GAPS: Grab Acoustic Positioning System

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2007

Canadian Technical Report of Hydrography and Ocean Sciences 252

Fisheries and Oceans Canada
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Pêches et Océans
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Canadian Technical Report of Hydrography and Ocean Sciences

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By

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Cat. No. Fs 97-18/252E ISSN 0711-6764

Correct Citation for this publication:

McKeown, D.L., D.J. Wildish and H.M. Akagi. 2007. GAPS: Grab acoustic positioning system. Can. Tech. Rep. Hydrog. Ocean Sci. 252: x + 77 p.

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Abstract

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A differential Global Positioning System receiver, an ultra-short baseline acoustic positioning unit, a data logging and navigation display module and purpose designed post-processing software have been integrated into a system that satisfies the following criteria:

1. Accurately locates replicate bottom samples.
2. Accurately locates towed survey platforms, ROV's and divers relative to sea floor features such as pockmarks.
3. Geo-references sea floor video and still imagery.
4. Can be mobilized quickly on vessels of opportunity.
5. Minimal technical support required to operate and maintain.

The contribution of each system component to the overall positioning error has been assessed and suggestions are made as to how these errors might be minimized. The procedures used to collect trial data during a benthic ecological study of pockmark features in an embayment and the application of the purpose designed software to the analysis of this data to derive the positions of a towed body and grab sampler are described.

Résumé

McKeown, D.L., D.J. Wildish and H.M. Akagi. 2007. GAPS: Grab acoustic positioning system. Can. Tech. Rep. Hydrog. Ocean Sci. 252: x + 77 p.

Un récepteur GPS différentiel, un dispositif de positionnement acoustique à base ultra courte, un module d'enregistrement de données et d'affichage d'information de navigation et un logiciel de post-traitement sur mesure ont été intégrés en un système qui satisfait aux critères suivants :

6. Positionne avec précision des échantillons dupliqués du fond.
7. Positionne avec précision des plates-formes remorquées de relevé, des submersibles télécommandés et des plongeurs par rapport à des caractéristiques du fond marin telles que des « pockmarks ».
8. Ajoute les géoréférences à la vidéo et aux images fixes du fond marin.
9. Peut se déployer rapidement à bord de navires de passage.
10. A un besoin minimal de soutien technique pour l'utilisation et l'entretien.

La contribution de chaque élément du système à l'erreur de positionnement globale a été évaluée, et des suggestions sont faites à l'égard de la façon dont ces erreurs pourraient être minimalisées. Les procédures utilisées pour collecter les données d'essai pendant une étude de l'écologique benthique des pockmarks dans un rentrant et l'application du logiciel sur mesure à l'analyse de ces données pour dériver les positions d'un objet et d'un échantillonneur à benne remorqués sont également décrites.

Introduction

Marine ecologists, geologists, and engineers are required to precisely position sampling and survey devices when undertaking sea floor studies. For example, a benthic ecologist would require such a methodology when undertaking a study of the relationship between macro fauna and geochemistry at an aquaculture site (Wildish, et al. 2005) or in the vicinity of a natural feature such as a pockmark (Wildish, et al., 2007). The workboats available for such field studies are often relatively small vessels of opportunity and manpower resources are often limited so the system must be simple to install and operate. Typically these boats are equipped with only a single screw and no bow thruster so they can be difficult to maneuver directly over a feature of interest, especially in the presence of strong currents. Even if the desired boat location is achieved, there is no guarantee that the survey or sampling device will be near the target when it reaches the seafloor. Therefore, a system capable of accomplishing the following tasks was required:

1. Accurately locate within a few metres replicate bottom samples.
2. Accurately locate within a few metres towed survey platforms, ROV’s and divers relative to sea floor features such as pockmarks.
3. Geo-reference within a few metres sea floor video and still imagery.
4. Rapid mobilization capability on vessels of opportunity.
5. Minimal technical support to operate and maintain.

The Grab Acoustic Positioning System (GAPS) described in this report was devised in order to address these requirements. It consists of five components:

1. A sub-system that locates the surface vessel relative to the target of interest;
2. A sub-system that locates the sampler or survey platform relative to the surface vessel;
3. A sub-system to log the positioning data;
4. A sub-system to display the relative positions of the surface vessel, underwater unit and target in real time;
5. Software to post-process the data in order to derive the maximum possible positional accuracy.

Also included in the report are recommended calibration and operating procedures and an error audit which establishes the overall accuracy of the system.

Positioning System: Overview

Positioning the surface vessel has become a trivial matter with the advent of inexpensive, readily available, simple to operate differential Global Positioning System (dGPS) receivers. However, special equipment is required to position samplers or survey apparatus underwater. The only practical way to do this accurately at depths greater than a few metres is by employing acoustic technology. There are basically two approaches currently in common use. Both utilize one or more autonomous acoustic units known as beacons or transponders. These are devices that emit a coded acoustic signal in response to an incoming one.

