 60 seconds in 1 second increments

The stop check "algorithm" is summarized below. The details of the checks and the actions they trigger are given above.

- System always checks:
  - → Motor current below 1500 mA
  - → Elapsed time less than profile time limit
  - → Battery voltage above 7.5 V
- System checks after the velocity ramp is complete:
  - → Pressure
  - → Pressure rate

Select 'd' or 'D' for done when the deployment definition is complete.

<u>Done</u>: Indicates to the MMP that parameter selection is complete. Selecting "Done" instructs the system to conduct parameter range and consistency checks and the endurance calculation. It does not start the deployment. Range violations and inconsistencies will trigger prompts for parameter changes. A programmed burst interval that is shorter than the calculated length of a burst is an example of a parameter inconsistency.

If no problems are found the system will prompt the operator to store the parameters in the non-volatile EEPROM. A 'no' response returns to the deployment menu for further parameter entry. This loop, including the system range and consistency checks and the endurance calculation, can be used to quickly develop and test sampling schedules during deployment planning. A 'yes' response stores the parameters and runs a single iteration of the Diagnostics routine. The latter includes the 10 V and 7.5 V battery warning checks. The system then prompts the operator to "Proceed with the deployment (Yes/No) [N] ?". It is at this time that the operator must decide whether or not to commit to the deployment.

That's it for the deployment definition parameters. Now you just have to get through a quick, bench top deployment. We congratulate you for staying awake this long and hope the coffee was of good quality. If you join us at MRL for the training course we will take you to Coffee Obsession of Falmouth, MA, the finest coffee shop in the known universe, to properly fortify you for the lectures.

Parameter Range and Consistency Checks and the Endurance Calculation

The parameter range checks verify that each of the deployment parameters is within its allowed range. The ranges are stated in the descriptions above. They are also included in each of the prompts when the operator is making changes. If a range violation is detected, the system will prompt the operator to change the parameter in question and then return to the deployment menu so that the operator can review the selections before proceeding.

When all of the deployment parameters are within the specified ranges, the system performs a consistency check on the proposed schedule. The consistency checks begin with the calculation of the minimum profile duration (MPD).

$$MPD = \left\{ \left[\frac{DPL - SPL}{NPS} + SLBP + SLAP \right] \left(1 + \frac{DGR}{DTR} \right) \right\} \times 1.10$$

where:

DPL	=	Deep Pressure Limit	[dbar]
SPL	=	Shallow Pressure Limit	[dbar]
NPS	=	Nominal Profiling Speed	[dbar/sec]
SLBP	=	Sensor Logging Before Profiling	[sec]
SLAP	=	Sensor Logging After Profiling	[sec]
DGR	=	Data Generation Rate	[byte/sec]
DTR	=	Data Transfer Rate	[byte/sec]

In summary, the minimum profile duration is the profile travel time plus the intervals of sensor logging that occur before motion starts and after it ends plus the amount of time required to transfer the generated data from the sensors to the flash card all padded by 10%.

If continuous profiling is selected (profile/pair start interval set to 000 00:00:00), no profile consistency check is performed. When the start interval is not zero, the system compares the MPD to the profile start interval (paired profiles disabled) or twice the calculated MPD to the pair start interval (paired profiles enabled). If the programmed start interval is shorter than the MPD the operator will be prompted to change the selections. The operator may choose to disregard the warning and proceed, keeping in mind that this will probably mean skipped profiles during the deployment (and possibly skipped bursts since all of the profiles scheduled for a burst are conducted before the burst is considered complete). An example is shown below. The pair start interval in the ongoing deployment example was reduced from 6 hours to 3 hours to trigger the warning.

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

Checking profile schedule . . . done.
Calculated minimum profile pair duration:    05:02:08        ← calculated pair duration

Estimated minimum profile pair duration exceeds pair         ← system alerts operator
start interval.  System will skip pairs whenever a
pair start time is missed.

Change selections (Yes/No) [Y] ?
```

If burst mode is disabled (profiles/pairs per burst set to 1) or if continuous bursts are selected (burst interval set to 00 00:00:00), no burst consistency check is performed. When burst mode is enabled and the burst interval is not zero, the system compares the minimum burst duration (MBD) with the burst interval. The MBD is one of:

- MPD × profiles per burst — if continuous profiling is enabled
- start interval × profiles per burst — if MPD < a non-zero start interval
- [MPD / start interval] × profiles per burst — if MPD ≥ a non-zero start interval

The third case accounts for an inconsistent (but operator approved) start interval. The quantity inside the square brackets is rounded up to the nearest integer value. If the programmed burst interval is shorter than the calculated time to conduct the burst the operator will be prompted to change the selections. Again, the operator may choose to disregard the warning and proceed, keeping in mind that this will probably mean skipped bursts during the deployment. An example is shown below. The burst interval in the ongoing deployment example was reduced from 7 days to 2 days. The burst of 12 profile pairs with a consistent 6 hour start interval requires 3 days to complete.

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

Checking profile schedule . . . done.
Calculated minimum profile pair duration:    05:02:08        ← calculated pair duration
Profile schedule selections are consistent.

Checking burst schedule . . . done.
Calculated burst duration:             003 00:00:00        ← calculated burst duration

Estimated minimum burst duration exceeds burst             ← system alerts operator
interval.  System will skip bursts whenever a
a burst start time is missed.

Change selections (Yes/No) [Y] ?
```

It is important to note that the consistency checks are based on the calculated travel time for a profile, not on the profile time limit set by the operator. The programmed profile time limit is not considered in the calculation of the MPD or the MBD and has no role in the comparisons of the MPD and MBD with the start and burst intervals.

When the consistency checks are complete the system calculates and displays the date on which the profiler will reach 1 million meters of travel during the deployment. The number of profiles required to reach this distance and the start time of Profile 1 (see Reference date/time above) are also calculated and displayed. The calculation involves some approximations and assumptions, particularly if the schedule is not consistent. The date it yields is reasonably accurate. One million meters is the nominal single deployment endurance of the profiler. The date is thus of considerable interest during deployment planning. The endurance calculation estimates the date on which sampling will end if the MMP is deployed with the current deployment definition parameters.

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

Checking profile schedule . . . done.
Calculated minimum profile pair duration:    05:02:08        ← calculated pair duration
Profile schedule selections are consistent.

Checking burst schedule . . . done.
Calculated burst duration:             003 00:00:00        ← calculated burst duration
Burst schedule selections are consistent.

Estimated Profile 1 start time:   02/18/2002 00:00:00      ← reference time is in the
                                                              future after Profile 0
Profiling distance will reach 1 million meters             ← endurance calculation
on 07/13/2002 after 500 profiles.                             for the deployment
                                                              parameters of the
Accept and store schedule selections (Yes/No) [Y] ?           ongoing example
```

The endurance calculation will generate warnings if the calculated date is later than 2038 or if the number of profiles required to reach 1 million meters exceeds the maximum number of profiles allowed under current file system restrictions. These warnings are unlikely when parameters suitable for an ocean deployment in deep water are programmed, but are not uncommon when an MMP is deployed in the MRL test well or in shallow shelf waters.

When the deployment definition parameters are consistent (or have been approved by the operator despite our well-intentioned warnings) and the results of the endurance calculation have been displayed, the system prompts the operator to store the parameters in the EEPROM.

A 'no' response returns to the deployment menu for further parameter entry. This feature can be used to quickly loop through the system range and consistency checks and the endurance calculation while making iterative adjustments to the deployment parameters. This loop can be a very useful tool when developing profiling schedules for an investigation.

A 'yes' response stores the deployment definition parameters in the EEPROM and then runs a single iteration of Diagnostics, the Main Menu utility that scrolls system status information. The call to Diagnostics includes the 10 V and 7.5 V battery warning checks, so there will be a warning message if more than ~90% of the energy in the battery has been used.

The system then prompts the operator to "Proceed with the deployment (Yes/No) [N] ?" and the operator must make the decision to start the deployment or return to the Main Menu. Note that the default response is 'No'. Committing to the deployment requires two separate keystrokes so that an accidental launch is less likely. The operator can, of course, always terminate the deployment with [CTRL]-[C]. However, when the operator commits to the deployment the system quickly begins to initialize the system for use. This includes reformatting the flash card, erasing any stored data files. Do not commit to a deployment if you need those files and have not archived them. After reformatting they cannot be recovered with commercially available disk recovery software.

```
Accept and store schedule selections (Yes/No) [Y] ?         ← default 'yes' response …

Storing deployment definition parameters . . . done.          … stores the parameters

CAUTION:  Deployment will erase all data                    ← data is not appended
          files stored on the flash card.
                                                            one line of Diagnostics
System status:                                              ↓

RTC: 03/13/2002 13:08:06   WDC: 03/13/2002 13:08:05   10.6 Vb      0 mA


Proceed with the deployment (Yes/No) [N] ?                  ← commit to the deployment
                                                                 the default is No
```

Summary of Profile and Deployment Termination Conditions

For easy reference, the conditions that will terminate a profile or deployment are listed below. Note that the deployment termination conditions are a critical subset of the profile termination conditions. Profiles are terminated by any of the following conditions:

- shallow or deep pressure limit reached
- zero pressure rate inside the shallow or deep error window
- time limit expired
- operator command
- flash card or file system full
- low average battery voltage
- zero pressure rate in mid-water more than five times
- high motor current more than five times
- too many open files (failure of file system hardware)

A combination of mid-water zero pressure rates and high motor currents totaling six is sufficient grounds for terminating a profile.

Deployments are only terminated by the conditions listed below. Deployments are only terminated by operator command or a condition that precludes further data collection.

- operator command
- flash card or file system full
- low average battery voltage
- too many open files (failure of file system hardware)

Bench Top Deployment

We complete this section, Deploy Profiler, with the transcript, in its entirety, of a simple bench top deployment. The ambient pressure is near zero on the bench and does not vary appreciably. For this reason we used the profile time limit, set to 1 minute, to end downward profiles. The time limit could have been set long enough to allow a zero pressure rate detection, but that would have made for an even longer transcript. (That would be an excellent scenario for readers to try, however. We suggest a profile time limit of 4 minutes.) We set the shallow pressure limit to a small positive value, 10 dbars, to end upward profiles based on ambient pressure (near zero pressure is more shallow than 10 dbars). We manually stopped the deployment after Profile 1 was complete.

During the deployment initialization process that follows the operator's commitment to the deployment, the system will first instruct you to leave the communications cable in place so that you can observe the process and respond to any problems which arise. The initialization lasts for approximately 1 minute. The system will tell you when to disconnect the communications cable. These messages can be found in the transcript below. The communications cable was, of course, left connected throughout to record the progress of the deployment.

It is very important to note that during deployment initialization the flash card is reformatted. MMP-N_NN.RUN and AUTOEXEC.BAT are preserved in TT8 RAM during reformatting and restored to the flash card when the operation is complete. Removing the data files left from previous deployments prevents large scale fragmentation of the file system. Fragmentation, if not addressed, will effectively reduce the storage capacity of the card, slow down file access during read and write operations, and eventually make the card unusable. Reformatting is the fastest way to clear the card. (PicoDOS does not support wild card arguments for the DEL command and deleting the data files one at a time with an automated loop can take more than an hour.) Reformatting, unlike deleting, means that the files cannot be recovered using commercial disk recovery software.

```
        McLane Research Laboratories, USA
             McLane Moored Profiler
      Version: mmp-2_08.c   S/N: ML00414-42

                   Main Menu
             Wed Mar 13 15:19:28 2002


      <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                              ← the deployment begins


 Clock reads 03/13/2002 15:19:31
 Change time & date (Yes/No) [N] ?

 Setting watchdog clock . . . done.

 Profiling odometer
   Total profiling distance:           0 meters
   Battery trip meter:                 0 meters

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


 Verification of CTD and ACM settings

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

  Selection  ? a                                    ← automated sensor verification


 Automated verification of CTD and ACM settings.

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

 Sending command  ***O


Open Mode


 Expected response received.
 Proceeding to next command.

 Sending command  ROP

1335
Scale is OFF
Address Operation is OFF
Auto is ON


 Expected response received.

 Standard CTD settings verified.
```

```
 Applying power to ACM . . .
 Starting verification . . .

 Sending command  ***O


OPEN MODE


 Expected response received.
 Proceeding to next command.

 Sending command  ROP

continuous clear

address op clear


Logging Ops Set
RLD checksum output cleared


 Expected response received.
 Proceeding to next command.

 Sending command  RDM

TX = ON, TY = ON, HX = ON, HY = ON, HZ = ON, VPATH = ON, 18



 Expected response received.
 Proceeding to next command.

 Sending command  TILT

TILT = on



 Expected response received.
 Proceeding to next command.

 Sending command  COMP

COMP = on



 Expected response received.
 Proceeding to next command.

 Sending command  NRML

NRML = on



 Expected response received.
 Proceeding to next command.
```

```
Sending command  AVGI

Averaging Interval Time = 00:15
Enter interval (mm:ss):

Expected response received.
Proceeding to next command.

Sending command




Expected response received.

Standard ACM settings verified.


Sensors initialized and ready for deployment.        ← sensors "good to go"

Press any key to continue.                           previously programmed
                                                     ↓       deployment menu

Start    1| Countdown delay        =     00:01:00 [HH:MM:SS]

Schedule 2| Profile start interval = 000 00:10:00 [DDD HH:MM:SS]
         3| Reference date/time    =   03/13/2002 15:00:00
         4| Burst interval         = 007 00:00:00 [DDD HH:MM:SS]
         5| Profiles per burst     =     Disabled
         6| Paired profiles              Disabled

Stops    7| Shallow pressure       =          5.0 [dbar]
         8| Deep pressure          =         10.0 [dbar]
         9| Shallow error          =          2.0 [dbar]
         A| Deep error             =          2.0 [dbar]
         B| Profile time limit     =     00:01:00 [HH:MM:SS]
         C| Stop check interval    =            5 [sec]

         D| Done

              Selection  ? d

Checking entries . . . done.                          ← parameter range and
All entries are within allowed ranges.                   consistency checks

Checking profile schedule . . . done.
Calculated minimum profile duration:         00:04:46      ← includes sensor logging
Profile schedule selections are consistent.                   intervals before and
                                                              after profiler motion
Checking burst schedule . . . done.
Burst mode disabled.

Estimated Profile 1 start time:   03/13/2002 15:40:00

Profiling distance will reach 1 million meters       ← endurance calculation
on 12/31/2005 after 200000 profiles.

Deployment is limited to 1362 profiles               ← maximum number of profiles will
and will end on 03/23/2002.                              limit deployment duration

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

Storing deployment definition parameters . . . done.
```

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

System status:

RTC: 03/13/2002 15:20:00   WDC: 03/13/2002 15:20:00   10.6 Vb      0 mA


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


>>> Initializing autonomous operation <<<

  Do NOT remove the communication cable               ← take note of this instruction
    until initialization is complete.

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

Initializing data pointers and status flags . . . done.

Initializing flash card . . .                         ← these steps take almost a minute
  Deleting all previous data files                    ← N.B. the flash card is reformatted
    (process requires ~45 seconds) . . . .              during this process, the files are
                                         . . .          not recoverable using commercial
  Initializing flash pointers . . .                     disk recovery software
  Creating DEPLOY.DAT . . .
  Creating PROFILES.DAT . . .
  Creating IRQ_XCPT.LOG . . .
Flash card initialization complete.

System is ready to deploy.

Transponder will ping in 30 seconds to confirm
successful transition to autonomous operation.

Remove communication cable NOW, apply dummy           ← remove the cable when launching
plug to communications port, and attach                  the MMP, remain connected
bottom cap to vehicle.                                   during training if desired

<03/13/2002 15:20:25> Sleeping . . .                  ← waiting for the ping …

                                                      ← … ping
03/13/2002 15:20:55                                   ← waiting for Profile 0

Initializing CTD logging pointers . . .               ← CTD logging started

Sending command  ***O


Open Mode


Expected response received.
Proceeding to next command.

Sending command  LOG=0



Expected response received.
Proceeding to next command.
```

```
 Sending command  LOG

log=0


 Expected response received.
 Proceeding to next command.

 Sending command  ***R



 Expected response received.
 Proceeding to next command.

 Sending command  START



 Expected response received.

 CTD logging pointers initialized.

 Initializing ACM logging pointers . . .              ← ACM logging started

 Sending command  ***O


OPEN MODE


 Expected response received.
 Proceeding to next command.

 Sending command  CLOG


Logging Ops Cleared



 Expected response received.
 Proceeding to next command.

 Sending command  LGPTR=65536



 Expected response received.
 Proceeding to next command.

 Sending command  LGPTR

65536


 Expected response received.
 Proceeding to next command.
```

```
 Sending command  READP=65536



 Expected response received.
 Proceeding to next command.

 Sending command  READP

65536


 Expected response received.
 Proceeding to next command.

 Sending command  ZMEM
 Execution requires ~8 seconds

Each '.' = 65536 bytes. Type 'S' to Stop.
. . . . . . . . . . . . . . . .
Logging Pointer Reset

Logging Memory Zeroed



 Expected response received.
 Proceeding to next command.

 Sending command  SLOG


Logging Ops Set



 Expected response received.
 Proceeding to next command.

 Sending command  ***R


•WARNING, NO AVERAGING PARAMETER(s) SELECTED, NORMAL RUN

Running, Fingers UP
Tilt Function is ON  Compass Function is ON




 Expected response received.

 ACM logging pointers initialized.

 03/13/2002 15:21:12                              ← sensor start time logged

 Continuing 120 second sensor warm-up.
 Initial dive to bottom stop will begin at  03/13/2002 15:22:55.


 <03/13/2002 15:21:14> Sleeping . . .
```

```
03/13/2002 15:22:55                                 ← wakes up to start Profile 0

Opening file E0000000.dat for storage of
profile 0 engineering data.

Beginning profile 0                                 ← motion begins
                                                    ← motion start time logged
Full speed reached.  Setting low power run mode.    ← velocity ramp complete


  28 mA   10.5 V                                    ← check for stop
Checking for stop . . . steady as we go.
Current pressure     1.193 dbar

<03/13/2002 15:23:28> Sleeping . . .


  26 mA   10.5 V                                    ← check for stop
Checking for stop . . . steady as we go.
Current pressure     1.258 dbar
Current speed        0.014 dbar/s

<03/13/2002 15:23:33> Sleeping . . .


  28 mA   10.6 V                                    ← check for stop
Checking for stop . . . steady as we go.
Current pressure     0.919 dbar
Current speed        0.029 dbar/s

<03/13/2002 15:23:38> Sleeping . . .


  29 mA   10.5 V                                    ← check for stop
Checking for stop . . . steady as we go.
Current pressure     1.183 dbar
Current speed        0.001 dbar/s

<03/13/2002 15:23:43> Sleeping . . .


  28 mA   10.5 V                                    ← check for stop
Checking for stop . . . steady as we go.
Current pressure     0.937 dbar
Current speed        0.013 dbar/s

<03/13/2002 15:23:48> Sleeping . . .


  28 mA   10.5 V                                    ← check for stop
Checking for stop . . . steady as we go.
Current pressure     1.190 dbar
Current speed        0.000 dbar/s

<03/13/2002 15:23:53> Sleeping . . .
```

```
  28 mA   10.5 V                                        ← check for stop
Checking for stop . . . steady as we go.
Current pressure     1.321 dbar
Current speed        0.004 dbar/s

<03/13/2002 15:23:58> Sleeping . . .


  28 mA   10.5 V                                        ← finds stop
Checking for stop . . . found stop.

Profile timer expired at 03/13/2002 15:24:01            ← based on time

03/13/2002 15:24:02                                     ← motion end time logged

Programmed pause to provide sensor data for
a post deployment sensor bias check, 120 seconds

<03/13/2002 15:24:03> Sleeping . . .


Halting ACM data logging . . .                          ← CTD and ACM data transfer
                                                          process begins by halting
Sending command  ***O                                     the sensors


OPEN MODE


Expected response received.

ACM data logging halted.

Halting CTD data logging . . .

Sending command  ***O


Open Mode


Expected response received.

CTD data logging halted.                                ← sensor stop time logged

Dumping CTD data to flash card . . .                    ← CTD data transfer begins

Sending command  LOG

log=5013


Sending command  LOG=0



Expected response received.
Proceeding to next command.
```

```
 Sending command  LOG

log=0


 Expected response received.
 Proceeding to next command.

 Sending command  DLEN=455



 Expected response received.
 Proceeding to next command.

 Sending command  DLEN

Dlen=455


 Expected response received.
 Proceeding to next command.

 Opening file C0000000.dat for storage of
 profile 0 CTD data.

 Sending command  BDMP


 Receiving block 0 of 1 . . .
 Writing block 0 of 1 . . .

 Sending command  BDMP


 Receiving block 1 of 1 . . .
 Writing block 1 of 1 . . .                       ← CTD data transfer ends

 Sending command  LOG=0                           ← resetting CTD for next profile



 Expected response received.
 Proceeding to next command.

 Sending command  LOG

log=0


 Expected response received.

 CTD profile data written to flash card.          ← CTD data secured
```

```
 Dumping ACM data to flash card . . .
```