The first method, known as the long baseline system (LBS), measures the distance between a transponder on the object to be positioned and an array of three or more sea floor acoustic transponders moored at known locations some hundreds to thousands of metres apart. While this method can be very accurate, a major effort is required to install and locate the reference transponders before using them and the area over which they are effective is very limited in shallow water.

The second method is referred to as an ultra-short baseline system (USBS). It employs a single transponder or beacon on the object to be positioned and a special acoustic transducer array and transceiver on a nearby surface vessel. This transducer array is constructed in such a way that the three dimensional polar coordinates, that is, slant range, horizontal bearing and vertical depression angle to the beacon can be measured. While usually not as accurate as the long baseline system, it is much easier to mobilize for an operation and is more readily moved between sites. In the early 1990’s such a positioning system had been developed for offshore continental benthic studies being conducted on large research vessels (McKeown and Heffler, 1997, McKeown and Gordon, 1997). It was felt that, with only a minimal effort, the technology could be adapted to inshore benthic sampling programs from smaller (e.g. 13m) workboats. A block diagram of the resulting system, GAPS, is illustrated in Fig. 1 and the corresponding fix geometry in Fig. 2. The nature of each component and the manner in which the position of the samplers, divers and survey platforms are calculated will be described in more detail in the sections that follow.

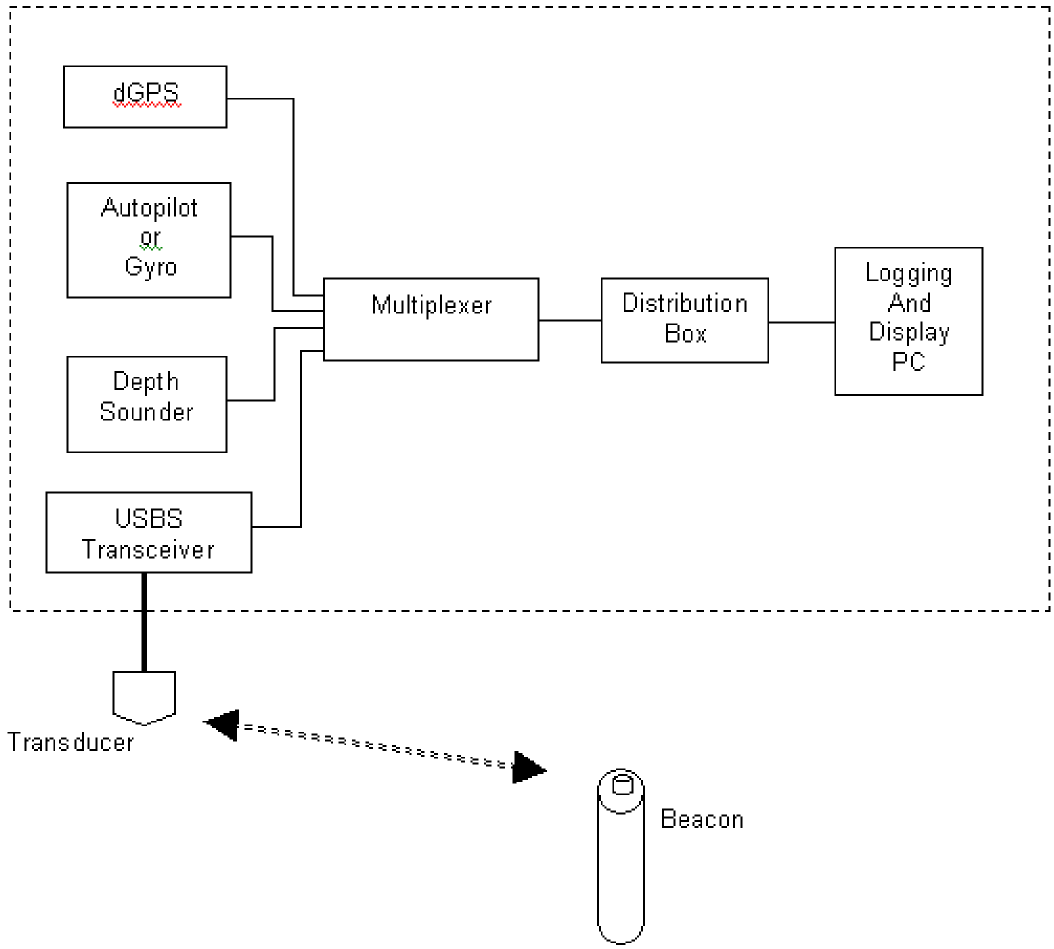


Figure 1. GAPS block diagram

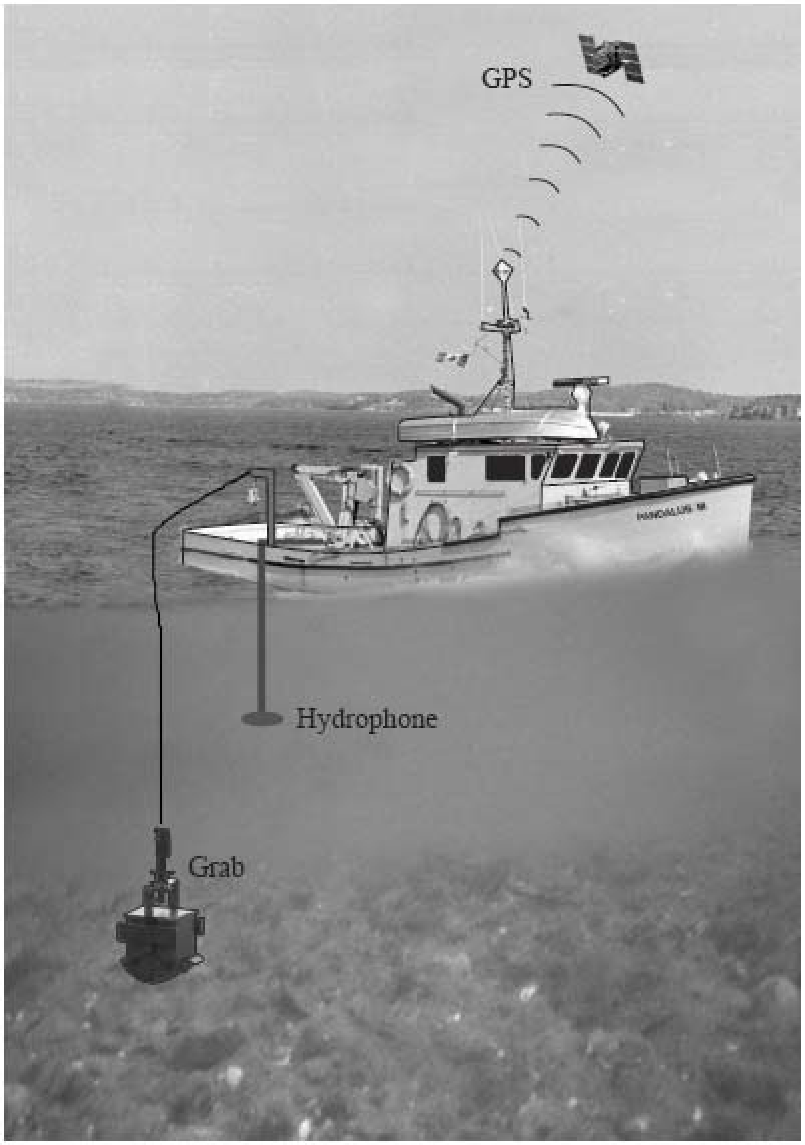


Figure 2 a). Overview of GAPS fix geometry when grab sampling.