← ACM data transfer begins

```
 Sending command  CLOG

Logging Ops Cleared


 Expected response received.
 Proceeding to next command.

 Sending command  RDM

TX = ON, TY = ON, HX = ON, HY = ON, HZ = ON, VPATH = ON, 18


 Sending command  LGPTR

75814


 Sending command  LGPTR=65536



 Expected response received.
 Proceeding to next command.

 Sending command  LGPTR

65536


 Expected response received.
 Proceeding to next command.

 Sending command  READP=65536



 Expected response received.
 Proceeding to next command.

 Sending command  READP

65536


 Expected response received.
 Proceeding to next command.

 Sending command  DLEN=227



 Expected response received.
 Proceeding to next command.
```

```
 Sending command  DLEN

227


 Expected response received.
 Proceeding to next command.

 Opening file A0000000.dat for storage of
 profile 0 ACM data.

 Sending command  BDMP


 Receiving block 0 of 2 . . .
 Writing block 0 of 2 . . .

 Sending command  BDMP


 Receiving block 1 of 2 . . .
 Writing block 1 of 2 . . .

 Sending command  BDMP


 Receiving block 2 of 2 . . .
 Writing block 2 of 2 . . .                    ← ACM data transfer ends

 Sending command  LGPTR=65536                  ← resetting ACM for next profile



 Expected response received.
 Proceeding to next command.

 Sending command  LGPTR

65536


 Expected response received.
 Proceeding to next command.

 Sending command  READP=65536



 Expected response received.
 Proceeding to next command.

 Sending command  READP

65536


 Expected response received.
 Proceeding to next command.
```

```
 Sending command  ZMEM
 Execution requires ~8 seconds

Each '.' = 65536 bytes. Type 'S' to Stop.
. . . . . . . . . . . . . . . .
Logging Pointer Reset

Logging Memory Zeroed


 Expected response received.

 ACM profile data written to flash card.            ← ACM data secured

 Closing engineering data file . . . done.          ← Profile 0 is complete

 <03/13/2002 15:27:02> Sleeping . . .               ← waiting for Profile 1


 03/13/2002 15:28:00                                ← 2 minutes early to start sensors

 Initializing CTD logging pointers . . .            ← CTD logging started

 Sending command  ***O

Open Mode


 Expected response received.
 Proceeding to next command.

 Sending command  LOG=0



 Expected response received.
 Proceeding to next command.

 Sending command  LOG

log=0


 Expected response received.
 Proceeding to next command.

 Sending command  ***R



 Expected response received.
 Proceeding to next command.

 Sending command  START



 Expected response received.

 CTD logging pointers initialized.
```

```
 Initializing ACM logging pointers . . .            ← ACM logging started

 Sending command  ***O

OPEN MODE

 Expected response received.
 Proceeding to next command.

 Sending command  CLOG

Logging Ops Cleared

 Expected response received.
 Proceeding to next command.

 Sending command  LGPTR=65536

 Expected response received.
 Proceeding to next command.

 Sending command  LGPTR

65536

 Expected response received.
 Proceeding to next command.

 Sending command  READP=65536

 Expected response received.
 Proceeding to next command.

 Sending command  READP

65536

 Expected response received.
 Proceeding to next command.
```

```
 Sending command  ZMEM
 Execution requires ~8 seconds

Each '.' = 65536 bytes. Type 'S' to Stop.
. . . . . . . . . . . . . . . .
Logging Pointer Reset

Logging Memory Zeroed



 Expected response received.
 Proceeding to next command.

 Sending command  SLOG


Logging Ops Set



 Expected response received.
 Proceeding to next command.

 Sending command  ***R


•WARNING, NO AVERAGING PARAMETER(s) SELECTED, NORMAL RUN

Running, Fingers UP
Tilt Function is ON  Compass Function is ON




 Expected response received.

 ACM logging pointers initialized.

 03/13/2002 15:28:18
 Continuing 120 second sensor warm-up.
 Next profile will begin at 03/13/2002 15:30:00.


 <03/13/2002 15:28:19> Sleeping . . .


 03/13/2002 15:30:00

 Opening file E0000001.dat for storage of
 profile 1 engineering data.

 Beginning profile 1                                 ← motion begins

 Full speed reached.  Setting low power run mode.


   27 mA   10.5 V                                    ← finds stop
 Checking for stop . . . found stop.

 Shallow pressure exit on a                          ← based on pressure
 measurement of 0.974 dbar at 03/13/2002 15:30:32

 03/13/2002 15:30:32
```

```
 Programmed pause to provide sensor data for
 a post deployment sensor bias check, 120 seconds

 <03/13/2002 15:30:34> Sleeping . . .


 Halting ACM data logging . . .

 Sending command  ***O


OPEN MODE


 Expected response received.

 ACM data logging halted.

 Halting CTD data logging . . .

 Sending command  ***O


Open Mode


 Expected response received.

 CTD data logging halted.

 Dumping CTD data to flash card . . .

 Sending command  LOG

log=4446


 Sending command  LOG=0




 Expected response received.
 Proceeding to next command.

 Sending command  LOG

log=0


 Expected response received.
 Proceeding to next command.

 Sending command  DLEN=455




 Expected response received.
 Proceeding to next command.
```

← data transfer process begins

```
 Sending command  DLEN

Dlen=455


 Expected response received.
 Proceeding to next command.

 Opening file C0000001.dat for storage of
 profile 1 CTD data.

 Sending command  BDMP


 Receiving block 0 of 1 . . .
 Writing block 0 of 1 . . .

 Sending command  BDMP


 Receiving block 1 of 1 . . .
 Writing block 1 of 1 . . .

 Sending command  LOG=0




 Expected response received.
 Proceeding to next command.

 Sending command  LOG

log=0


 Expected response received.

 CTD profile data written to flash card.

 Dumping ACM data to flash card . . .

 Sending command  CLOG


Logging Ops Cleared


 Expected response received.
 Proceeding to next command.

 Sending command  RDM

TX = ON, TY = ON, HX = ON, HY = ON, HZ = ON, VPATH = ON, 18


 Sending command  LGPTR

74572
```

```
 Sending command  LGPTR=65536



 Expected response received.
 Proceeding to next command.

 Sending command  LGPTR

65536


 Expected response received.
 Proceeding to next command.

 Sending command  READP=65536



 Expected response received.
 Proceeding to next command.

 Sending command  READP

65536


 Expected response received.
 Proceeding to next command.

 Sending command  DLEN=227



 Expected response received.
 Proceeding to next command.

 Sending command  DLEN

227


 Expected response received.
 Proceeding to next command.

 Opening file A0000001.dat for storage of
 profile 1 ACM data.

 Sending command  BDMP


 Receiving block 0 of 2 . . .
 Writing block 0 of 2 . . .

 Sending command  BDMP


 Receiving block 1 of 2 . . .
 Writing block 1 of 2 . . .
```

```
Sending command  BDMP


Receiving block 2 of 2 . . .
Writing block 2 of 2 . . .

Sending command  LGPTR=65536




Expected response received.
Proceeding to next command.

Sending command  LGPTR

65536


Expected response received.
Proceeding to next command.

Sending command  READP=65536




Expected response received.
Proceeding to next command.

Sending command  READP

65536


Expected response received.
Proceeding to next command.

Sending command  ZMEM
Execution requires ~8 seconds

Each '.' = 65536 bytes. Type 'S' to Stop.
. . . . . . . . . . . . . . .
Logging Pointer Reset

Logging Memory Zeroed



Expected response received.

ACM profile data written to flash card.

Closing engineering data file . . . done.          ← Profile 1 is complete

<03/13/2002 15:33:40> Sleeping . . .               ← waiting for Profile 2

Enter <CTRL-C> now to wake up?◘                    ← operator terminates deployment
                                                       with [CTRL]-[C]
Deployment terminated by operator.

Deployment complete.
Please recover me.
```

```
        McLane Research Laboratories, USA           ← back to the Main Menu
             McLane Moored Profiler
      Version: mmp-2_08.c   S/N: ML00414-42

        ╔══════════════════════════════════╗
        ║            Main Menu             ║
        ╚══════════════════════════════════╝
             Wed Mar 13 15:33:42 2002


      <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  ? o                              ← and a quick check of the
                                                       odometer and trip meter
Profiling odometer
  Total profiling distance:          16 meters      ← it wasn't a very long deployment
  Battery trip meter:                16 meters

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

We will examine the data files generated during this bench top deployment below, in Offload Deployment Data.

Quick Reference to the Deployment Definition Parameters

Countdown delay: A countdown delay is specified in hours, minutes, and seconds. The countdown begins when the system pings the transponder (1 to 2 minutes after the operator commits to the deployment). Profile 0 begins when the countdown reaches zero.

Allowed range: 0 seconds to 24 hours in 1 second increments

Scheduled start: A scheduled start is specified as an absolute date and time. Profile 0 begins when the RTC reaches the specified time.

Allowed range: Years 1970 to 2038 in 1 second increments and at least 10 minutes in the future as measured by the RTC.

Profile start interval/Pair start interval: The interval between profiles or pairs of profiles. The interval is measured between the start of profiling motion of sequential profiles or pairs of profiles. Continuous profiling is selected by setting the start interval to 0.

Allowed range: 0 seconds to 366 days in 1 second increments

Reference date/time: The initial reference time for the deployment. All subsequent profiles are referenced to this time.

Allowed range: Years 1970 to 2038 in 1 second increments

Burst interval: The interval between bursts of profiles or pairs of profiles. Continuous bursts are selected by setting the burst interval to 0.

Allowed range: 0 seconds to 366 days in 1 second increments

Profiles per burst/ Pairs per burst: The number of profiles or pairs of profiles in a burst. Setting this parameter to 1 disables burst profiling.

Allowed range: 1 - 1000 profiles or pairs of profiles

Paired profiles: Enables or disables paired profiles. When paired profiles are enabled, the deployment is scheduled in up-down pairs.

Allowed range: Enabled/Disabled

Shallow pressure: The intended "top" of the profiling range. The system stops profiling on an upward profile when the ambient pressure becomes less than the shallow pressure limit.

Allowed range: 0.0 dbar to Deep pressure

Deep pressure: The intended "bottom" of the profiling range. The system stops profiling on a downward profile when the ambient pressure becomes greater than the deep pressure limit.

Allowed range: Shallow pressure to 6000.0 dbar

Shallow error: Defines a window beginning below (deeper than) the shallow pressure stop and extending upwards without limit. If the system detects a zero pressure rate while inside the shallow error window on an upward profile, the "obstacle" is assumed to be the shallow bumper and the system stops profiling.

Allowed range: 0.0 dbar to 6000.0 dbar

Deep error: Defines a window beginning above (more shallow than) the deep pressure stop and extending downwards without limit. If the system detects a zero pressure rate while inside the deep error window on a downward profile, the "obstacle" is assumed to be the deep bumper and the system stops profiling.

Allowed range: 0.0 dbar to 6000.0 dbar

Profile time limit: The maximum time allowed for profiler motion. If the time limit expires while the MMP is profiling, the system halts profiler motion. The time limit calculated by the SCP is:

profile time limit = 1.25 × (deep pressure - shallow pressure) / nominal profiling speed

Allowed range: 10 seconds to 8 hours in 1 second increments

Stop check interval: Controls how often during profile motion the system checks to see if it has reached the stop. The checks include examination of the ambient pressure, the pressure rate, the elapsed time, the battery voltage and the motor current.

Allowed range: 1 second to 60 seconds in 1 second increments

Done: Indicates to the MMP that parameter selection is complete. Selecting "Done" instructs the system to conduct parameter range and consistency checks and the endurance calculation. It does not start the deployment.

<7> Offload Deployment Data

The on-board offload utility, Main Menu Option 7, works with the file capture feature of Crosscut or Tattle Term. See Operating Crosscut and TattleTerm for more information about file capture. Offload processes the binary data stored in the engineering, CTD, and ACM data files on the flash card and scrolls them to the screen as ASCII text. There they can be read by the operator and captured by the serial communications program for storage in an ASCII text file on the PC. Essentially all numerical analysis packages can work with ASCII text. Note, however, that editing to remove messages and punctuation from the ASCII engineering files and headers from the ASCII sensor files will be necessary first. The on-board version of offload produces "human readable" rather than "machine readable" files.[32] PDP-N_NN.EXE, the high-speed MMP Profiler Data Processor, is more full featured and allows the operator to specify the output format.

The speed of offload is limited by the baud rate of the serial communications port. This is arguably a more serious limitation than the human readable format. The conversion of binary data to ASCII text expands the number of bytes that must pass through the serial port by a factor of approximately four. At 9600 baud more than 10 days would be required to dump the 220 Mbytes of stored measurements from a million meter deployment. Offload will recover the data, but its real utility is clearly for training and bench testing with relatively small data sets. In these cases it is often extremely convenient to be able to view the data without removing the flash card from the pressure housing.

For data from an actual deployment, the high-speed processor is the preferred method. To recover data using PDP-N_NN, the flash card must be transferred from the MMP to a PCMCIA slot on a PC. PCMCIA ATA flash card drives that attached through the USB or parallel ports of a PC are commercially available for systems without an internal flash card slot.[33] The binary data and deployment definition files can then be copied from the card to the hard disk at bus speeds, creating a binary archive for the experiment. The archive can be replicated on an optical disk as well. Once on the hard disk, PDP-N_NN can operate on the data without the bottleneck of the serial port. 220 Mbytes of binary data can (potentially, it depends on your computer) be archived and processed in less than 10 minutes, including the time it takes to open the pressure housing and transfer the flash card. The remainder of this section describes the on-board offload utility. For further information about PDP-N_NN see Data Offload, Processing, and Interpretation.

Note that offload only <u>reads</u> from the flash card. The binary data files remain resident and are not altered by offload. The data files on the flash card are erased only when (1) the system is re-deployed (recall that the flash card is reformatted during deployment initialization after the operator commits to the deployment), (2) the operator manually deletes them using the tools in the Flash Card Operations menu, or (3) the operator manually deletes them using file manipulation tools on the PC. The offload process can be stopped at any time with a [CTRL]-[C] command. (PDP-N_NN is also non-destructive. It reads the archived binary files on the hard disk and creates a set of ASCII files.)

---

[32] "Human readable" ASCII files include embedded messages, headers, date/time punctuation, and other material that, while helpful to a human reader, make loading by a numerical analysis package somewhat problematic. "Machine readable" ASCII files include only space separated columns of numbers and can be loaded without modification by essentially all numerical analysis packages.

[33] For example, www.envoydata.com/fdusb.htm (USB port, $79.00) and www.envoydata.com/lpc01.html (parallel port, $149.00). We have tried both of these products under several versions of the Windows and Windows NT operating systems. The software and hardware installed easily in all cases. The drives have worked smoothly, quickly, and without difficulty since installation.

Offload acquires almost all of the information it displays from the files on the flash card. The exceptions are the deployment termination message and termination time, which are loaded from the EEPROM. The deployment termination message specifies the condition that terminated the deployment. In the example from the previous section the condition was an operator command. Other possibilities are low average battery voltage, a flash card or file system that is full, or a failure of the file system hardware. Loading and displaying the deployment termination condition and time are the first steps of the offload process. This is followed by loading and displaying the deployment definition information stored on the flash card in DEPLOY.DAT. While this information is not needed to unpack the data, it does record the conditions under which the data were collected. DEPLOY.DAT has traveled with the engineering and sensor files and it should be permanently archived with them as well. DEPLOY.DAT is also used by PDP-N_NN.

The final step before processing the engineering and sensor files is loading the profile count from PROFILES.DAT. The profile count is the limiting index into the data files. Recall that the files are assigned names of the form XNNNNNNN.DAT, where X is an E, C, or A, identifying the file as engineering, CTD, or ACM data, and NNNNNNN is the profile number, padded with leading zeros (0000000, 0000001, 0000002, …, 0000414, …). The profile count stored in PROFILES.DAT is the number of the last profile of the deployment. If the profile count is, for some reason, not available, the system uses the maximum number of files that the file system can accommodate as a limiting index. Offload allows the operator to select which engineering and sensor files to process. Knowledge of some limiting index is required to constrain that selection.

To demonstrate data offload, we will use the files generated during the bench top deployment from the previous section of this chapter. Don't forget to initiate the Crosscut or TattleTerm file capture utility. Offload does provide a reminder, just in case. Stop file capture when the offload is complete. As with any data files, <u>make backup copies</u>. We begin with Options 1, 2, and 3 of the Flash Card Operations menu.

```
         Selection  ? 1


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

 439.329 Mbyte flash card installed                          ← a small portion of the
 439.058 Mbyte currently free                                   card is occupied

 File system can accommodate  4091 data files
 Deployment can include up to 1362 profiles


         Selection  ? 2

Directory of A:                                              ← a directory listing
MMP-2_08.RUN       168,004 03-12-02 22:24                    ← system control program
AUTOEXEC.BAT            10 03-13-02 15:20                    ← autoexec
DEPLOY.DAT              80 03-13-02 15:20                    ← deployment definition
PROFILES.DAT             4 03-13-02 15:30                    ← profile count
IRQ_XCPT.LOG             6 03-13-02 15:20                    ← IRQ and exception log
E0000000.DAT           264 03-13-02 15:27                    ← Profile 0 engineering file
C0000000.DAT         5,013 03-13-02 15:26                    ← Profile 0 CTD file
A0000000.DAT        10,278 03-13-02 15:26                    ← Profile 0 ACM file
E0000001.DAT           152 03-13-02 15:33                    ← Profile 1 engineering file
C0000001.DAT         4,446 03-13-02 15:32                    ← Profile 1 CTD file
A0000001.DAT         9,036 03-13-02 15:33                    ← Profile 1 ACM file

    439,058,432 bytes free
```

```
          Selection  ? 3

LOCATION  CONTENTS
00000000  0000 0001        ← number of the last complete profile in hexadecimal format (hexadecimal
                              bears a striking resemblance to decimal until you get up past 9 or so)
```

As previously discussed, we suggest using the flash card utilities in this manner immediately after recovering the profiler (and terminating the deployment if necessary). Note that the listing of files with Option 2 of the Flash Card Ops menu cannot be interrupted with a [CTRL]-[C].

The Offload Deployment Data menu is shown below.

```
         ╔══════════════════════════════╗
         ║ Offload Deployment Data Files ║
         ╚══════════════════════════════╝
           Sat Mar 16 18:56:46 2002

  Offload all:                  Offload a range of:
    <1> Data files
    <2> Engineering files         <5> Engineering files
    <3> CTD data files            <6> CTD data files
    <4> ACM data files            <7> ACM data files

  Offload all files from a:
    <8> Single profile            <X> Offload IRQ/Xcpt log
    <9> Range of profiles         <M> Return to Main Menu

        Selection  ?
```

Option 1, which we will use here, offloads all of the data. It processes and displays in profile sequence first the engineering files, then the CTD files, and finally the ACM files. The file capture utility will place all of this information into a single large ASCII file. Options 2, 3, and 4 process and display each of those subsets individually. Options 5, 6, and 7 prompt the operator to select a range of profiles from one of the subsets, engineering, CTD, or ACM data. Options 8 and 9 allow the operator to select all of the data from a single profile or from a range of profiles. The operator specifies profiles and profile ranges with profile numbers. The reader is encouraged to experiment with these other options after running a bench top deployment to generate some data files.

Option 1 produces the ASCII text file shown below. The bulk of the sensor data has been excised to keep the transcript brief. It would otherwise go on for pages and provide little in the way of enlightenment.

```
         Selection  ? 1                                       ← offload all data files

To copy the screen display of the engineering and sensor      ← reminder to start file
data files to a disk file, initiate your communication            capture
program's file logging command now and then press any key
to start the transfer.  The instrument data files will
remain resident and are not deleted by this procedure.



Deployment terminated by operator.                            ← termination condition
03/13/2002 15:33:42                                               and termination time

DEPLOYMENT PARAMETERS
_____________________

Countdown delay       =     00:01:00 [HH:MM:SS]               ← deployment definition
Profile start interval = 000 00:10:00 [DDD HH:MM:SS]              information loaded
Reference date/time   =   03/13/2002 15:00:00                     from DEPLOY.DAT
Burst interval        = 007 00:00:00 [DDD HH:MM:SS]
Profiles per burst    =     Disabled
Paired profiles             Disabled
Shallow pressure      =          5.0 [dbar]
Deep pressure         =         10.0 [dbar]
Shallow error         =          2.0 [dbar]
Deep error            =          2.0 [dbar]
Profile time limit    =     00:01:00 [HH:MM:SS]
Stop check interval   =            5 [sec]

ENGINEERING DATA                                              ← engineering data for
________________                                                  all profiles first

Opening file E0000000.dat,
engineering data for profile 0 of 1.

Sensors were turned on at  03/13/2002 15:21:12                ← sensor and motion
Vehicle began profiling at 03/13/2002 15:22:56                    start times

   Date      Time     [mA]    [V]    [dbar]

03/13/2002 15:22:56     0.   10.6     0.000                   ← engineering data
03/13/2002 15:23:01     28   10.5     0.000                   ← system logs 0.000 for
03/13/2002 15:23:06     30   10.5     0.000                       pressure during the
03/13/2002 15:23:11     28   10.5     0.000                       velocity ramp, the CTD
03/13/2002 15:23:16     27   10.5     0.000                       is not queried during
03/13/2002 15:23:21     28   10.5     0.000                       the ramp
03/13/2002 15:23:26     27   10.5     0.000
03/13/2002 15:23:26     28   10.5     1.193                   ← first stop check after
03/13/2002 15:23:31     26   10.5     1.258                      completion of the
03/13/2002 15:23:36     28   10.6     0.919                      of the velocity ramp
03/13/2002 15:23:41     29   10.5     1.183
03/13/2002 15:23:46     28   10.5     0.937
03/13/2002 15:23:51     28   10.5     1.190
03/13/2002 15:23:56     28   10.5     1.321
03/13/2002 15:24:01     28   10.5     0.000

Ramp exit:     SMOOTH RUNNING                                 ← velocity ramp and profile
Profile exit:  TIMER EXPIRED                                     exit conditions
```

```
Vehicle motion stopped at 03/13/2002 15:24:02          ← sensor and motion
Sensor logging stopped at 03/13/2002 15:26:03             stop times

Opening file E0000001.dat,
engineering data for profile 1 of 1.

Sensors were turned on at  03/13/2002 15:28:18         ← sensor and motion
Vehicle began profiling at 03/13/2002 15:30:01            start times

   Date      Time     [mA]    [V]    [dbar]

03/13/2002 15:30:01     0.   10.6      0.000
03/13/2002 15:30:06     25   10.5      0.000
03/13/2002 15:30:11     26   10.5      0.000
03/13/2002 15:30:16     26   10.5      0.000
03/13/2002 15:30:21     26   10.5      0.000
03/13/2002 15:30:26     26   10.5      0.000
03/13/2002 15:30:31     26   10.5      0.000
03/13/2002 15:30:31     27   10.5      0.974               ← first stop check after
                                                              velocity ramp
Ramp exit:     SMOOTH RUNNING                          ← velocity ramp and profile
Profile exit:  TOP PRESSURE                               exit conditions

Vehicle motion stopped at 03/13/2002 15:30:32          ← sensor and motion
Sensor logging stopped at 03/13/2002 15:32:33             stop times

End of engineering data files.

CTD DATA                                               ← CTD data for all
________                                                  profiles second

Opening file C0000000.dat,
CTD data for profile 0 of 1.

 mmho/cm   Celsius    dbars

+13.7792  +21.1573  +0000.960                          ← first CTD record
+13.7787  +21.1673  +0000.935
+13.7793  +21.1716  +0000.921
+13.7787  +21.1740  +0000.807
+13.7789  +21.1744  +0000.842
. . .                                                  ← excised CTD records
+13.7799  +21.1940  +0001.112
+13.7800  +21.1942  +0001.048
+13.7806  +21.1942  +0001.260
+13.7796  +21.1946  +0001.173
+13.7801  +21.1949  +0001.190                          ← last CTD record

End of file mark reached for file C0000000.dat

Opening file C0000001.dat,
CTD data for profile 1 of 1.

 mmho/cm   Celsius    dbars

+13.7799  +21.1715  +0001.607                          ← first CTD record
+13.7802  +21.1821  +0001.423
+13.7807  +21.1869  +0001.295
+13.7806  +21.1895  +0001.165
+13.7807  +21.1910  +0001.058
. . .
```

```
+13.7806  +21.2177  +0000.963
+13.7806  +21.2179  +0001.000
+13.7807  +21.2179  +0000.984
+13.7806  +21.2182  +0000.941
+13.7807  +21.2184  +0001.097                      ← last CTD record

End of file mark reached for file C0000001.dat

End of CTD data files.

ACM DATA                                           ← ACM data for all
________                                             profiles last

Opening file A0000000.dat,
ACM data for profile 0 of 1.

  TX      TY      HX       HY       HZ       VPAB     VPCD     VPEF     VPGH

+01.51  +01.41  +0.3333  -0.0198  -0.9426  +002.08  -002.68  -003.62  -000.95
+01.43  +01.48  +0.3349  -0.0163  -0.9421  +001.90  -002.73  -003.60  -000.95
+01.49  +01.55  +0.3333  -0.0188  -0.9426  +001.97  -002.73  -003.60  -000.96
+01.41  +01.58  +0.3345  -0.0151  -0.9423  +001.88  -002.75  -003.62  -000.93
+01.40  +01.56  +0.3331  -0.0182  -0.9427  +001.92  -002.77  -003.57  -000.93
. . .
+01.49  +01.40  +0.3337  -0.0185  -0.9425  +002.01  -002.79  -003.64  -000.96
+01.45  +01.45  +0.3348  -0.0153  -0.9422  +001.97  -002.71  -003.67  -000.98
+01.44  +01.50  +0.3331  -0.0182  -0.9427  +001.93  -002.75  -003.64  -000.93
+01.50  +01.49  +0.3349  -0.0148  -0.9422  +001.87  -002.76  -003.67  -000.97
+01.46  +01.45  +0.3334  -0.0195  -0.9426  +001.95  -002.71  -003.64  -000.93

End of file mark reached for file A0000000.dat

Opening file A0000001.dat,
ACM data for profile 1 of 1.

  TX      TY      HX       HY       HZ       VPAB     VPCD     VPEF     VPGH

+01.56  +01.50  +0.3349  -0.0145  -0.9422  +002.07  -002.74  -003.63  -000.94
+01.49  +01.45  +0.3335  -0.0170  -0.9426  +001.95  -002.77  -003.58  -000.98
+01.48  +01.51  +0.3344  -0.0144  -0.9423  +001.96  -002.76  -003.65  -000.95
+01.45  +01.48  +0.3335  -0.0176  -0.9426  +001.95  -002.72  -003.66  -000.97
+01.49  +01.48  +0.3344  -0.0141  -0.9423  +001.97  -002.77  -003.63  -001.00
. . .
+01.44  +01.55  +0.3357  -0.0119  -0.9419  +001.88  -002.82  -003.69  -001.02
+01.34  +01.53  +0.3351  -0.0131  -0.9421  +001.94  -002.77  -003.66  -000.95
+01.38  +01.52  +0.3353  -0.0128  -0.9420  +001.91  -002.80  -003.66  -000.94
+01.30  +01.48  +0.3353  -0.0128  -0.9420  +001.99  -002.77  -003.64  -000.99
+01.34  +01.58  +0.3347  -0.0138  -0.9422  +001.98  -002.74  -003.69  -000.93

End of file mark reached for file A0000001.dat

End of ACM data files.

Terminate file logging operation now               ← offload complete, stop
and press any key to continue.                       file capture if you wish
```

Option 5, which prompts for a range selection, produces the output below. Note that the profile numbers supplied by the operator to define a range are included in the range.

```
         Selection  ? 5                                        ← offload a range of
                                                                  engineering files
To copy the screen display of the engineering and sensor
data files to a disk file, initiate your communication
program's file logging command now and then press any key
to start the transfer.  The instrument data files will
remain resident and are not deleted by this procedure.



Deployment terminated by operator.
03/13/2002 15:33:42

DEPLOYMENT PARAMETERS
_____________________

Countdown delay        =     00:01:00 [HH:MM:SS]
Profile start interval = 000 00:10:00 [DDD HH:MM:SS]
Reference date/time    =   03/13/2002 15:00:00
Burst interval         = 007 00:00:00 [DDD HH:MM:SS]
Profiles per burst     =     Disabled
Paired profiles              Disabled
Shallow pressure       =          5.0 [dbar]
Deep pressure          =         10.0 [dbar]
Shallow error          =          2.0 [dbar]
Deep error             =          2.0 [dbar]
Profile time limit     =     00:01:00 [HH:MM:SS]
Stop check interval    =            5 [sec]

Enter first profile number in range (    0 to    1) ? 0    ← select the profile range
Enter last profile number in range  (    0 to    1) ? 0       for offload

ENGINEERING DATA
________________

Opening file E0000000.dat,
engineering data for profile 0 of 1.

Sensors were turned on at  03/13/2002 15:21:12
Vehicle began profiling at 03/13/2002 15:22:56

   Date      Time      [mA]    [V]    [dbar]

03/13/2002 15:22:56     0.   10.6      0.000
03/13/2002 15:23:01     28   10.5      0.000
03/13/2002 15:23:06     30   10.5      0.000
03/13/2002 15:23:11     28   10.5      0.000
03/13/2002 15:23:16     27   10.5      0.000
03/13/2002 15:23:21     28   10.5      0.000
03/13/2002 15:23:26     27   10.5      0.000
03/13/2002 15:23:26     28   10.5      1.193
03/13/2002 15:23:31     26   10.5      1.258
03/13/2002 15:23:36     28   10.6      0.919
03/13/2002 15:23:41     29   10.5      1.183
03/13/2002 15:23:46     28   10.5      0.937
03/13/2002 15:23:51     28   10.5      1.190
03/13/2002 15:23:56     28   10.5      1.321
03/13/2002 15:24:01     28   10.5      0.000

Ramp exit:     SMOOTH RUNNING
Profile exit:  TIMER EXPIRED
```

```
Vehicle motion stopped at 03/13/2002 15:24:02
Sensor logging stopped at 03/13/2002 15:26:03

End of engineering data files.
```

Offload Option X displays the time tagged log of interrupt requests (IRQs) and exceptions. In this case the file contains only its own generation time. The log from a longer deployment would include entries for each watchdog and transponder interrupt.

```
         Selection  ? x                                          ← offload IRQ/Xcpt log

To copy the screen display of the engineering and sensor
data files to a disk file, initiate your communication
program's file logging command now and then press any key
to start the transfer.  The instrument data files will
remain resident and are not deleted by this procedure.



Deployment terminated by operator.
03/13/2002 15:33:42

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

03/13/2002 15:20:23  Log file creation time.                     ← the only entry is the
                                                                    creation time of the log
End of file mark reached for file IRQ_XCPT.LOG

Terminate file logging operation now
and press any key to continue.
```

The first entry in the IRQ and exception log is always the creation time of the file. Subsequent entries include regular watchdog IRQs at one minute after each hour and irregular transponder IRQs. The bench top deployment was not timed to include a case of "one minute after the hour" and the system was not connected to a transponder, so there are no examples of these entries in the file.

That's all there is to using the on-board offload utility. Remember that offload only reads the files, it does not alter or erase them. Offload can be run any number of times. It can also be stopped in the middle of unpacking data ([CTRL]-[C]) and started again at the beginning if you forgot to start a file capture process.

<8> Contacting McLane

Contacting McLane displays contact information for the McLane Research Laboratories, Inc. A customer once asked if this utility would open actual communications links with MRL. In case anyone else is wondering, the answer is no, this option does not actually contact us. However, it does put our phone number where you can find it at sea when you forgot to pack this manual and really need to speak with us.

```
        McLane Research Laboratories, Inc.
        Falmouth Technology Park
        121 Bernard E. Saint Jean Drive
        East Falmouth, MA 02536, USA

        Tel:    (508) 495-4000
        Fax:    (508) 495-3333
        Email:  mclane@mclanelabs.com
        WWW:    http://www.mclanelabs.com

        Software version:  mmp-2_08.c
        Compiled:          Apr  8 2002 15:21:58
        Profiler S/N:      ML00414-42
```

Reporting a Problem

If you do contact us with a question about system behavior, particularly if you have observed a problem, it will be very helpful if you can provide a text file showing the information above and, if at all possible, showing the behavior or problem. The text file can be created using the file capture utility of Crosscut or TattleTerm (see Operating Crosscut and TattleTerm) and emailed to MRL at mclane@mclanelabs.com. You should also try to describe what you observed.

<W> Watchdog Initialization

Watchdog Initialization is a hidden option on the Main Menu. 'W' or 'w' will command the system to re-initialize the watchdog, prompt the user to set the RTC, and then synchronize the WDC.

```
        Selection  ? w

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

Clock reads 01/30/2002 12:04:16
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 [01/30/2002 12:04:19] ? 1 30 2002 12 4 35

Clock reads 01/30/102  12:04:35
Change time & date (Yes/No) [N] ?

Setting watchdog clock . . . done.
```

If the automatic watchdog initialization that occurs during the power-up sequence fails, the system will instruct the operator to select this option. The system locks out all watchdog operations, both automatic and operator initiated, until the watchdog is successfully initialized. This includes deploying the profiler. The MMP cannot (and should not) be deployed if the watchdog is not functioning properly and communicating cleanly with the system.

<O> Profiling Odometer

Reading the profiling odometer and trip meter is another hidden option on the Main Menu. 'O' or 'o' (those are the upper and lower case letters 'O' and 'o', not the numeral '0' or zero) will trigger a display of the current odometer and trip meter readings. The operator is given an opportunity to reset the trip meter to zero. The odometer cannot be reset. The odometer can be used to schedule and track major system maintenance procedures. For example, it is likely that some components of the drive train will require replacement or servicing after a million meters of travel. The trip meter is used to monitor the remaining energy capacity of the battery. The operator normally resets the trip meter when a new battery is installed.

```
Profiling odometer
  Total profiling distance:         16 meters
  Battery trip meter:                0 meters

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

The nominal endurance of the MMP with a standard, 240 Ahr, lithium battery pack is 1 to 1.2 million meters (Morrison, et al., 2001). An estimate of the remaining battery capacity in meters is obtained by subtracting the trip meter from the nominal endurance. This assumes that the operator reset the trip meter when the battery was installed. We suggesting rounding the result to the nearest 50,000 or 100,000 meters for deployment planning purposes (see below).