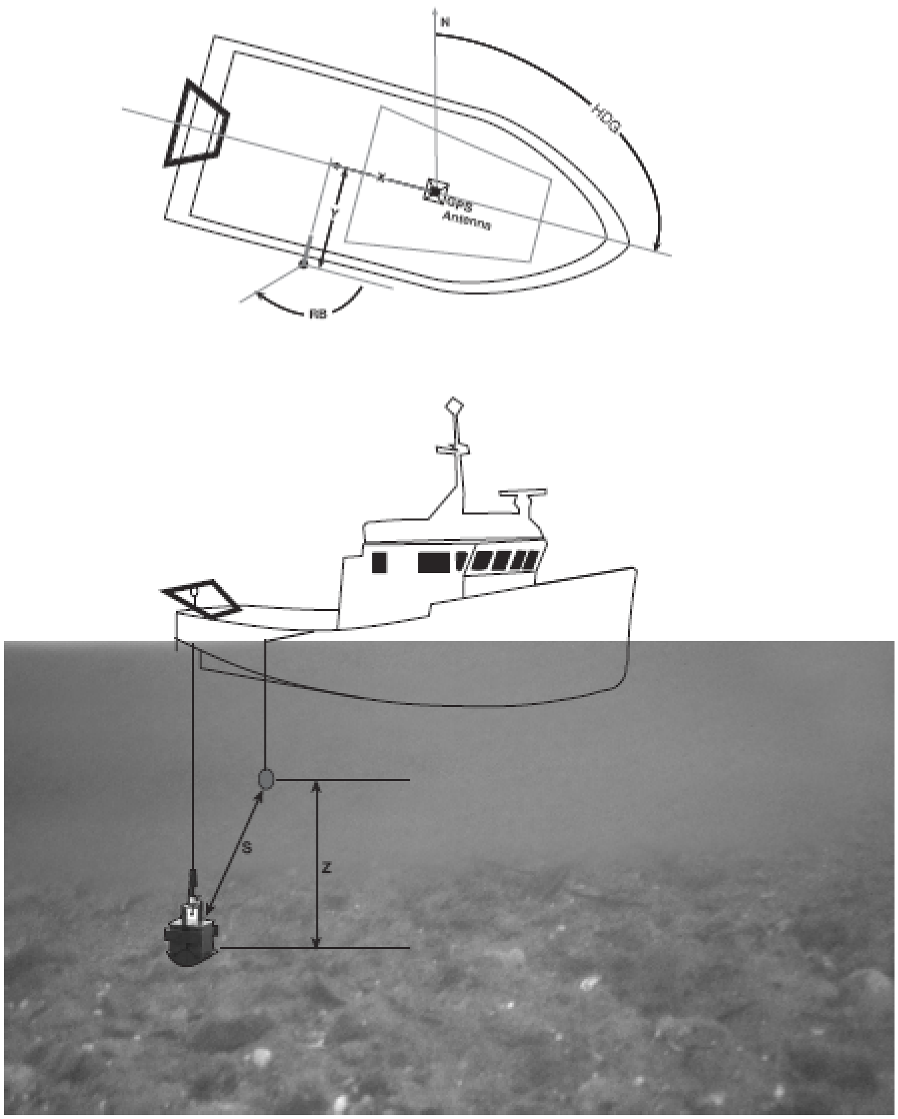


Figure 2 b). Schematic of GAPS fix geometry. The USBS measures RB, Z and S.

Surface Vessel Positioning Sub-System

The ubiquitous and accurate differential Global Positioning System (dGPS) permanently fitted on the ships being used for this program is the obvious choice for positioning the surface vessel. While there are more accurate surface positioning systems available, their complexity, lack of universal availability, increased operating overhead and other factors make them a poor second choice. Although the published accuracy of dGPS in the marine areas of Canada is better than 10m (Canadian Coast Guard, 2000), the actual accuracy is in the order of 3-4m in most cases (Grant, 1996). In order to realize this accuracy, the receiver must be programmed to output latitude and longitude to a resolution of better than 1 metre. This means to four decimal places if the format is decimal minutes and six decimal places if the format is decimal degrees. Furthermore, corrections must be made for any offsets that may exist between the GPS antenna location and the reference position on the vessel.

As can be seen in Fig. 2, the vessel's heading must also be determined in order to compute the position of the beacon. This data can usually be obtained from either the vessel's autopilot or gyro. Prior to use in this application, the heading indicator must be properly calibrated. If neither is fitted then a portable, self-calibrating KVH fluxgate compass can be used (KVH Industries, www.kvh.com).

While not an essential part of the computation, a record of the water depth under the vessel serves as a useful check on other means of establishing the beacon depth. Thus, it is useful to also record the output of the vessel's depth sounder.

Underwater Positioning Sub-System

The position of underwater beacon can be determined relative to the support vessel using any one of a number of commercial ultra-short baseline acoustic positioning systems (USBS). These devices employ an array of receiving elements contained within a single, compact underwater transducer housing to determine the three dimensional polar coordinates of an acoustic source relative to the hydrophone location. With reference to Fig. 2a) and b), these coordinates are slant range [S], horizontal bearing [RB] and vertical depression angle from which depth [Z] can be derived. An ORE International Inc. Model 4410C Trackpoint II USBS was chosen for this program on the basis of cost and performance.

The system consists of four major components, the Command/Display module, a hydrophone, an interconnecting cable and a multi-beacon (Fig. 3). The Command/Display module houses the interrogation, receiving, measuring and display electronics and has a keypad for operator interaction. The system is capable of tracking up to nine beacons and any two can be tracked nearly simultaneously by automatically interrogating each on alternate two-second cycles. The maximum operating range of the system is 1000m.

Figure 3. Trackpoint II system components.

The multi-beacon combines the functions of an acoustic responder that replies acoustically to an electronic key pulse and an acoustic transponder which replies acoustically to an incoming coded acoustic signal. It is small (70mm diameter by 280mm long) and nearly neutrally buoyant in water (1.1 Kg) so it is easily attached to a sampling device, survey platform or carried by a diver (Fig. 4 a)). When used with a grab sampler, the acoustic beacon is placed inside a robust aluminium tube and clamped to the wire about 1m above the grab to protect it from damage when the grab impacts the bottom (Fig. 4 b)). Details of this protective housing may be found in Appendix D. The housing undoubtedly attenuates the acoustic signal somewhat but, given that the working range of the unhoused beacon is 1000m, this should not be a problem in most cases. No adverse effect on performance has been noted when the housed multi-beacon was used in water depths in excess of 200m. The multi-beacon is powered by a rechargeable battery that can be turned on and off and recharged without opening the case. This battery provides an operating life of about 100 hours at the maximum interrogation rate of once per two seconds (See the Multi-Beacon section in Appendix A for further details).

a)

b)

Figure 4. a) Trackpoint multi-beacon and b) multi-beacon attached to grab wire.

A telemetering version of the multi-beacon is also available. Upon interrogation, it responds with the same acoustic signal as the multi-beacon and then sends a second acoustic signal at an interval proportional to the water depth as determined by a self-contained pressure sensor. These units can be very effective in some circumstances but are much more expensive, larger, heavier and have a shorter battery operating life. Both types are rated for use to a maximum depth of 1000 metres. They receive at a preset frequency of 17 or 19KHz and transmit on pre-set frequencies in the range 22-30KHz. The units are reasonably robust but care must be taken to avoid any mechanical damage to the rubber-covered transducer.

The hydrophone contains a transmitting transducer to interrogate underwater beacons and a three-dimensional array of receiving transducers. Slant range is derived from a measurement of the round trip travel time of the acoustic signal. The source direction in both the horizontal (Relative Bearing or RB) and vertical planes (depression angle) is determined by measuring the phase of the arriving acoustic wave front as it passes across the receiving array. The unit also contains pitch and roll sensors to enable the Command/Display module to correct for some degree of hydrophone tilt. The vessel's speed must never exceed six knots with the hydrophone deployed in order to avoid mechanical damage to the transducer elements. Great care must be exercised when handling the hydrophone as it can easily be damaged if dropped or struck by an object. While it is tempting to place a protective shield around it, this must not be done, as it would severely degrade the accuracy of the acoustic position measurement.

On *CCGS Pandalus III*, one of the workboats selected for equipment trials, the Trackpoint II hydrophone is installed on the bottom of an aluminium strut. It is secured on the workboat's side well forward of the propeller(s) as illustrated in Fig. 5. The strut can be rotated out of the water to a horizontal position when not required and can be rotated through a small angle in the horizontal plane so that its reference direction can be set parallel to the vessel's fore/aft axis each time it is installed (See "Hydrophone Alignment" section in Appendix A). On the *CCGS J.L.Hart*, another vessel employed during the trials, the hydrophone was attached to the bottom of a long 4"x4" wooden pole. At the top end is a fitting that secures the pole to the starboard rail amidships and allows it to pivot to the horizontal when steaming between work areas. Fore and aft stays are employed to maintain the pole in a vertical orientation while the vessel is manoeuvring or steaming at slow speed.

The receiver utilizes four signal-processing techniques to reduce target jitter and optimise accuracy. An automatic "Range Gate" is used to prevent activation of the measuring electronics by bogus signals arriving outside acceptable limits of slant range values. This gate is automatically re-centred for each successive measurement cycle. If signals are lost for a significant period, the gate opens fully until it re-acquires a valid signal that then resets the range gate limits. The second technique is "Threshold" which controls the level at which the incoming beacon signal must exceed the noise background before it triggers the balance of the receiver's signal processing electronics. Once passed by the "Range Gate" and "Threshold", the "Velocity Filter" then validates signals. It determines what velocity would be required to move from the previous valid fix to this calculated position. If the velocity is within the limits set by the operator, the new fix is approved. Once positions have passed these tests, "Smoothing" is applied to reduce position jitter. All four processes are under operator control. It is recommended that the user start with the "Minimum Range" set to 1m, "Threshold" and "Filter" be set to their lowest levels and "Smoothing" turned off.

If reception problems are encountered then these settings can be adjusted to minimize the problem.