During a deployment the odometer and trip meter are updated and stored in the EEPROM at the end of each profile. The number of meters added to each total is calculated as

additional meters = (motion stop time - motion start time) × nominal profiling speed

with a correction made for the slower average speed during the velocity ramp at the beginning of the profile. Note that this is an estimate of travel distance being used as a surrogate for energy consumption. It is not a direct measurement of the energy removed from or remaining in the battery. This is a simple, practical approach, intended only to provide guidance for maintenance and for battery use and replacement during deployment planning. We anticipate that the estimate of travel distance will be accurate to ~10,000 meters for a million meter deployment (~1%), but this remains to be demonstrated in the field. We do not expect the estimate of energy remaining in the battery to be more accurate than 50,000 to 100,000 meters, 5% to 10% of the total energy capacity of the battery. There are simply too many variables affecting the rate of energy use and the actual available battery energy to be more precise.

Exiting to the Monitor (TOM8>)

At the Main Menu prompt press 'q' or 'Q' followed by [ENTER]. A password prompt will appear. Type "mclane", no quotes, all lower case, and press [ENTER]. This will halt execution of the SCP and cause an exit to the TOM8 monitor (Tiny Onset Monitor, TT8). This removes the running copy of the SCP in RAM, however, the SCP remains resident on the flash card.

```
     Selection  ? q   Password:  mclane

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

TOM8>
```

The system draws a relatively high current (~40 mA) from the battery while in the monitor. We recommend that you limit the time the system stays in this state. Generally, the only reason to enter the monitor is to perform a "warm" re-boot of the MMP. To re-start the system control program type 'g' or "go", no quotes, followed by [ENTER] at the TOM8 prompt. This will start the normal power-up initialization sequence.

Coda

Congratulations! You have reached the end of a fairly complete description of the MMP User interface and MMP operation. You are ready to solo. Go ahead and take your profiler out for a short spin around the lab. We'll meet you afterwards at Coffee Obsession.

V. Data Offload, Processing, and Interpretation

Binary Data Recovery and Archiving

The MMP collects approximately 220 Mbytes of compressed binary data during a million meter deployment. During the translation from binary to ASCII the engineering files expand by a factor of 3.4. The CTD and ACM files expand by factors of 3.9 and 4.4. When weighted for relative file size, the expansion factor for profiler data is 4.25. A million meter deployment with 220 Mbytes of compressed binary data will produce 925 Mbytes of ASCII data. Recovering these data through the 9600 baud serial port of the MMP would require more than 10 days of continuous spooling to complete.

Fortunately there is a faster way. The flash card is compatible with DOS/Windows and can be read directly on a suitably equipped PC. PDP-N_NN, the McLane Profiler Data Processor (PDP), can translate the binary data files into ASCII text on a PC, unfettered by the limiting bandwidth of the serial port. Those ASCII files can be read directly by most numerical analysis programs. The stages of this process are described below.

Data Recovery Benchmark

How long does it actually take to copy a large data set from a flash card to the hard disk of a PC and then translate the binary information into ASCII text? The speed of the data recovery process was benchmarked using the files collected during the first science deployment of the first production model MMP. In the course of that deployment the profiler conducted 1008 profiles, traveled 935,000 meters, and collected 188 Mbytes of data in over 3000 binary data files. The computer used during recovery was an 800 MHz Pentium III desktop PC with a 133 MHz motherboard and a 30 Gbyte, 7200 rpm, hard drive. (Dell Dimension XPS B800r, purchased in May of 2000). The OS was Windows 2000 and the flash card was read using an Envoy Data model FD-USB external drive connected to a USB port on the PC. (This was before the release of USB 2.0, so it is probably the bandwidth of the USB that limits the transfer speed.)

It took less than a minute to open the pressure housing and extract the flash card.[34] Copying the files on the card to the hard disk of the PC required 8 minutes and 13 seconds. Unpacking them on the PC with PDP-2_08 required 7 minutes and 35 seconds. The ASCII files occupied 788 Mbytes on the disk. The entire operation lasted less than 20 minutes. That is more than 800 times faster than spooling ASCII data through the serial port. We made it as far as the galley and back for coffee. A run to Coffee Obsession was out of the question.

Recovering the Flash Card

Once the profiler has been recovered and disconnected from the mooring cable (see Launch and Recovery), it should be hosed down with fresh water. At a minimum, the pressure housing, end cap, and connectors should be flushed with fresh water before connecting a PC to the communications port or opening the housing. The rest of the profiler can be cleaned and the maintenance procedures can be run after the flash card is removed. It is OK for the drive motor to be running while you secure the profiler and flush the end cap and connectors; no harm is done to the system and there is no need to hurry. See Cleaning and Maintenance for more information.

[34] We use an electric screwdriver and we've had lots of practice. The first few times you do this it may take several minutes.

MRL strongly recommends that you move the profiler into the ship's lab or other sheltered location after flushing (or preliminary flushing) is complete and before proceeding with flash card recovery. The pressure housing must be opened to recover the card. Exposure of the electronics or flash card to salt water or salt spray should be avoided. If the electronics do get wet you should disconnect power immediately. Then remove the salt water by immersing the electronics (not the lithium battery!) in clean fresh water. Follow this by air-drying or blow-drying. Contact McLane for advice and assistance. Salt water exposure is not necessarily a disaster, but you must respond quickly.

After the area around the pressure housing end cap has been flushed and dried and the profiler has been moved to a safe location, connect a PC that is already booted and already running Crosscut or TattleTerm to the communications port on the pressure housing end cap. Use the communications cable provided in the tool kit. Connecting to the MMP is described more fully in Operating Crosscut and TattleTerm. Be sure to enable file capture so that you will have a record of your recovery procedures.

Terminate the deployment, if it is still in progress, with one or more [CTRL]-[C]s. If the deployment was automatically terminated by the system before recovery the [CTRL]-[C]s will wake the system from low power sleep. If the MMP is in the middle of conducting a profile the operator will be prompted after the first [CTRL]-[C] to save or discard that portion of the data. The data may be useful even though they were collected during mooring recovery. This decision is up to the operator.

At this point you may wish to examine the profile count or list the data files using the utilities on the Flash Card Operations menu. Once the user interface has returned to the Main Menu, and not before, you can recover the flash card. To begin, manually open the pressure relief valve to equalize the internal and external pressure (see Pressure Housings, Cables, and the Drive Train). Disconnect the CTD, ACM, drive motor, and transponder cables and remove the 6 socket head stainless steel cap screws that secure the end cap. Pry open the housing and slide out the electronics assembly. Finally, disconnect the battery or run the Exchange flash cards option of the Flash Card Operations menu. Slide the flash card out of its socket and remove it from the MMP. Further profiler maintenance and flushing can be conducted while the data on the flash card are copied to your PC. Be sure to replace the end cap before flushing or immersing the profiler.

Archiving the Data

Insert the flash card in the PCMCIA slot of your PC and copy the contents to your hard disk using standard DOS or Windows commands. The data are not removed from the flash card during this procedure. MRL strongly recommends that you immediately make a second copy of the binary data. The second copy serves as a long-term backup and should use an archival storage media. Optical disks are an excellent choice for archival storage.

If you are unfamiliar or uncomfortable with DOS or Windows file operations these brief descriptions may be helpful. Assume, for example, that the flash card is drive F:\ and that you wish to move the data to C:\MMP.[35]

- In DOS:
  → At the DOS prompt type: COPY F:*.* C:\MMP

- In Windows:
  → Double click on the F:\ icon in My Computer to open the flash card. The profiler data and auxiliary files will be listed.
  → Similarly, open the C:\MMP folder. (You may have to create this folder using New on the File menu of the C:\ drive.)
  → Choose Select All from the Edit menu of F:\ and drag the files to C:\MMP with the mouse.

There are several other possible approaches using Windows tools, but this is arguably the most straightforward. An average PC should be able to copy 200 Mbytes of binary files from the flash card to a hard disk in less than 10 minutes. Making an archival copy on an optical disk will require a further 5 minutes, approximately.

PDP-N_NN: Unpacking the Binary Files

The PDP Main Menu

With the files securely archived, the next step is unpacking the binary data using PDP-N_NN. N_NN is the data processor version number (e.g., PDP-2_08). It should match the version number of the SCP in use during the deployment (e.g., MMP-2_08). McLane's Profiler Data Processor is a DOS/Windows executable program (PDP-2_08.exe). To start execution (but not unpacking) type PDP-2_08 (or other appropriate version) at the DOS prompt or double click on the PDP-2_08 icon in Windows. Under DOS you will need to work from the directory in which the executable is resident or add that directory to your path. In Windows you can create a short cut on your desk top and double click on that to start execution. The PDP menu, shown below, will be displayed.

[35] C:\MMP is the PDP-N_NN default directory for both binary input files and ASCII output files. Those input and output paths can be changed by the operator. Recall, however, the DOS/Windows limit on the number of files that can be placed in the root directory of a drive. The several thousand files produced by a long deployment can be copied to a subdirectory such as C:\MMP without restriction. Copying to C:\ will probably not be permitted by the operating system. (The actual limit for writing files varies from OS to OS and from device to device. The limit does not, apparently, apply to reading files that are already present. If you manage to contact Bill Gates and get some answers about this please let us know.)

```
MMP Data Unpacker - Version 1.7  Apr 14 2002  15:12:15
For use with data collected under Version 2.08 of the System Control Program

Current options:

  Format for text files:   MACHINE READABLE
  Screen display of data:  NONE
  Partial display size:    1
  Scroll size:             0  (no scrolling)

  Input data path:  C:\MMP
  Output data path: C:\MMP


        Unpack Deployment Data Files

 Offload all:                 Offload a range of:
   <1> Data files
   <2> Engineering files        <5> Engineering files
   <3> CTD data files           <6> CTD data files
   <4> ACM data files           <7> ACM data files

 Offload all files from a:
   <8> Single profile           <X> Offload IRQ/Xcpt log
   <9> Range of profiles        <O> Set Options
                                <Q> Quit

         Selection   ?
```

The PDP menu options controlling the selection of files to be processed duplicate the options of the on-board offload utility and will already be familiar to you. Option 1 unpacks all of the data, processing in profile sequence first the engineering files, then the CTD files, and finally the ACM files. Options 2, 3, and 4 process each of those subsets individually. Options 5, 6, and 7 prompt the operator to select a range of profiles from one of the subsets, engineering, CTD, or ACM data. Options 8 and 9 allow the operator to select all of the data from a single profile or from a range of profiles. Profiles and profile ranges are specified with profile numbers. Unlike the on-board offload utility, which captures the data through a scrolling screen dump to a single ASCII file, the PDP creates a separate ASCII file for the data from each binary file. Option X displays the time tagged log of interrupt requests (IRQ) and exceptions. Options 1 to 9 produce text files and, at the discretion of the operator, a screen display. Option X produces only a screen display.

Processing can be stopped with a [CTRL]-[C]. Use Option Q to stop the PDP program and exit when processing is complete.

The PDP Options Menu

Unlike the offload utility, the Profiler Data Processor allows the operator to control the format of the ASCII text files. In particular, the format can be set such that the text files can be read immediately by numerical analysis programs. Recall that the text files produced by the offload utility, particularly the engineering files, include a number of embedded messages and punctuation marks that must be removed before the data can be read. The PDP also offers several screen display options for operators who wish to monitor the process.

To change the behavior of the PDP, type 'o' or 'O' followed by [ENTER] (those are the lower and upper case letters, not the number zero). The PDP options menu will be displayed.

```
        Selection   ? o                        ← letter 'o' for options, upper or lower case

          Set Unpacker Options

Current options:

  Format for text files:   MACHINE READABLE
  Screen display of data:  NONE
  Partial display size:    1                   PDP options chosen for maximum
  Scroll size:             0  (no scrolling)      processing speed

  Input data path:  C:\MMP
  Output data path: C:\MMP

   <1> Set Output File Format
   <2> Set Display Mode
   <3> Set Partial Display Size
   <4> Set Scroll Size
   <5> Set INPUT files
   <6> Set PATH for OUTPUT files
   <7> Restore Default Options
   <M> Return to main menu
```

Each of the PDP options is described in one of the boxes below.

Set Output File Format: Select the human or the machine readable format for the ASCII files.

The human readable format is similar to the text produced by the on-board offload utility, with embedded comments and date/time punctuation. It is useful during training and system familiarization. It may also be useful to unpack the engineering files in human readable format to identify instances of obstacle detection and other unusual events. Editing is generally required before human readable files can be read by numerical analysis programs.

The machine readable format produces columns of numbers with no embedded messages and no punctuation. Machine readable files can be read by Excel, Matlab, and other numerical analysis software without editing.

Translating the binary to machine readable format is marginally faster than producing human readable format.

Set Display Mode: There are three display modes.

Full - Display the complete text of the ASCII files on the screen as they are processed. This option allows the operator to monitor the data while it is unpacked. However, it slows down the processing and the operator will need to read very quickly unless the scroll size, Option 4, is non-zero.

Partial - Display the first few unpacked records from each binary file as unpacking proceeds. The number of records displayed is set in Option 3. This option allows the operator a quick overview of the data while it is unpacked. It slows down the processing, but not to the same degree that Full Display does. The operator's eyes don't have to be quite as fast either.

None - Do not display data on the screen as unpacking proceeds. Display only the name of the binary file currently being unpacked. This option is fastest. No reading is required.

Set Partial Display Size: Set the number of records from each binary file to display on the screen when the partial display mode is enabled. For example, view the first five records from each file as it is processed.

Set Scroll Size: Set the number of lines to scroll on the screen before pausing for operator input (press any key). For those familiar with Unix or Linux, this is equivalent to piping the display through more. Scroll size is used with the full or partial display mode to permit on-screen examination of the data during processing. A scroll size of zero disables the feature in favor of continuous scrolling (the way a screen normally works). A non-zero scroll size does permit the operator to examine the data, but it reduces processing speed by at least an order of magnitude (and may lead to carpal tunnel syndrome).

Set PATH for INPUT files: Tell the PDP where to look for the binary data and the auxiliary files. The full path, not a relative path, should be specified. The default directory is C:\MMP. The input and output directories do not need to be the same. The input and output directories and the directory containing the PDP executable can be on different disks or logical partitions.

Note that all directories on the input path must conform to the DOS 8.3 naming convention (8 characters or fewer in the file name, 3 characters or fewer in the extension). This restriction is imposed for PDP compatibility with the widest possible range of DOS/Windows systems. If any directories on the path do not conform, they must be entered using the DOS 8.3 substitute names automatically generated by the OS. The substitute names usually include a twiddle, '~'. To view the substitute names on a path follow the Crosscut file capture directions in Operating Crosscut and TattleTerm. The "Open file" window uses the substitute names and you can use it to follow the path.

Set PATH for OUTPUT files: Tell the PDP where to place the ASCII text files that it creates. The full path, not a relative path, should be specified. The default directory is C:\MMP. The input and output directories do not need to be the same. The input and output directories and the directory containing the PDP executable can be on different disks or logical partitions.

Note that all directories on the output path must conform to the DOS 8.3 naming convention (8 characters or fewer in the file name, 3 characters or fewer in the extension). This restriction is imposed for PDP compatibility with the widest possible range of DOS/Windows systems. If any directories on the path do not conform, they must be entered using the DOS 8.3 substitute names automatically generated by the OS. The substitute names usually include a twiddle, '~'. To view the substitute names on a path follow the Crosscut file capture directions in Operating Crosscut and TattleTerm. The "Open file" window uses the substitute names and you can use it to follow the path.

Restore Default Options: Restore the default PDP options. The default options are loaded by the PDP the first time it is run on a PC, before an operator makes adjustments and an options file is created (see below). The defaults are also used if the options file has been deleted or moved out of the default PDP directory, C:\MMP.

Return to main menu: Returns to the PDP Main Menu. Profiler data processing is initiated from the Main Menu.

Because the Profiler Data Processor can operate across partition and device boundaries, it is possible to unpack the binary files from the flash card directly to the hard disk. While this is convenient, there are two reasons you might prefer to proceed as described above, with separate file transfer and unpacking steps. The first is archiving of the deployment data, which will require considerably less storage space as binary than as ASCII. The ASCII files from a million meter deployment will not fit on a single optical disk, but the binary files will. Of course, you could write an optical disk directly from the flash card as well. The second reason is system dependent. On some systems, data can be transferred between the hard disk and another device at significantly higher rates than between a pair of devices that does not include the hard disk. Additionally, a system may have localized choke points, such as the link between the PC and the PCMCIA reader. It may actually be faster to copy from the flash card to the hard disk and then archive and unpack, than to work directly from the flash card for both operations.

The Profiler Data Processor creates (or re-writes if it already exists) a file, OFFLOAD.OPT, in the default PDP directory, C:\MMP, each time the operator quits the program. OFFLOAD.OPT records the current PDP options settings, which are loaded the next time the program is run. You are free to changes the options at any time, but your last settings, typically the ones you use most often, are preserved for next time and do not need to be re-entered.

Like the on-board offload utility, the PDP checks for DEPLOY.DAT and PROFILES.DAT, looking in the input directory. If DEPLOY.DAT is present, the PDP will display the deployment definition parameters on the screen. If PROFILES.DAT is not found, the PDP will prompt the operator to use the maximum possible file count to index through the files during unpacking. The operator has the option of using the maximum count or terminating data processing.

The PDP creates an ASCII text file for each engineering, CTD, and ACM file that it is instructed to unpack. The same file names are used, but the extension is changed from .DAT to .TXT. For example, E0000414.DAT is unpacked into E0000414.TXT. In addition to these files, the PDP also creates a file, TIMETAGS.TXT, that contains start and stop times for each profile. This information is otherwise only available if the engineering files are unpacked in human readable form. Each line in TIMETAGS.TXT contains, in order, the profile number, the date and time for sensor turn on, the date and time for motion start, the date and time for motion stop, and the date and time for sensor turn off.

Like the on-board offload utility, the Profiler Data Processor is non-destructive. The binary files are not altered by unpacking and the process can be run repeatedly. Operators should be sure, in advance, that there is sufficient disk and file system space for the unpacked files. The expansion factor is ~4.25. Existing ASCII text files will be overwritten each time unless they are moved to another directory or the output directory is changed. An average PC should be able to translate 200 Mbytes of binary date into ASCII text in less than 10 minutes.

Like the MMP, operating the PDP becomes easier with practice. Data files for use in training are quickly produced by a bench top deployment.

Data Processing and Interpretation

This section of the manual is intended to guide you through the preliminary data processing and interpretation of MMP data. There are two distinct tasks. First, the raw acoustic path velocity measurements logged in the ACM data files need to be mapped to velocities in the local Cartesian earth frame. That transformation requires an accurate determination of the heading angle of the ACM sting. The first portion of this section is, therefore, a description of ACM compass calibration, the subsequent calculation of the heading angle, and, finally, the mapping of velocity measurements into the earth frame.