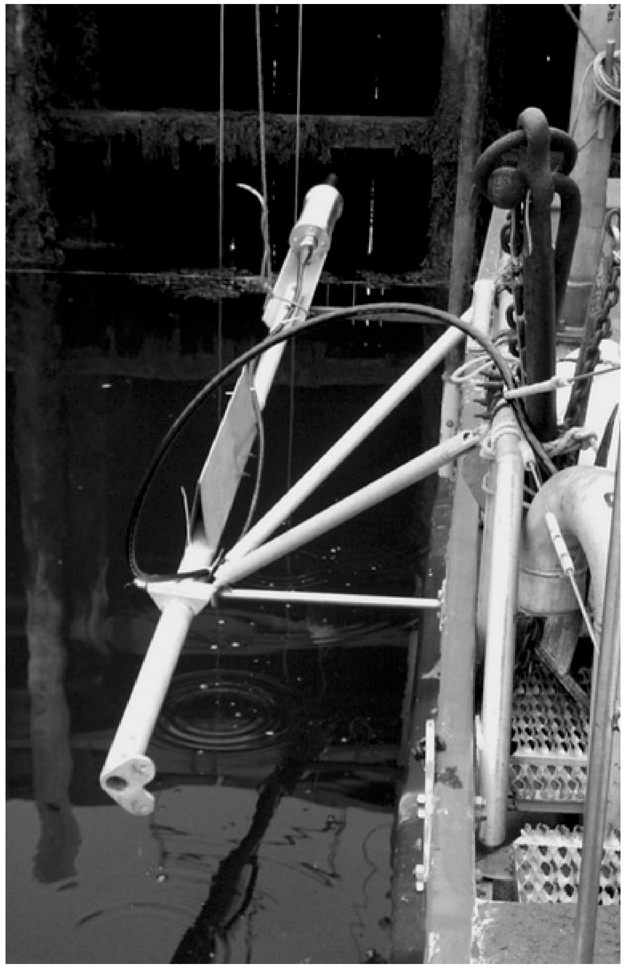


Figure 5. Trackpoint II hydrophone and supporting structure on *CCGS Pandalus III*. The boom is shown in the stowed position.

A comprehensive operating manual accompanies the equipment. Abbreviated operating instructions are provided in Appendix A of this report.

Logging Sub-System

Modern marine electronic navigation devices communicate with each other and with personal computers by means of a serial port in accordance with two complementary standards. The first is known as RS-232/RS-422 and it dictates the form the hardware interconnection and communication protocols take. The standard is supposed to ensure that devices can be directly plugged together and can exchange meaningful characters with each other. The serial connector may have nine (DB-9) or twenty-five pins (DB-25) or may be a proprietary one. Commercial adapters exist to interconnect DB-9 to DB-25 and to change the gender of a connector. The communication protocol governs such things as the number of bits that constitute a character (e.g. 8 bits), the rate of transmission of bits (i.e. baud rate) and whether or not a parity bit is included with each character.

Conceptually the RS-232 standard assumes that there would be one Master and multiple Slaves. Problems arise when one tries to connect two Masters, e.g. two computers, together. They both talk (transmit) and listen (receive) on the same connector pins so straight through connection accomplishes nothing. In such cases, one must use a Crossover cable or Null Modem. Because it is not always obvious how each device is wired in spite of the standard, one often has to make connections via trial-and-error process.

The second standard that governs interconnection of marine electronic equipment describes the structure of the data sentences that pass between devices via the RS-232 or RS-422 protocol. The National Marine Electronics Association devised it and the current version is known as NMEA0183 (Anon., 1987). It specifies that data be transmitted as 8 bit characters with no parity at 4800 baud. However, sometimes non-standard higher transmission rates are encountered when large volumes of data must be dealt with. For example, the serial navigation data network on *CCGS Hudson* operates at 9600 baud.

A NMEA sentence is made up of a series of comma delimited fields. It must be no longer than 80 characters plus the terminating Carriage Return and Line Feed characters. The first character is always ‘$’ followed immediately by several characters that constitute the address or identification code of the originating device. This must be followed by at least one data field. If data for a field is unavailable a “null” field, that is, nothing between the delimiting commas, can be sent. Some navigation devices such as GPS receivers are referred to as “talkers” and others, such as plotters, are “listeners” (Master and Slaves respectively in RS-232 parlance).

The first two characters immediately following the '$' in the address identify the type of "Talker". The following are examples of the ones of most interest in the context of this report:

AP	Autopilot (magnetic)
GP	Global Positioning System
HC	Magnetic compass
HE	Gyroscope
RA	Radar
SD	Depth sounder
VW	Mechanical speed log
VM	Magnetic speed log
VD	Doppler speed log
WI	Weather

The next three characters identify type of data from the Talker such as:

GGA	time and position as latitude and longitude
VTG	course and speed made good
ZDA	time and date

This address is followed by a series of comma delimited alphanumeric data values that are of variable length. Commonly, there is a two-character check sum at the end of the data string. If it exists, it is separated from the last character of the data string by an asterisk ('*').

The address code is defined for many standard sources. However, the NMEA standard also permits the use of "proprietary" address codes, which are denoted by setting the second character in the identification field to "P".. The subsequent characters can be whatever the user desires. This presents a convenient way of merging scientific data into a NMEA navigation data stream by generating a serial data string that starts with a proprietary address code before adding it to the navigation data.