Note that the response of the compass will change from one deployment to the next. The change is caused by physical shifts and rotations of components during maintenance and the new magnetic field associated with a new battery pack. Other factors, such as drift in the compass electronics, may also affect the calibration. The compass should be recalibrated, as described below, before and after each deployment. This is, of course, the recommended practice with all sensors.

The second task is synchronizing the sensor data streams to a common clock. CTD and ACM records are not individually time tagged. Sensor and motion start and stop times are recorded in the engineering files, but, as described in previous chapters, there are errors associated with those logged times. The sensor start times in particular are late by several seconds. To further complicate matters, the sensors do not start and stop at precisely the same time and do not record synchronously. While the nominal sample rate of both sensors is 1.85 Hz, they are not phase-locked to prevent drift. They operate independently and must be synchronized during post-processing. The second portion of this section describes how to tie both sensor data streams to the common real-time clock of the MMP.

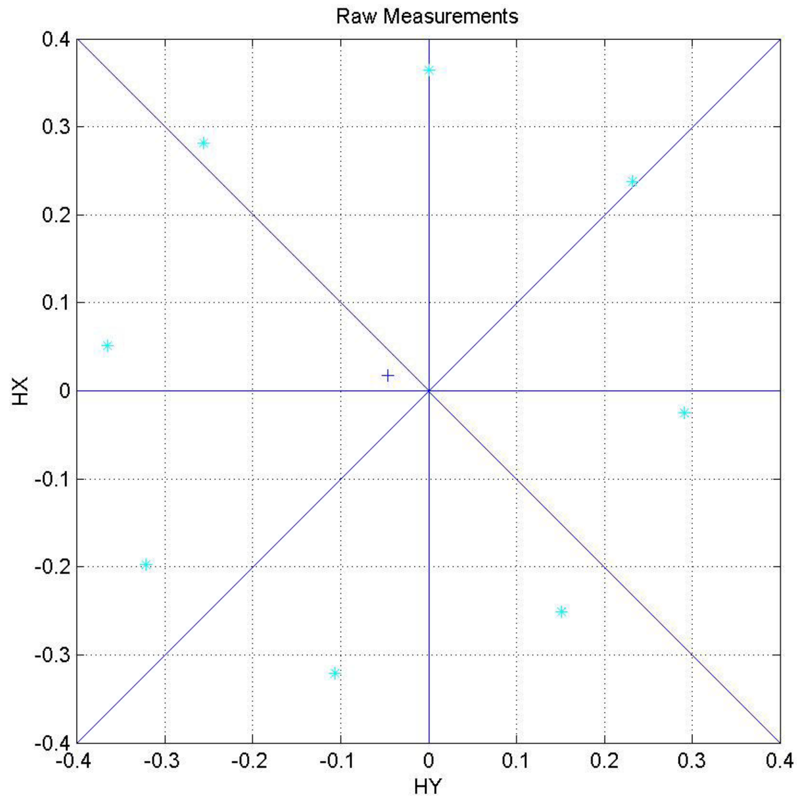
The data are ready for oceanographic analysis after the preliminary processing is complete. We will leave that part to you.

ACM Compass Calibration - Mapping Raw Measurements to the Unit Circle

The calibration of the compass is undertaken in stages. First, the horizontal compass measurements must be mapped to the unit circle.[36] This step is normally carried out with field data, which are presumably less influenced by the strong local magnetic fields of buildings, docks, and ships. For simplicity, however, we will first illustrate the procedure using the measurements collected for the discussion in Bench Test - ACM Communications. We can also imagine this to be "spin test" data, which will be needed for the next stage of the calibration.

Sting Direction		HX	HY	HZ	φ	θ_H
N	90°	0.3645	0.0008	-0.9312	-68.6°	82.8°
NE	45°	0.2383	0.2321	-0.9430	-70.6°	37.7°
E	0°	-0.0246	0.2914	-0.9563	-73.0°	-7.4°
SE	-45°	-0.2508	0.1515	-0.9561	-73.0°	-53.7°
S	-90°	-0.3212	-0.1064	-0.9410	-70.2°	-101.2°
SW	-135°	-0.1979	-0.3218	-0.9259	-67.8°	-143.1°
W	180°	0.0511	-0.3652	-0.9295	-68.4°	174.7°
NW	135°	0.2817	-0.2563	-0.9246	-67.6°	130.4°

[36] Mooring tilt is generally small enough to ignore during data processing. The operator should, of course, verify this for each deployment. The techniques described here can be extended to include HZ if necessary. In that case the measurements must be mapped to the unit sphere (three offsets and three scale factors) and then corrected for two bias angles. Then the calculation of sting heading with horizontal normalization (described under Bench Test - ACM Communications) can be applied. Experience with a number of profiler deployments has shown that the added computational complexity is seldom, if ever, necessary.



If we plot the raw measurements of HX and HY the need for calibration becomes apparent. HX and HY, the normalized components of the magnetic flux, are, by definition, proportional to the sine and cosine of the heading angle of the sting in "mathematical" compass coordinates. As such, the points should lie on a circle centered at the origin. In the plot above the eight measurements are shown by asterisks and the vector average of the points is marked by a cross. Clearly the measurements are not centered on the origin. Closer examination will also show that they lie on an ellipse rather than a circle.

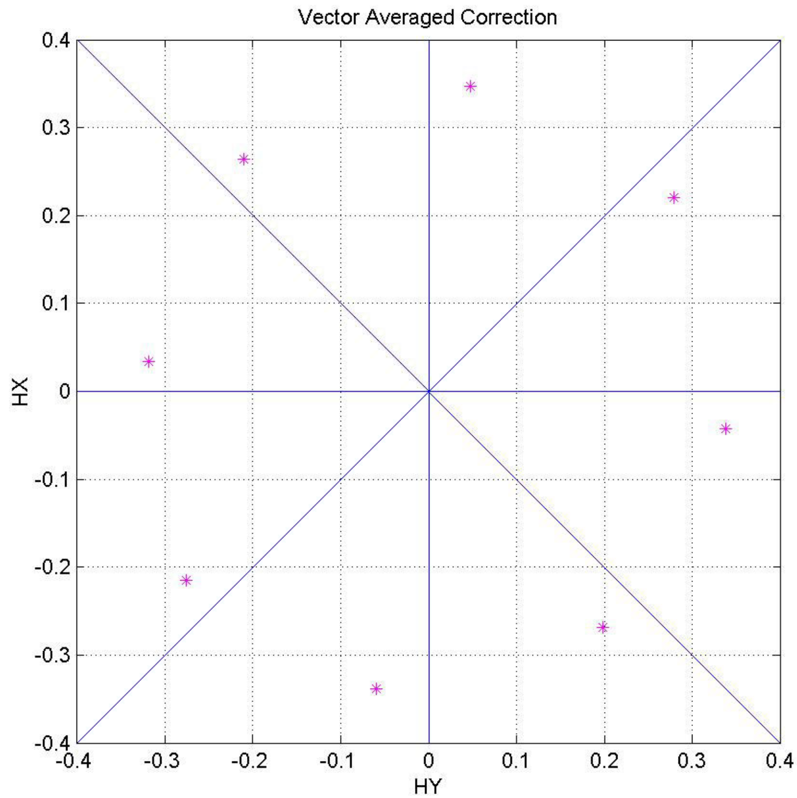
The errors are caused by slightly different biases, gains, and alignments in the two horizontal components of the compass, each of which measures local magnetic flux relative to itself. The alignment errors add a bias angle (an apparent rotation about the vertical axis), which we can ignore until the second stage of the compass correction. To correct for the biases and gains we need to determine offset and scale parameters that map the measurements to the unit circle. These parameters are defined by the equation

$$\left(\frac{HX - X_O}{X_S}\right)^2 + \left(\frac{HY - Y_O}{Y_S}\right)^2 = 1$$

where HX and HY are the raw measurements, X_O and Y_O are the offsets, and X_S and Y_S are the scale factors. The expressions in the parentheses will be the corrected HX and HY values.

One approach, which has been used with success, is simply to adjust these four parameters by hand, iterating manually until the desired result is achieved. A second, more systematic method, is to vector average[37] the measurements and use those components as the offsets. Then, using the offset corrected measurements, the scale factors are max(abs(HX_O)) and max(abs(HY_O)), that is, the element of each component set with the largest magnitude after the offsets have been applied.

[37] To vector average the measurements calculate the means of the HX and HY measurements separately.

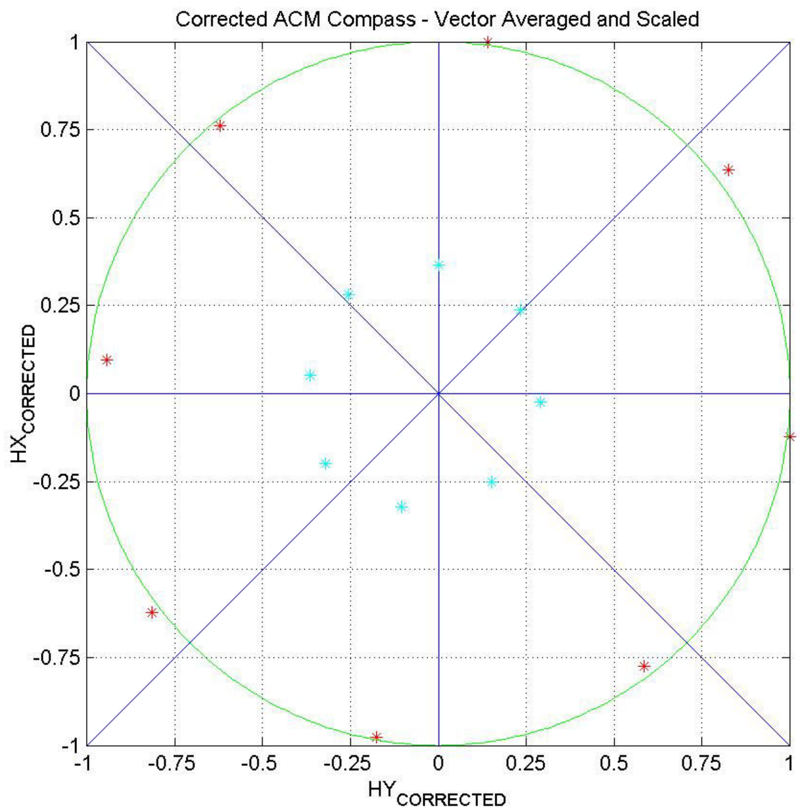


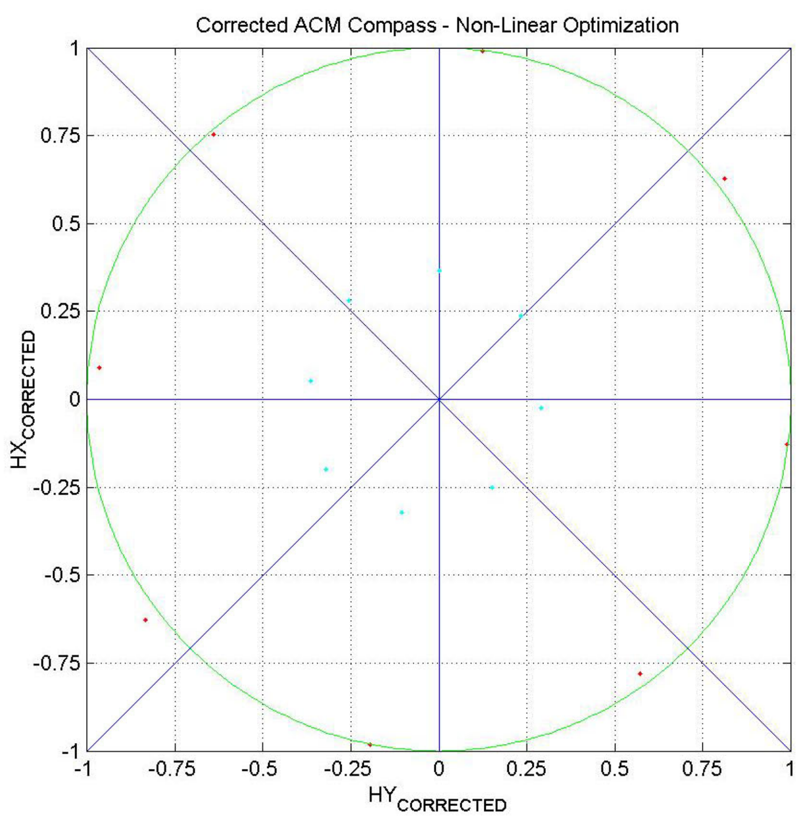
The two steps of the second method are shown in the plots above and below. In the first plot, titled "Vector Averaged Correction", the components of the vector average have been subtracted from the components of each measurement, shifting the ellipse so that it is centered at the origin. In the second plot, "Corrected ACM Compass - Vector Averaged and Scaled", the scale factors have been determined and applied to the offset measurements. The corrected compass measurements fall roughly on the unit circle. The raw measurements are shown for comparison. (Note the change of scale between the two plots.)

The vector averaging approach is conceptually straightforward and it produces an acceptably accurate result. It is easily implemented with either field or spin test data and can be carried out by hand if necessary. The numerical results in this case, which can be applied to other portions of the data from that compass, are:

$X_O = +0.018 \qquad Y_O = -0.047$
$X_S = +0.347 \qquad Y_S = +0.338$

Note, however, that the original measurements must be approximately evenly spaced in angle to produce a good vector average. Consider the result of vector averaging if you used north, east, and south measurements, but not west. Keep this limitation in mind if you use this method with field data. There will almost certainly be different numbers of measurements from each quadrant and representative values will have to be chosen manually for even coverage. It is also necessary to have measurements near to the north, east, south, and west directions so that the two scale factors can be calculated. Again, keep this limitation in mind if you use this method.


Corrected ACM Compass - Vector Averaged and Scaled
HX CORRECTED
HY CORRECTED
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1


Corrected ACM Compass - Non-Linear Optimization
HX CORRECTED
HY CORRECTED
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1

The final method is fully non-linear optimization. In this approach the Nelder-Mead simplex algorithm is used to adjust the four parameters to achieve an "optimal" result. First we define MX and MY, the corrected measurements.

$$MX = HX_{CORRECTED} = \frac{HX - X_O}{X_S}$$

$$MY = HY_{CORRECTED} = \frac{HY - Y_O}{Y_S}$$

Then we define a measure, E_N, of the collective deviation of the corrected measurements from the unit circle.

$$E_N = \left\{ \sum_j \left| \left(MX_j^2 + MY_j^2 \right) - 1 \right|^2 \right\}^{\frac{1}{2}}$$

The algorithm iteratively adjusts the four parameters until the collective deviation, E_N, is minimized. The Nelder-Mead simplex algorithm is not the most efficient calculation of this type, but it is robust and seldom gets trapped in local minima. Running the algorithm more than once, with the previous result as an initial value, is recommended.[38]

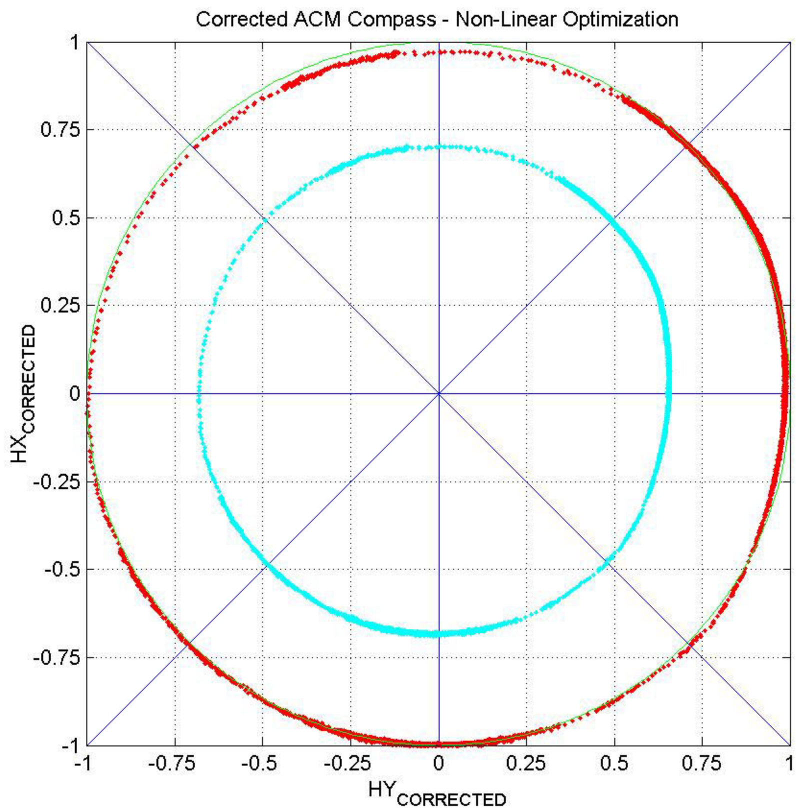
The result of the non-linear optimization is shown in the plot above, "Corrected ACM Compass - Non-Linear Optimization". The numerical results,

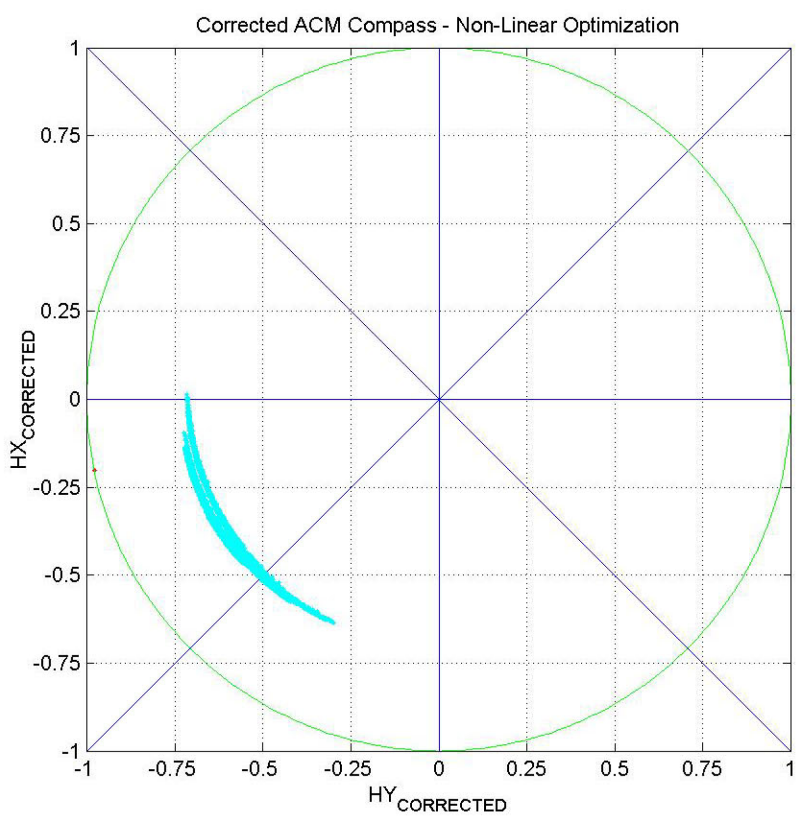
$X_O = +0.020 \qquad Y_O = -0.041$
$X_S = +0.348 \qquad Y_S = +0.336$

are not significantly different from those obtained by vector averaging and scaling with maximum values.

The advantage of the simplex algorithm is that measurements with regular angular spacing and some elements near the principal north-south and east-west axes are not required. Nelder-Mead can be applied to MMP field data without manual preprocessing. The obvious disadvantage is the difficulty of implementation. Anticipating this problem, McLane has written two programs, both freely distributable, that process ACM data using non-linear Nelder-Mead optimization. The first program must be run under Matlab, the numerical analysis and computation software package sold by The MathWorks. The second program is a compiled version of the first that will run under DOS and Windows after an installation routine is run on your PC. The compiled version can be run without purchasing Matlab. The programs can process both ACM field data (9 data columns) and spin test data (5 data columns). The latter are generated using the ACM Tilt and Compass Bench Test utility. See ACM Compass Calibration for more information about installing and running the programs.

[38] An enlightening and entertaining description of the algorithm can be found in Section 10.4 of Numerical Recipes in C, Press, W. H., Flannery, B. P., Teukolsky, S. A., Vetterling, W. T., Cambridge University Press, Cambridge, 1988.


Corrected ACM Compass - Non-Linear Optimization
HX_CORRECTED
HY_CORRECTED


Corrected ACM Compass - Non-Linear Optimization
HX_CORRECTED
HY_CORRECTED

If possible, the compass offsets and scale factors should be calculated using field data. Such measurements are generally less contaminated by the strong, localized anomalies in the earth's magnetic field that are associated with buildings, docks, and ships. The MMP is designed to self-align so that the sting always points into the flow. During a profile the MMP will, not uncommonly, experience a number of complete rotations due to depth and time dependent variations in the direction of flow. Compass measurements from these profiles map to all four quadrants of an HX vs. HY compass plot and can be used to calculate offsets and scale factors. An example is shown above. The offsets and scale factors calculated for this data set, using the simplex algorithm, are

$$X_O = +0.019 \qquad Y_O = -0.009$$
$$X_S = +0.703 \qquad Y_S = +0.675$$

In a vertically uniform flow field, however, the heading will stay relatively constant and measurements on a compass plot will fall into a single quadrant. While data processed with the Nelder-Mead routines do not need to be evenly distributed, they do need to be distributed through all four quadrants. Compass measurements from these profiles cannot be used to determine offsets and scale factors. An example is shown above. The simplex algorithm fails when applied to these data, returning patently false results after an unreasonably large number of iterations.

ACM Compass Calibration - Conducting a Spin Test

If suitable field data are not available, you can calculate the offsets and scale factors using spin test measurements. Correcting the compass measurements for angular bias (see below) can only be done with pre- or post-deployment spin test measurements, so these data will necessarily be available. The one tool you will need is a good quality hand compass. A compass that allows you to sight bearings accurately is best.

Spin tests should be conducted, if possible, well away from local variations in the earth's magnetic field. In particular, be aware that the steel reinforcing bars inside concrete, from which docks and buildings are often built, typically carry strong magnetic fields. The same can be said of the steel hulls of ships. Fortunately, the hand compass is a very reasonable anomaly detector. If the compass shows reasonable agreement with the known direction of magnetic north and, importantly, the direction in which the compass points does not vary as you move it about the area, then that location is suitable for a spin test.

Run the communications cable from the serial communications connector up through the hole in the bottom rib of the frame and out through the oval hole in the back of the skin. This will allow communications with the lower faired end cap in place during the test. Hold the profiler vertically, balanced on the lower faired end cap. It is important that the profiler not deviate from the vertical while measurements are being made. Visual observations are generally accurate enough, though you are welcome to use a plumb line or a carpenter's level. To avoid abrasion of the fairing, we suggest that you place several sheets of cardboard or a block of wood or plastic under the profiler.

Begin scrolling tilt and compass measurements using that Bench Test utility. Alternatively, use the ACM communications pass-through and manually trigger the measurements as needed. In either case, log the output with the Crosscut or TattleTerm file capture utility. There are two parts to the procedure. First, slowly turn the profiler through one or more complete turns, taking care that the frame remains vertical. We suggest that you begin with the sting pointed north and rotate towards the east, but this is not essential. This portion of the spin test data can be used to calculate the offsets and scale factors as described in the previous section.

Compass measurements associated with known headings of the sting are needed to remove the bias angle. That part of the compass calibration procedure is described in the next section. To collect the data, carefully and accurately align the sting with magnetic north. You may be able to achieve greater accuracy by resting the hand compass on the top of the profiler. Since you are using the hand compass as the reference it is important that it be in close proximity to the compass in the ACM. Record the measurements for ten seconds or more. Turn the profiler and accurately align the sting with northeast. Make sure the profiler is vertical and record the compass measurements for an additional ten seconds or more. Continue in this manner through the remaining six cardinal points of the compass. The quality of the compass calibration depends directly on the accuracy with which the sting is aligned to these eight headings. This portion of the spin test data will be used to calculate the bias angle.

The bias angle data should be reduced to eight elements, one associated with each of the eight cardinal directions. The operator has the option of selecting a representative measurement or calculating an average for each heading from the data collected in the second portion of the spin test. The spin test data used above to illustrate the calculation of offsets and scale factors are an example of eight element data.

ACM Compass Calibration - Removing the Bias Angle

Mapping the raw horizontal compass measurements to the unit circle, as previously noted, does not remove the bias angle. The bias may be as large as 10° to 20°. An angular bias of 5° to 10° or more is clearly evident in the plots of corrected, eight element, spin test data presented earlier. We will make a more precise measurement in a moment.

Two sources contribute to the total bias angle. First is the bias angle, B_C, associated with the compass module itself. B_C is an inherent characteristic of each compass. It might, possibly, drift during a deployment, but interpolation using pre- and post-deployment spin test data could be used to make a time varying correction. Significant compass drift has not been a problem historically. B_C generally has a small angular dependence. It may, for example, be larger to the south than to the north. Interpolation can be used to make a bearing dependent correction or the small differences can be ignored.

The second source of bias is the mechanical pointing error, B_M. Mounting misalignments between the compass module and the ACM electronics housing and between the ACM housing and the MMP frame and sting both contribute to B_M. To accurately account for the latter contribution, the spin test and the deployment must be conducted without removing the ACM housing from the bracket that secures it to the profiler frame. Removing and remounting the housing will invariably introduce a rotation of the compass relative to the MMP frame and sting. For the same reason, refrain from inspecting the ACM electronics in the interval between the spin test and the deployment. B_M is a constant for a deployment. It can be kept small through careful mechanical alignment of the ACM housing in the frame of the MMP.

The bias angles are simple additive errors to the sting heading angle, θ_H. It is the total bias that is of concern, so it is not necessary to differentiate between the two sources. We simply need to measure the total. We can do this by measuring the difference between the heading calculated using MX and MY, the offset and scale corrected measurements, and the "true" heading, as measured using the hand compass. This is the purpose of the eight element spin test data.

Consider this expression for the sting heading angle in a true north Cartesian earth frame.

$$\theta_H = \tan^{-1}\left(\frac{MX}{MY}\right) + B_C + B_M + B_P + M_{Dev}$$

M_{DEV} is the magnetic deviation, the bearing of magnetic north measured from true north in mathematical compass coordinates. M_{DEV} is positive in the North Atlantic and negative in the North Pacific. B_P is the error between the actual magnetic bearing of the sting and the target magnetic bearing during the spin test. M_{DEV} for any location on the earth can be looked up in a reference and used to correct the heading angle. The total bias angle, $B_T = B_C + B_M$, can be measured, but the accuracy of that measurement is limited by the magnitude of B_P. This is why good alignment of the sting using the hand compass is a critical part of the spin test. A good alignment, which we must assume, means B_P is negligibly small, leaving us with

$$\theta_H = \tan^{-1}\left(\frac{MX}{MY}\right) + B_T + M_{DEV}$$

Working in the magnetic or compass frame, B_T can be measured at each of the eight cardinal points of the compass:

$$B_T = \theta_H - \tan^{-1}\left(\frac{MX}{MY}\right)$$

θ_H is the actual magnetic bearing in mathematical compass coordinates (90° for magnetic north, 45° for magnetic northeast, 0° for magnetic east, etc.). MX and MY are derived from the raw measurements and the corrections obtained by mapping those measurements to the unit circle. This calculation is simple enough to be performed quickly with a hand calculator.

Alternatively, the Nelder-Mead simplex minimization programs developed by MRL will do the work. The calculation of B_T at the eight cardinal points is triggered whenever the raw data being processed include exactly eight elements in a file named spintest.txt. The calculation assumes the data are in north, northeast, east, southeast, south, southwest, west, northwest order. The operator is responsible for insuring this is true.

The B_T values for the eight element data we have been using to illustrate the compass correction process are:

N	NE	E	SE	S	SW	W	NW
+7.2°	+7.3°	+7.4°	+8.7°	+11.2°	+8.1°	+5.3°	+4.6°

Average angular bias: +7.5°

Observe that the bias angle varies with bearing over a range of 6.6°. The operator may choose to use a constant correction, the average angular bias calculated by the programs, for example, or may interpolate through each octant using the eight measurements of B_T.

ACM Compass Calibration - Summary

In summary, you first need to calculate five compass correction parameters, X_O, Y_O, X_S, Y_S, and B_T. The latter may have some non-negligible dependence on the heading angle. Fortunately, it is the offset and scaled heading angle, θ_{OS}, the arctangent term in the equation below, that is used to make the correction, not θ_H. Several methods by which the parameters can be calculated from field and spin test data are described above. In addition, two programs that carry out the actual calculations are available. Using the derived parameters and the known magnetic deviation for the site of the deployment, θ_H, the heading angle of the sting in mathematical compass coordinates, can be calculated.

$$\theta_H = \tan^{-1}\left(\frac{\left(\frac{HX - X_O}{X_S}\right)}{\left(\frac{HY - Y_O}{Y_S}\right)}\right) + B_T(\theta_{OS}) + M_{DEV}$$

Mapping Velocity Measurements to the Cartesian Earth Frame

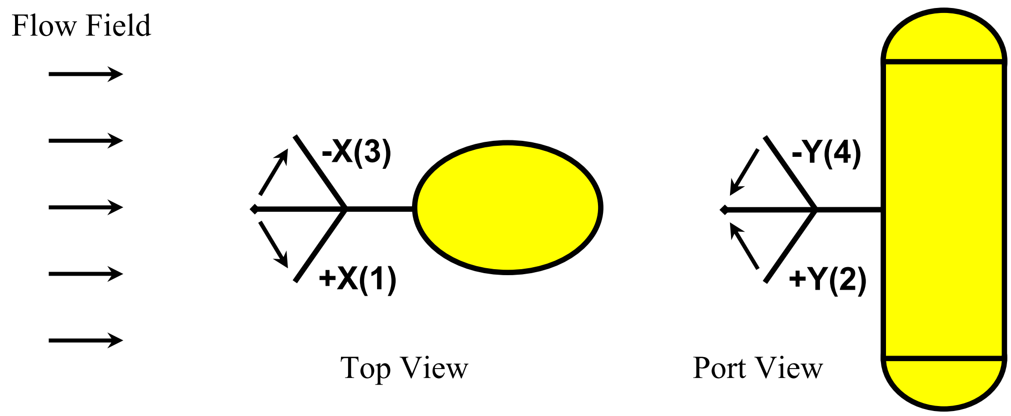
The velocity transformation is a relatively simple matter of geometry. We assume here that the velocity sensor acoustic paths have been calibrated and that the sting was mounted to the MMP with the correct orientation. For reference, the description and sketch of sting and acoustic path geometry from the discussion of ACM Communications in an earlier chapter is repeated below.

Sting and Acoustic Path Geometry

The final four numbers in each ACM scan are the velocities along the acoustic axes of the sting. The units are cm/s. The fingers of the sting are labeled +X, +Y, -X, and -Y. The first velocity in a scan is from the +X path, the second is from +Y, the third is from -X, and the fourth velocity is from the -Y path. By convention, the sting is mounted on the MMP with the -Y finger up. This places the +Y finger down, the +X finger to port, and the -X finger to starboard.

For the X fingers, velocity is defined to be positive for flow along the acoustic path from the central post of the sting towards the finger. For the Y fingers, velocity is defined to be positive for flow along the acoustic path from the finger towards the central post. With the sting pointed into the flow, the X-path velocities will be positive and the Y-path velocities will be negative. The angle between each acoustic path and the central post is 45°.

These definitions and relationships are summarized in the schematic below. The arrows indicate the direction of positive flow along each acoustic path. The parenthetical values indicate the order in which the measurements appear in the scan.



Velocity Transformation

First, transform the four path velocities into a velocity vector, (u, v, w), in the frame of the MMP. Recall that the Cartesian co-ordinate frame of the MMP is defined to have the +x-axis pointing forward, the direction in which the sting of the ACM points. The +y-axis points to port and the +z-axis points up. From the geometry we then have

$$u = \frac{\left(-V_{+X} - V_{-X}\right)}{\sqrt{2}} \qquad v = \frac{\left(+V_{+X} - V_{-X}\right)}{\sqrt{2}}$$

$$w_U = \frac{2 \cdot \left(+u - V_{-Y}\right)}{\sqrt{2}} \qquad w_D = \frac{2 \cdot \left(-u + V_{+Y}\right)}{\sqrt{2}}$$

Use $w = w_U$ for an upward (odd numbered) profile and $w = w_D$ for a downward (even numbered) profile. It is important to make this distinction rather than just combining the +Y and -Y measurements as the +X and -X measurements are combined to measure the horizontal velocity. This is because the trailing Y-path is contaminated by the sheet-flow wake of the central post of the sting when the MMP is profiling. The leading acoustic path is in relatively clean flow.

Note that w is the sum of the ambient vertical flow field and the vertical motion of the profiler. The vertical motion of the profiler can be removed, to a reasonable level of accuracy, by subtracting the pressure rate, dP/dt, which can be determined from the CTD measurements. The geometry of the acoustic paths and the near zero tilt of the profiler mean that u and v, the horizontal components of the velocity, are relatively uncontaminated by the vertical motion of the profiler.

The horizontal speed and direction of the flow, in the MMP frame, are given by

$$S_H = \sqrt{u^2 + v^2} \qquad \theta_V = \tan^{-1}\left(\frac{v}{u}\right)$$

θ_V is measured in the usual mathematical sense, positive counter-clockwise from the positive x-axis of the MMP frame. θ_V will typically be close to 180° with the sting pointing into the flow.

The direction of flow in the true north Cartesian earth frame is then simply

$$\theta_T = \theta_V + \theta_H$$

All three quantities are expressed in mathematical compass coordinates. It may be necessary to wrap θ_T into the range $-180° < \theta_T \leq +180°$ by adding or subtracting 360°.

Finally, the eastward and northward velocities in the true north Cartesian earth frame are:

$$U_E = S_H \cos\theta_T \qquad V_N = S_H \sin\theta_T$$

Synchronizing the Data Streams

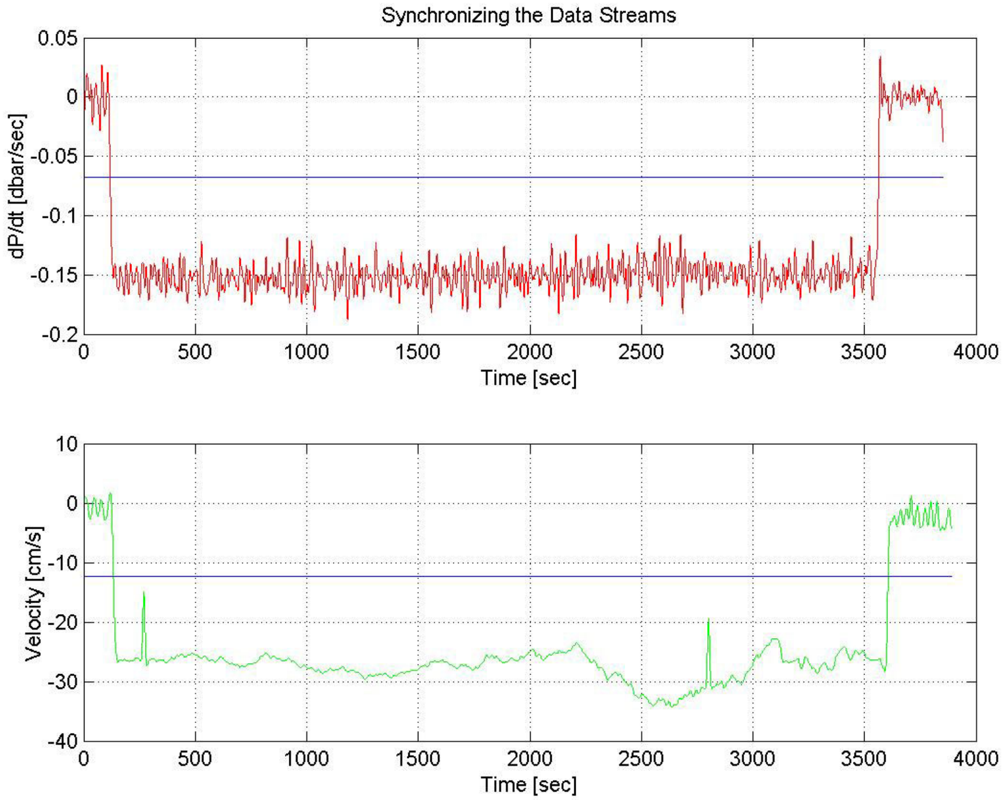
Individual records in the CTD and ACM files are not time tagged. Sensor and motion start and stop times for each profile are recorded in the engineering files and in TIMETAGS.TXT. The engineering files also include a subset of the CTD pressure measurements, each one with a time tag that is accurate to 0.5 second. The motion start and stop tags are accurate to better than one second of the RTC. The motion start time is logged at the beginning of the velocity ramp. The motion stop time is logged when the brake is set at the end. The stop is far more abrupt than the start.

In contrast, starting and stopping sensor logging, particularly starting, require conversations of some complexity over the serial links to the sensors. In consequence, the sensor start is late by approximately 15 to 20 seconds for the CTD and by approximately 5 to 10 seconds for the ACM. These times are variable. The stop times are also late, but by no more than 5 seconds and usually by less than one or two seconds. The ACM stops logging first. The CTD follows, generally less than a second later.

The nominal sample rate of both sensors is 1.85 Hz, but they are not phase-locked and cannot be assumed to record synchronously. Reliably aligning the CTD and ACM data streams therefore requires identifying common features in the two time-series. The method that has worked most reliably in the past has been to compare *w*, the vertical velocity measured by the ACM, with dP/dt, the pressure rate that can be derived from the CTD pressure measurements.

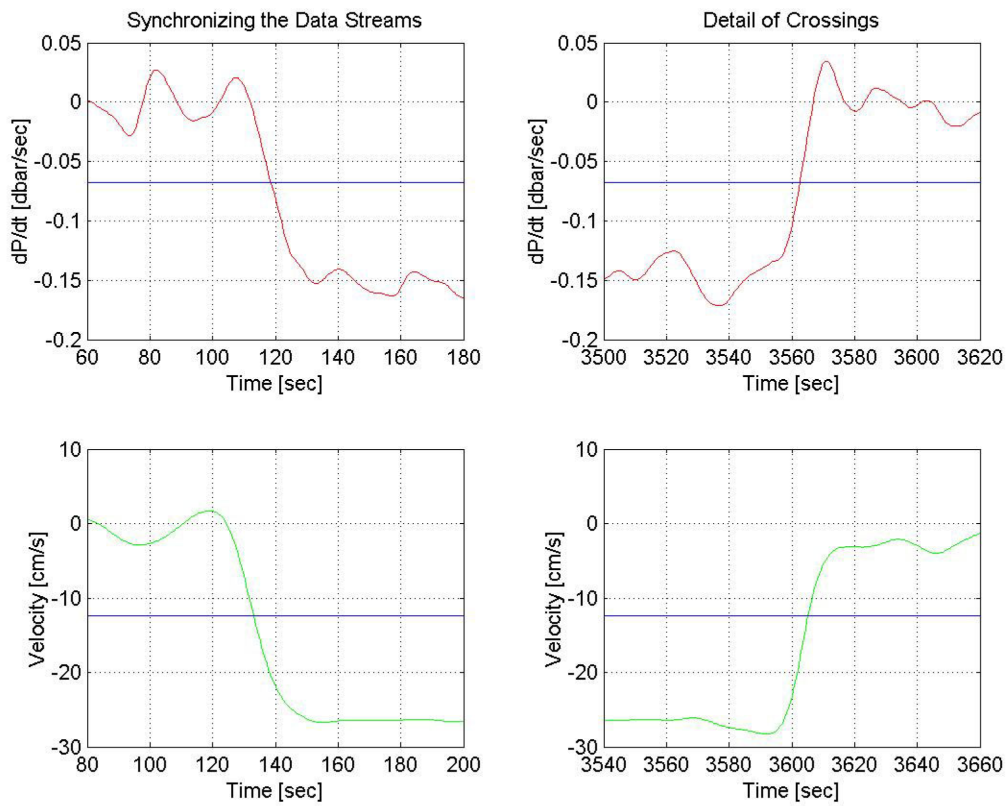
Begin by matching CTD pressures to time tagged pressures in the engineering record. Then interpolate linearly between the known points to fill up the central portion of the record. Take care of the ends of the record by extrapolating at the sample rate measured by your interpolation. Presumably this will be close to 1.85 Hz. Verify that the result is consistent with the sensor and motion start and stop times stored in the engineering and time tag files.

Calculate dP/dt and run the result through some form of low pass filtering to smooth it. Again, verify that the result is consistent with the recorded start and stop times. Pass the vertical velocity measurements of the ACM through the same low pass filter. Two features, the velocity ramp near the beginning and the stop near the end, will be readily identifiable in both filtered records. An example using field data is shown in the plot below. The top panel shows dP/dt and the bottom panel shows the vertical velocity measurement. Both signals have been filtered. The time axes are initial estimates.



Calculate the means of both series. Align the velocity record to the pressure rate time series by matching the points at which both reach half of their mean values. In each panel above the blue line marks the level of half the mean value. The four panel plot below shows details of the half mean value crossings. Interpolate the velocity record linearly between these two times. Extrapolate the beginning and end of the series by extrapolating at the sample rate measured by your interpolation. Other clear features in the records may permit you to "fine tune" the alignment at various interior points. Verify that the two time series are consistent with each other and with the recorded start and stop times.

In summary, use the accurate pressure time tags in the engineering record to align the CTD record and synchronize it to the RTC. Then align the ACM record using the start and stop transients of the vertical velocity and pressure rate records. Congratulations, your sensor and engineering records now share a common time base.



Data Processing Shareware

A suite of Matlab programs designed to process MMP data has been developed at the Woods Hole Oceanographic Institution. The programs are freely available to all members of the moored profiler community, however, you must be running Matlab to take advantage of this suite of processing tools. Contact McLane Research for the URL.

VI. Deployment Parameter Selection

Developing a sampling schedule that meets the scientific goals of an investigation without exceeding the capabilities of an instrument system is a time consuming but absolutely necessary part of planning for any deployment. The MMP system control program includes tools to assist an investigator with this typically iterative process. The tools are part of the Deploy Profiler option of the Main Menu and include consistency checks of proposed profile and burst schedules and a calculation of mission endurance. The interactive Deployment Menu and the planning tools make answering the question "What happens if we do it this way instead?" both fast and easy.

Two illustrative examples are presented below. The first is a deep-water deployment with a profile range of several thousand meters. As shown in the example, deep-water deployments are commonly limited by profiling speed. Long duration deep-water deployments are further constrained by system endurance. The second example describes a hypothetical deployment on the continental slope with a profiling range of several hundred meters. The primary limitation for a short profiling range is imposed by flash card compatibility with DOS/Windows; the file system is full after 1362 profiles. As we will see below, that doesn't take long on a short mooring. A restricted profiling range on a deep-water mooring will face the same constraint. This file system limitation will be addressed in a future revision of the SCP.

Deep-Water Deployment

Consider these proposed or preliminary requirements for a deep-water deployment:

- profile between 50 meters and 5500 meters, the full water column at the intended location (very important, post-deployment modeling of meso-scale motions and tides will involve decomposition into orthogonal dynamical modes, the boundary conditions, the conditions at the top and bottom of the water column, must be measured)
- 12 month deployment duration (important, seasonal variation being investigated)
- 12 hour start interval between pairs or 6 hour start interval between single profiles (more frequent if possible, tidal aliasing)
- paired profiles (weak constraint, biofouling when parked at the top of the profiling range)

The requirements have been ranked in importance based on the goals of the investigation. Paired profiles is considered a "weak" constraint because the 12 hour start interval and regular sampling will prevent the profiler from spending a significant period of time parked at the top of the range.

Deployment parameters for the first iteration, meeting all of the proposed requirements, are shown below.

```
Start    1| Countdown delay        =     12:00:00 [HH:MM:SS]

Schedule 2| Pair start interval    = 000 12:00:00 [DDD HH:MM:SS]
         3| Reference date/time    =   04/10/2002 00:00:00
         4| Burst interval         = 007 00:00:00 [DDD HH:MM:SS]
         5| Pairs per burst        =     Disabled
         6| Paired profiles              Enabled

Stops    7| Shallow pressure       =         50.0 [dbar]
         8| Deep pressure          =       5500.0 [dbar]
         9| Shallow error          =        250.0 [dbar]
         A| Deep error             =         50.0 [dbar]
         B| Profile time limit     =     07:34:10 [HH:MM:SS]
         C| Stop check interval    =           30 [sec]

         D| Done

        Selection  ? d                                      ← evaluate the schedule

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

Checking profile schedule . . . done.
Calculated minimum profile pair duration:    13:28:08

Estimated minimum profile pair duration exceeds pair        ← a pair of profiles cannot
start interval.  System will skip pairs whenever a             be completed in less than
pair start time is missed.                                     12 hours, more than
                                                               13 hours are needed
Change selections (Yes/No) [Y] ? n                          ← continue checks to see
                                                               what other schedule
Checking burst schedule . . . done.                            modifications may be
Burst mode disabled.                                           necessary

Estimated Profile 1 start time:   04/10/2002 00:00:00

Profiling distance will reach 1 million meters              ← this will be a problem,
on 07/10/2002 after 183 profiles.                              but we'll consider it
                                                               after making the profile
Accept and store schedule selections (Yes/No) [Y] ? n          schedule consistent
```

The consistency checks and the calculated profile time limit indicate that no more than three single profiles can be completed in a 24 hour period over the proposed profiling distance. The profiling distance must not be shortened; the full extent of the water column must be sampled. However, the requirement for paired profiles can be waived without significant cost. Conducting three profiles per day is not optimal, but four profiles per day are simply not possible.

Deployment parameters for the second iteration are shown below.

```
Start    1| Countdown delay       =     12:00:00 [HH:MM:SS]

Schedule 2| Profile start interval = 000 08:00:00 [DDD HH:MM:SS]
         3| Reference date/time   =   04/10/2002 00:00:00
         4| Burst interval        = 007 00:00:00 [DDD HH:MM:SS]
         5| Profiles per burst    =     Disabled
         6| Paired profiles             Disabled

Stops    7| Shallow pressure      =         50.0 [dbar]
         8| Deep pressure         =       5500.0 [dbar]
         9| Shallow error         =        250.0 [dbar]
         A| Deep error            =         50.0 [dbar]
         B| Profile time limit    =     07:34:10 [HH:MM:SS]
         C| Stop check interval   =           30 [sec]

         D| Done

        Selection  ? d                                   ← evaluate the schedule

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

Checking profile schedule . . . done.
Calculated minimum profile duration:        06:44:04
Profile schedule selections are consistent.              ← profile schedule is now
                                                           consistent
Checking burst schedule . . . done.
Burst mode disabled.                                     ← burst mode remains
                                                           disabled
Estimated Profile 1 start time:   04/10/2002 00:00:00

Profiling distance will reach 1 million meters           ← endurance requirement
on 06/09/2002 after 183 profiles.                          is not met

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

The profile schedule is now consistent. The MMP will begin a new profile every 8 hours, reaching 1 million meters of cumulative travel in approximately 2 months. Unfortunately, this is woefully short of the "important" 12 month deployment duration requirement. Profiling in bursts can extend the duration.

A six-fold increase in coverage is needed. Three possibilities are (1) a 1 month burst every 6 months, (2) a 1 week burst every 6 weeks, and (3) a 1 day burst every 6 days. Any schedule with a duty cycle of 1 part in 6 will extend the deployment duration to 12 months. The question that must be answered is: "Which burst interval will adequately sample the phenomena of interest?" Put another way: "What are the time scales of interest?" The first schedule will not resolve seasonal variations, which are considered important. The third schedule is not quite adequate for tidal and diurnal events, though it comes close. Resolution is limited here by the minimum duration of a single profile within a burst. A 1 day burst with a 6 day burst interval would allow resolution of the spring-neap cycle, but would expose the profiler to biofouling for a period of 5 days after every second burst. A schedule with an even number of profiles in each burst makes good sense, but resolution of the spring-neap cycle will be lost.

A schedule with bursts of 6 profiles (2 days) and a burst interval of 12 days is shown below. This set of parameters satisfies the two most important requirements of the investigation. The other requirements cannot be met at the proposed location using a single profiler for a one year deployment. Tidal time scales could be resolved using multiple, synchronized MMPs, each assigned to a different portion of the mooring or to a different portion of the water column on separate moorings. Another approach would be multiple deployments of a single profiler, each of 3 to 6 months duration. In either case, cost becomes an additional constraint.

```
Start    1| Countdown delay        =     12:00:00 [HH:MM:SS]

Schedule 2| Profile start interval = 000 08:00:00 [DDD HH:MM:SS]
         3| Reference date/time    =   04/10/2002 00:00:00
         4| Burst interval         = 012 00:00:00 [DDD HH:MM:SS]
         5| Profiles per burst     =            6
         6| Paired profiles              Disabled

Stops    7| Shallow pressure       =         50.0 [dbar]
         8| Deep pressure          =       5500.0 [dbar]
         9| Shallow error          =        250.0 [dbar]
         A| Deep error             =         50.0 [dbar]
         B| Profile time limit     =     07:34:10 [HH:MM:SS]
         C| Stop check interval    =           30 [sec]

         D| Done

        Selection  ? d                                      ← evaluate the schedule

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

Checking profile schedule . . . done.
Calculated minimum profile duration:         06:44:04
Profile schedule selections are consistent.

Checking burst schedule . . . done.
Calculated burst duration:               002 00:00:00
Burst schedule selections are consistent.

Estimated Profile 1 start time:   04/10/2002 00:00:00

Profiling distance will reach 1 million meters              ← 1 million meters of
on 04/09/2003 after 183 profiles.                              travel over 1 year

Accept and store schedule selections (Yes/No) [Y] ? y       ← we have a winner
```

The third iteration is a reasonable, but not unique solution. Further refinement of the original requirements might, for example, point to a longer burst or some other variation. Though mildly contrived, this example does demonstrate how deployment parameters are iteratively selected and programmed. Importantly, it also demonstrates the tradeoffs that are part of planning a long duration, deep-water, MMP deployment.

Deployment on the Continental Slope

Consider these initial requirements for a deployment on the continental slope:

- 12 month deployment duration, 2 turn-around cruises are allowed (one target is seasonal variations in mixed layer depth, others are changes in the position of a shelf break front and characteristics of the different water masses that have been previously observed)
- sample at the highest possible rate, no less frequently than a profile every 3 hours (yet other targets are tidally generated internal waves propagating onto the shelf and diurnal vertical migrations of plankton, the sensor suite has been enhanced with a fluorometer and an optical backscatter sensor, this has a mild effect on the energy budget)
- profile between 25 meters and 200 meters (essentially the full water column, the site is on the slope, not far beyond the shelf break)
- park at the bottom (site is biologically active, growth on the transmit and receive windows of the optical instruments will compromise their operation, the depth is only 200 meters, but it's better than staying at the surface)

This is a multidisciplinary cruise with a number of investigators. Ranking the requirements has been difficult. They are listed in order, but are not well separated in importance. Further discussion will be necessary, but the investigators first need to know what is possible. An initial set of deployment definition parameters is shown below.

```
Start    1| Countdown delay        =     12:00:00 [HH:MM:SS]

Schedule 2| Profile start interval = 000 00:00:00 [DDD HH:MM:SS]
         3| Reference date/time    =   04/10/2002 00:00:00
         4| Burst interval         = 000 00:00:00 [DDD HH:MM:SS]
         5| Profiles per burst     =     Disabled
         6| Paired profiles              Disabled

Stops    7| Shallow pressure       =         25.0 [dbar]
         8| Deep pressure          =        200.0 [dbar]
         9| Shallow error          =         50.0 [dbar]
         A| Deep error             =         25.0 [dbar]
         B| Profile time limit     =     00:14:35 [HH:MM:SS]
         C| Stop check interval    =           10 [sec]

         D| Done

        Selection  ? d                                    ← evaluate the schedule

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

Checking profile schedule . . . done.
Calculated minimum profile duration:        00:17:14      ← more than 3 profiles
Continuous profiling selected.                               per hour, a fairly
                                                             high sampling rate

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

Estimated Profile 1 start time:   04/09/2002 04:16:19     ← the start interval is zero
                                                             so the reference time
Profiling distance will reach 1 million meters               is ignored
on 06/16/2002 after 5714 profiles.

Deployment is limited to 1362 profiles                    ← the system is constrained
and will end on 04/25/2002.                                  by the file system, not
                                                             by battery capacity
Accept and store schedule selections (Yes/No) [Y] ? n
```

The initial iteration used continuous profiling through out the deployment. This is the highest possible sampling rate and provides a quick indication of the degree to which the profile start interval must be lengthened. A 4 month minimum deployment duration is needed if both turn-around cruises are used.

Not unexpectedly, the deployment is constrained by the file system. Each profile requires less than 20 minutes to complete and continuous profiling will reach the 1362 profile limit after only 16 days (~2 weeks). Increasing the profile start interval to 2 hours, a factor of approximately 7, may be sufficient.

```
Start    1| Countdown delay        =     12:00:00 [HH:MM:SS]

Schedule 2| Profile start interval = 000 02:00:00 [DDD HH:MM:SS]
         3| Reference date/time    =   04/10/2002 00:00:00
         4| Burst interval         = 000 00:00:00 [DDD HH:MM:SS]
         5| Profiles per burst     =     Disabled
         6| Paired profiles              Disabled

Stops    7| Shallow pressure       =         25.0 [dbar]
         8| Deep pressure          =        200.0 [dbar]
         9| Shallow error          =         50.0 [dbar]
         A| Deep error             =         25.0 [dbar]
         B| Profile time limit     =     00:14:35 [HH:MM:SS]
         C| Stop check interval    =           10 [sec]

         D| Done

        Selection  ? d                                    ← evaluate the schedule

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

Checking profile schedule . . . done.
Calculated minimum profile duration:        00:17:14
Profile schedule selections are consistent.

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

Estimated Profile 1 start time:   04/10/2002 00:00:00

Profiling distance will reach 1 million meters
on 07/30/2003 after 5714 profiles.

Deployment is limited to 1362 profiles                    ← still file system limited,
and will end on 08/01/2002.                                  but the duration is now
                                                             almost sufficient
Accept and store schedule selections (Yes/No) [Y] ?
```

Increasing the start interval to 2 hours is, by itself, almost sufficient. Clearly a further increase to 2.5 or 3 hours would yield a duration in excess of 4 months. While this would also reduce the sampling rate, it is a viable solution and should be considered. Two further alternatives are shown below. The first uses a continuous burst of 50 profiles once each week. This approach offers high frequency sampling for 14 hours (slightly more than a tidal period) once each week for about 6 months. The coverage is less complete, but a very high sampling rate is possible and only one turn-around cruise is necessary. This reduces costs and may have other benefits. For example, it may be easier to schedule the deployment, turn-around, and recovery cruises around winter storms with a 6 month window.

```
Start     1| Countdown delay        =     12:00:00 [HH:MM:SS]

Schedule 2| Profile start interval = 000 00:00:00 [DDD HH:MM:SS]
         3| Reference date/time    =   04/10/2002 00:00:00
         4| Burst interval         = 007 00:00:00 [DDD HH:MM:SS]
         5| Profiles per burst     =           50
         6| Paired profiles              Disabled

Stops    7| Shallow pressure       =         25.0 [dbar]
         8| Deep pressure          =        200.0 [dbar]
         9| Shallow error          =         50.0 [dbar]
         A| Deep error             =         25.0 [dbar]
         B| Profile time limit     =     00:14:35 [HH:MM:SS]
         C| Stop check interval    =           10 [sec]

         D| Done

        Selection  ? d                                      ← evaluate the schedule

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

Checking profile schedule . . . done.
Calculated minimum profile duration:         00:17:14
Continuous profiling selected.

Checking burst schedule . . . done.
Calculated burst duration:               000 14:21:40
Burst schedule selections are consistent.

Estimated Profile 1 start time:   04/09/2002 05:34:01

Profiling distance will reach 1 million meters
on 06/17/2004 after 5714 profiles.

Deployment is limited to 1362 profiles
and will end on 10/16/2002.                                 ← 6 month duration

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

The third alternative schedules bursts of 24 pairs at 1 hour intervals every 5 days (48 single profiles at 30 minute intervals would provide almost the same coverage). The duration to the file system limit is 4.5 months. This approach provides regular coverage at a relatively high sample rate, almost certainly high enough to resolve the target processes. The 4.5 month duration offers some flexibility for turn-around and recovery scheduling and provides protection from weather and ship delays.

```
Start    1| Countdown delay       =     12:00:00 [HH:MM:SS]

Schedule 2| Pair start interval   = 000 01:00:00 [DDD HH:MM:SS]
         3| Reference date/time   =   04/10/2002 00:00:00
         4| Burst interval        = 005 00:00:00 [DDD HH:MM:SS]
         5| Pairs per burst       =           24
         6| Paired profiles              Enabled

Stops    7| Shallow pressure      =         25.0 [dbar]
         8| Deep pressure         =        200.0 [dbar]
         9| Shallow error         =         50.0 [dbar]
         A| Deep error            =         25.0 [dbar]
         B| Profile time limit    =     00:14:35 [HH:MM:SS]
         C| Stop check interval   =           10 [sec]

         D| Done

        Selection  ? d                                        ← evaluate the schedule

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

Checking profile schedule . . . done.
Calculated minimum profile pair duration:    00:34:28
Profile schedule selections are consistent.

Checking burst schedule . . . done.
Calculated burst duration:              001 00:00:00
Burst schedule selections are consistent.

Estimated Profile 1 start time:   04/10/2002 00:00:00

Profiling distance will reach 1 million meters
on 11/26/2003 after 5714 profiles.

Deployment is limited to 1362 profiles
and will end on 08/29/2002.                                   ← 4.5 month duration

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

Clearly a number of other variations are possible and it is apparent that none of them will be endurance (battery) limited. The additional current drain of the enhanced sensor suite should not present a problem. The file system constraint is typical for deployments with a short profiling range. Two points are worth noting. First, the deployment requirements, as described, can be met. Second, a set of workable, specific scenarios was generated with relative ease using the deployment planning tools built into the MMP system control program. This information will be invaluable to the varied group of investigators planning this multidisciplinary study. The tools are an important feature of the McLane Moored Profiler. We hope you find them useful.

VII. Operating Crosscut and TattleTerm

Crosscut and TattleTerm are available for download from the MRL web site. The URLs are:
www.mclanelabs.com/downloads/crosscut.zip
www.mclanelabs.com/downloads/tattleterm.zip
The files are compressed archives, each with a full distribution of one of the emulators. They can be opened with WinZip, which is freely available from:
www.winzip.com

First Time Operation: Crosscut

Crosscut is a DOS based program that runs on a PC. It is freely distributed by Onset Computer for TT8 communication. Crosscut will run without modification or difficulty under DOS, Windows up to Windows 98, 1st edition, and Windows NT up to Version 4.0, Service Pack 5. Later releases of these operating systems commonly require a change to the registry of your PC to disable power management of the serial port. Modifications may also be required to enable the mouse. Detailed instructions for the registry change can be found below and on the MRL web site. The URL is www.mclanelabs.com/laptops_and_crosscut.html. Contact MRL or Onset Computer for additional information (www.onsetcomp.com).

Place the six Crosscut files from the disk provided in the tool kit into a directory that is on your path or create a new directory for them and add it to your path. Alternatively, create a Crosscut directory, place the six Crosscut files there, and always operate Crosscut from that directory. For that approach no changes to your path are necessary.

Type "crosscut" (without the quotes) at the DOS prompt or click on the Crosscut icon to run the program. You may also choose to establish a short cut from your desktop. Do not connect the PC to the TT8 yet.

Using your mouse, select "CommPort" from the menu bar at the top of the Crosscut window and then "Port setup" from the submenu. If you don't have a mouse use the keyboard combination [ALT]-[P]. Use your mouse or the [TAB] and arrow keys to set the COMM port to COM1 or COM2 (whichever one you are going to use), 9600 baud, 8 data bits, 1 stop bit, no handshaking, and no parity (9600, 8, N, 1). The copy of Crosscut on the floppy disk will normally have these values preset. When you finish, select "OK" and these values will be stored in the configuration files. They will be used both now and whenever you start Crosscut in the future (unless you change them, of course).

You can now connect your PC to the MMP.

Editing the Registry to Enable Crosscut

On the desktop of your PC, which is running a recent version of Windows, click on START and select RUN from the pop up menu. In the prompt box type "regedit" (without the quotes) and click on OK to start the registry editor window. The editor will display a Windows directory tree in the left half of the window and a folder contents display in the right half of the window. Click your way through the directory tree following this path:

HKEY_LOCAL_MACHINE / SYSTEM / CurrentControlSet / Services / VxD / VCOMM

Click on the VCOMM folder and its contents will be displayed in the right half of the window. Double click on ENABLE POWER MANAGEMENT in the right half of the window and change its value from "01 00 00 00" to "00 00 00 00" using the editing tool that pops up. After the value has been changed, work your way back out through the directory tree and exit the registry editor. Then, exit all programs, restart your PC, and try Crosscut again.

First Time Operation: TattleTerm

TattleTerm is a Windows based program that runs on a PC. It is freely distributed by Onset Computer for TT8 communication. TattleTerm will run without modification or difficulty under all currently available versions of Windows, including 95, 98, Me, NT, and 2000. Contact MRL or Onset Computer for additional information (www.onsetcomp.com).

Create a TattleTerm directory and copy into it the three TattleTerm files from the disk provided in the tool kit. It may be necessary to add this directory to your path, though we have not experienced that problem on any of the systems on which we have run TattleTerm.

Click on the TattleTerm icon to run the program. You may also choose to establish a short cut from your desktop. Do not connect the PC to the TT8 yet.

Using your mouse, select "ComPort" from the menu bar at the top of the TattleTerm window and then "Settings" from the submenu. Select the COMM port you intend to use and set the port parameters to 9600 baud, 8 data bits, 1 stop bit, and no parity (9600, 8, N, 1). The copy of TattleTerm on the floppy disk will normally have these values preset. When you finish, select "OK" and these values will be stored by the program They will be used both now and whenever you start TattleTerm in the future (unless you change them, of course).

You can now connect your PC to the MMP.

Connecting to a PC

A passive circuit designed at MRL and included on the MMP motherboard and MRL's new low power sleep software together provide considerable immunity from the TT8 "comm port crash". The crash is caused by signals or apparent signals on the receive pin of the communications port if they arrive when the TT8 is in low power sleep and if the ground connection between the TT8 and the PC is intermittent.[39] This unlikely sounding combination can be generated quite easily when connecting a DB-9 or DB-25 connector to the serial port of a PC, an action commonly accomplished by rocking the connector back and forth. The operator must remove and then restore power to recover control of the MMP after such a crash.

The MMP is largely immune to this problem and has non-volatile data storage. Nonetheless, MRL strongly recommends the following procedures for connecting and disconnecting the communications cable.

1) Always boot the PC and start the terminal emulator before connecting the communications cable to a running TT8.
2) Always connect the communications cable to the PC first and to the MMP last when making a connection to a running TT8.
3) Always disconnect the communications cable from the MMP first and from the PC last when breaking a connection with a running TT8.
4) Connect to and disconnect from the MMP as smoothly as possible. Try to prevent repeated intermittent contacts.
5) Leave the PC and the emulator running until the connection with a running TT8 is broken.
6) These precautions are not necessary if power has not yet been applied to the TT8. However, we recommend that you boot the PC, start the terminal emulator, connect the cable to the PC, connect the cable to the MMP, and apply power to the TT8 *in that order*, if only to establish a good habit.

Normal Operations

To Start Crosscut

To start Crosscut simply type "crosscut" (without the quotes) at a DOS prompt or click on the Crosscut icon. Make sure you are in the Crosscut directory or that the Crosscut directory is on your path when you do this.

To Start TattleTerm

To start TattleTerm simply click on the TattleTerm icon. It may be necessary to place the TattleTerm directory on your path.

[39] The circuit also provides considerable protection against aberrations in the boot scripts of PCs and against modem based terminal emulation software such as ProComm. ProComm has a long history of crashing running TT8s and MRL strongly recommends that you do not use ProComm or similar terminal emulators. Crosscut is our recommended first choice, closely followed by TattleTerm. HyperTerminal has also been a safe choice to date.

To Capture a Data File with Crosscut

To capture a data file after a deployment select "CommPort" from the menu bar and "Capture to File" from the submenu. Select a directory and a name for the file using the keyboard and the software buttons on the "Open file" window that will appear in the Crosscut window. [ALT]-[Z] will bring up the "Open file" window from the keyboard and you can simply type the path and name of the file in the "Name" field or use the [TAB] and [ENTER] keys to select the directory and enter the name in the "Name" field.

Once the capture is started, everything that appears in the Crosscut window, whether from the instrument or the keyboard, will be written to the file. Run the offload utility and the data unpacked from the flash card will be captured in the named log file. Note that Crosscut always overwrites the information in an existing log file. There is no append mode. File logging is terminated by selecting "CommPort" and "Capture to File" again or by simply typing [ALT]-[Z].

The format of the captured data file is ASCII text. We suggest you use the extension ".TXT" for the file name. ASCII text files can be loaded and edited by all of the common word and text processors. Crosscut assigns a default file name of CAPTURE.TXT to log files. The operator can, as described above, change the name before logging begins. That name then becomes the default during that Crosscut session. Alternatively, the file can be renamed afterwards, once captured to the hard disk of the PC. In either case, keep in mind that Crosscut does not append; each log file must eventually be given a unique name and path or it will be overwritten and lost.

File logging is not just for data file capture. It can be used during all of your interactions with the MMP to create a log of operations, deployment settings, and recovery procedures. MRL recommends this use of file capture for all deployments.

To Capture a Data File with TattleTerm

To capture a data file after a deployment select "ComPort" from the menu bar and "Capture" from the submenu. Enter a "Capture file name" in the box and select "Overwrite" or "Append" by clicking on the box. Overwrite replaces any information in an existing log file. Append adds new information to an existing file. Click "OK" to start logging.

Once the capture is started, everything that appears in the TattleTerm window, whether from the instrument or the keyboard, will be written to the file. Run the offload utility and the data unpacked from the flash card will be captured in the named log file. File logging is terminated by selecting "ComPort" and "Capture" again and then clicking "OK".

The format of the captured data file is ASCII text. We suggest you use the extension ".TXT" for the file name. ASCII text files can be loaded and edited by all of the common word and text processors. TattleTerm requires the operator to supply a name for the log file the first time the capture utility is called during a TattleTerm session. That name then becomes the default for the remainder of the session. As with Crosscut, the file can be renamed after capture on the hard disk of the PC. In either case, keep in mind that TattleTerm will overwrite if not set to append; each log file must eventually be given a unique name and path or it may be overwritten and lost.

File logging is not just for data file capture. It can be used during all of your interactions with the MMP to create a log of operations, deployment settings, and recovery procedures. MRL recommends this use of file capture for all deployments.

To Exit Crosscut

To exit Crosscut select "File" from the menu bar and "Quit" from the submenu or simply type [ALT]-[Q] from the keyboard.

To Exit TattleTerm

To exit TattleTerm select "File" from the menu bar and "Exit" from the submenu or simply click on the exit box in the upper right corner of the window.

Additional Documentation

A much more detailed and complete description of Crosscut operations can be found in the file "crosscut.doc", which is included in the Crosscut distribution. TattleTerm has a help utility which can be queried by selecting "Help" from the menu bar and "Help" from the submenu. Both of these terminal emulators have many fairly advanced capabilities for working with Tattletale 8s. For most users, however, the features described above will be amply sufficient. As always, MRL is available by phone or email to answer any questions you may have and to assist you with the operation of your MMP.

VIII. ACM Compass Calibration

Two programs that calculate compass offsets, scale factors, and angular bias are included with the software in the tool kit. These corrections to the raw compass measurements are discussed at length in Data Offload, Processing, and Interpretation. The first program, acm_corr.m, runs under Matlab Version 5 and higher.[40] If you normally run Matlab or otherwise have access to Matlab, we recommend this version of the compass correction code. For those who do not have access to Matlab, acm_corr.exe is a stand-alone version of the m-file routine. Following a short installation procedure, which is described below, it will run on a PC that does not have Matlab installed. Both programs use the Nelder-Mead simplex algorithm to minimize a defined error norm and determine an "optimal" set of offset and scale factors.

The programs operate on two types of ASCII text files. The first type is unpacked ACM files from a deployment. These files have names of the form A0000414.txt. The data are present in nine columns with the compass data in the third, fourth, and fifth columns. The second file type is spin test data produced by the scrolling tilt and compass display in the Bench Test utilities. Files of this type must be named spintest.txt. The data are present in five columns with the compass data in the third, fourth, and fifth columns. Whichever version of the program you are using, it should be run in the same directory as the files it is processing.

Angular bias is calculated by both programs for the special case of eight element spin test data. A five column, eight row file named spintest.txt triggers the calculation. The rows must be in north, northeast, east, southeast, south, southwest, west, northwest order for the calculation to return accurate results. There are two ways to create such a file. Record the scrolling tilt and compass display while sequentially orienting the MMP to the eight cardinal points of the compass (a basic spin test). Then edit the text file, removing all but eight lines, each one representative of one of the cardinal points. Be sure the rows are in the proper order. Alternatively, you can create the text file manually. Fill the first, second, and fifth columns with zeros. Then scroll tilt and compass or use the pass-through ACM communications utility to make a compass measurement at each of the eight cardinal points. Enter these values in the third (HX) and fourth (HY) columns of the file. Again, be sure the rows are in the proper order.

[40] The program will almost certainly run under Matlab Version 4, but we did not have a platform available on which to run a test. If there is a problem with the call to fminsearch() in p_corr.m under Version 4, try replacing the call with one to fmins(). If an options argument is necessary for fmins() to run, create a default options argument in p_corr.m with the instruction: options = foptions ;

Running acm_corr.m

The following executable Matlab files (and the MMP data files) must be present in the current working directory to run the program: acm_corr.m, acm_corr.fig, p_corr.m, c_circle.m.

1) Start Matlab and set the current working directory to the folder containing acm_corr.m, acm_corr.fig, p_corr.m, c_circle.m, and the data files.
2) Type acm_corr at the Matlab prompt. This will start the GUI interface and generate an empty plot window.
3) Enter a file name in the text entry box above the "Process" and "Quit" buttons of the GUI. Do not include the .txt extension. The default file name is spintest. Other possible entries are A0000000, A0000414, and A0000711.
4) Click the "Process" button to start the calculation. Depending on the speed of you computer and the size of the file, execution may require up to several seconds.
5) Offset and scale factors will be displayed in the "Offset" and "Scale" text boxes. The plot window will display the corrected and uncorrected data. If the data were in an eight element file named spintest, the eight angular biases and the average angular bias will also be displayed.
6) Repeat steps 3) to 5) to process additional data files. Click the "Quit" button to exit from the program.
7) The plots can be printed or saved to a file using the icons in the tool bar at the top of the plot window and the options in the "File" menu of the plot window.

Running acm_corr.exe

To run acm_corr.exe, you must first perform a short installation procedure. The installation only needs to be performed once. A new entry will be made on your system path and a folder will be created at C:\MLMGRTL during the installation. The executable and a support folder will be added to the directory where the compass data will be processed. If you wish to uninstall the changes you only need to remove the entry from your system path and delete the new folders and files. The files you will need are acm_corr.exe, mglinstaller.exe, and a folder named bin that contains two files, FigureMenuBar.fig and FigureToolBar.fig.

1) Copy the provided executable, mglinstaller.exe, to C:\, the root directory of your C: drive.
2) Run mglinstaller.exe by double clicking on it or calling it from DOS.
3) Specify C:\MLMGRTL when prompted for a directory into which the Matlab math and graphics run-time libraries are to be installed.
4) Once mglinstaller has finished running you can remove it from your hard drive (at over 7 Mbytes it is a fairly large file).
5) Add C:\MLMGRTL\bin\win32 to your system path. You may need to refer to system specific instructions to do this. In Windows, go to the Control Panel, select System, and edit the environment variable called "Path" to include C:\MLMGRTL\bin\win32. If you have a Matlab directory on your path the new entry must be listed first.
6) It may be necessary to restart your PC before the path change will take effect.
7) Copy acm_corr.exe and bin, the folder containing the two .fig files, to the folder where the compass data will be processed.

It will now be possible to run acm_corr.exe on your PC. Operation of the stand-alone routine, which was compiled using the m-files as the source code, is identical to running the m-files under Matlab. Those who are interested in the mechanics of the calculation are invited to examine the m-files.

1) Start acm_corr.exe by double clicking on its icon or with a command line call from DOS. The executable should be in the same directory as the data files that are to be processed. This will start the GUI interface and generate an empty plot window.
2) Enter a file name in the text entry box above the "Process" and "Quit" buttons of the GUI. Do not include the .txt extension. The default file name is spintest. Other possible entries are A0000000, A0000414, and A0000711.
3) Click the "Process" button to start the calculation. Depending on the speed of you computer and the size of the file, execution may require up to several seconds.
4) Offset and scale factors will be displayed in the "Offset" and "Scale" text boxes. The plot window will display the corrected and uncorrected data. If the data were in an eight element file named spintest, the eight angular biases and the average angular bias will also be displayed.
5) Repeat steps 3) to 5) to process additional data files. Click the "Quit" button to exit from the program.
6) The plots can be printed or saved to a file using the icons in the tool bar at the top of the plot window and the options in the "File" menu of the plot window.

Applying the Compass Correction Parameters

The compass correction parameters are applied to the raw data in two stages First, the offsets are subtracted from the raw measurements and the results are divided by the scale factors to produce MX and MY.

$$MX = HX_{CORRECTED} = \frac{HX - X_O}{X_S}$$

$$MY = HY_{CORRECTED} = \frac{HY - Y_O}{Y_S}$$

True heading is then calculated from the corrected compass components as

$$\theta_H = \tan^{-1}\left(\frac{MX}{MY}\right) + B_T + M_{DEV}$$

M_{DEV}, the magnetic deviation, is available from independent sources. B_T is calculated at eight points by the acm_corr programs. The operator may use the average value of the bias angle or may perform an interpolation across each octant.