The following are examples of some commonly encountered NMEA data sentences.

<u>GPS Ship Position</u>

```
$GPGGA,000001,4425.7760,N,05754.9631,W,2,06,01.2,15.5,M,-13.2,M,07.9,0336*62
        Time   Latitude    Longitude    |
                                       Flag,  0=Unavailable
                                              1=GPS
                                              2=dGPS
                                              3=PPS mode
```

<u>Ship's Heading</u>

```
$HEHDT,074.4,T
```

<u>Trackpoint Fix Data</u> (as generated by AGCNAV and REGULUS)

```
$POREB,2,000006,,188.0,86.9,-9.8,-70.4,50.0,0.0,64,-1.2,-1.3*4C
```

```
B    T     RB     S     X      Y     Z  ZT  EC    R     P  CS
```

Where	B	Beacon identification number
	T	Trackpoint receiver clock time
	RB	Relative bearing
	S	Slant range
	X	Athwart ships component of beacon position
	Y	Fore/Aft component of beacon position
	Z	Beacon depth
	ZT	Telemetered depth
	EC	Error code (see Table 1)
	R	Hydrophone roll angle
	P	Hydrophone pitch angle
	CS	Check sum

<u>Trackpoint Position</u> (Created by AGCNAV and REGULUS)

```
$POREP,3,4705.751422,N,4813.768568,E*41
            Latitude      Longitude
```

<u>UTC Time and Date from GPS</u>

```
$GPZDA,163225,14,06,2000,-3,00*56
```

<u>Course and Speed Over Ground from GPS</u>

```
$GPVTG,088.2,T,110,M,002.8,N,005.3,K*5E
       COG (True)       SOG (Kts)
```

<u>Echo Sounder</u>

```
$SDDBK,0223.0,f,0068.0,M,037.0,F
                  Depth (metres)
```

Table 1. Commonly Encountered Trackpoint II Error Codes

Code	Description
0	No errors detected
1	Unusable signal received
4	Apparent target depth exceeds slant range
5	Target velocity excessive
6	No valid signals
7	Minimum range error
15	Relative bearing outside preset limits
50	Depth calculated from depression angle may be invalid
52	Depression angle less than 20^0
53	Depression angle 20^0 to 45^0
56	Depression angle greater than 45^0, using input depth
57	Input depth greater than measured slant range
64	Fix quality suspect

Display Sub-System

AGCNAV

There are currently a number of real-time navigation display systems available in the marketplace that are capable of recording the Trackpoint data and displaying the computed position of the beacon and vessel. The first of two chosen for use on this project is AGCNAV. Bedford Institute of Oceanography scientists developed it in the late '80's when few such software systems existed and none had the functionality required to do survey operations and display Trackpoint positions (McKeown and Heffler, 1997).

It is an easy-to-learn MS-DOS-based navigation display and logging program specifically developed for marine scientific surveying and sampling. It accepts and records NMEA (National Marine Electronics Association) format data from navigation devices such as the vessel's dGPS receiver and autopilot and from the Trackpoint II system. AGCNAV maintains and uses a database of waypoints and survey lines. Waypoints are the locations of target sample sites, ends of survey lines, and other points of potential interest. Each waypoint entry consists of an identifier or label and a position (latitude and longitude). The user can construct or modify waypoint files containing sample locations, survey line endpoints or destinations using either the waypoint editor contained within AGCNAV or an external text editor. Fixes (i.e. current ship position) can be added to this database at the press of a single key. This causes the current ship position and UTC time to be added to the database file and to appear as a labelled mark on the computer display. Once created, the waypoint database can be used to set up a pattern of sequential survey lines. AGCNAV assumes a spherical earth so the lengths and azimuths of very long survey line lengths may differ slightly from those calculated using correct geodetic constants. More information concerning the creation and structure of the waypoint file is included in the “Data Processing” section.

AGCNAV produces a versatile display of the positions of the ship and up to six different acoustic beacons simultaneously in real time. Important data such as day, time, ship position, heading and speed are displayed as text alongside the graphical information. The following display modes are available:

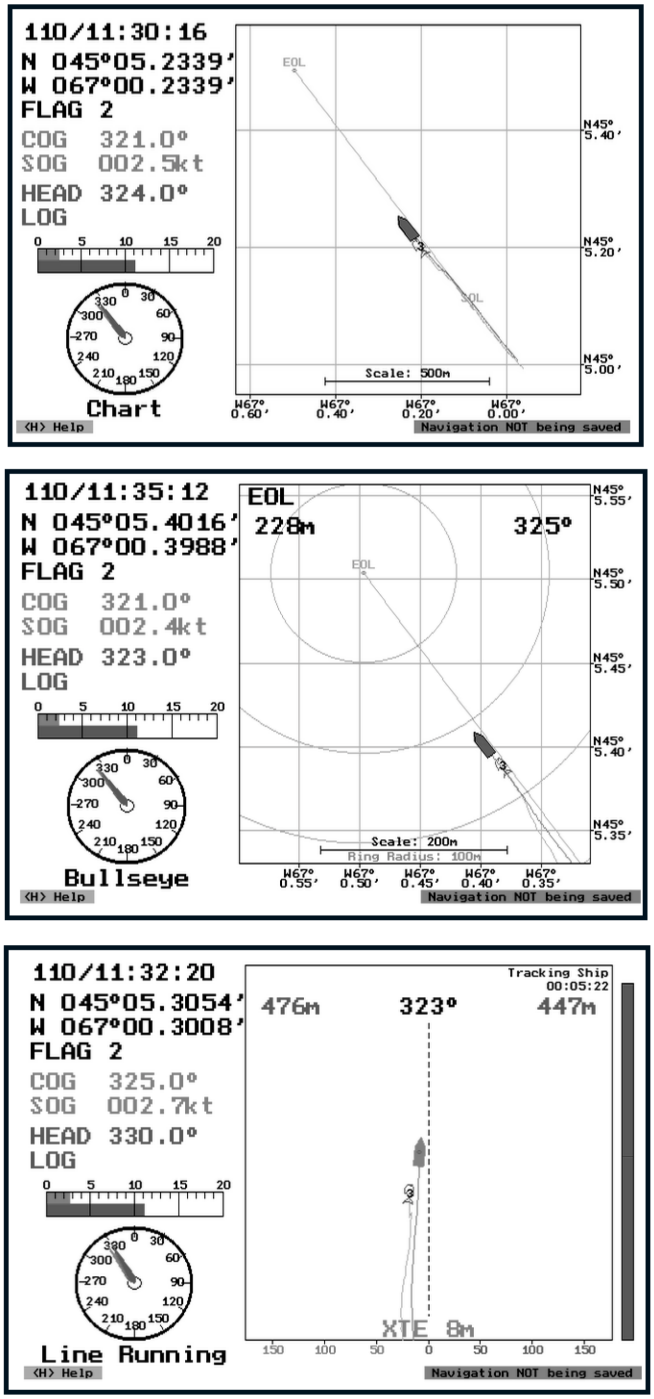
Chart – Ship appears on conventional lat/long grid similar to a nautical chart (Fig. 6 a)).

Bullseye – Used when approaching a target waypoint or holding station. Similar to Chart mode except range rings are included and distance/direction to target waypoint is displayed (Fig. 6 b)).

Line Running –Used when running survey lines. Ship position displayed relative to next survey line in a pre-defined sequence (Fig. 6 c)).

Operations such as logging a fix or changing the display format or scale are accomplished with simple keystrokes. Multiple independent displays can be set up throughout the ship by connecting additional PC's to the navigation data network. While the technology is somewhat dated, it continues to be used because it has proven reliable, robust and simple to operate during a decade of use on many vessels of the Canadian Department of Fisheries and Oceans science fleet. However, it lacks the ability to overlay navigation data on raster or vector images such as electronic charts or multibeam images.

Initialising and operating the software by pull-down menus is intuitive but does require some training and experience. When the program is used for the first time, a set-up procedure must be carried out to define serial port communication parameters, antenna and Trackpoint hydrophone positions, parsing of NMEA navigational data, sentences to be logged, and so on. This information is saved in a computer file (AGCNAV.INI) that is updated whenever any changes are made to the set-up. At any future time when AGCNAV is restarted, the program initially defaults to these settings. (Refer to Appendix B for more specific set-up and operating instructions)



a) Chart

b) Bullseye

c) Line Running

Figure 6. AGCNAV display modes. All three are different versions of the same ship track and waypoint/survey line geometry. The fish icon indicates the location of a Trackpoint multi-beacon on an underwater platform being towed by the ship.

AGCNAV has the capability of logging incoming serial navigation and scientific data providing it corresponds to the NMEA standard. The operator can define which incoming data sentences are to be logged and at what frequency. The program automatically creates a logging file named "ssssdddA.yyE" where:

ssss	Ship identifier (e.g. PAND for *CCGS Pandalus III*)
ddd	Julian day (e.g. 175)
A	Sequence identifier (never changes)
yy	Year (e.g. 05 for 2005)
E	Indicates file contains "E-type" or NMEA formatted data

Throughout the day, each new line of data is appended to this file and then the file is closed to preserve the integrity of the data in the event of a power or computer failure. If the program is shut down and then re-started on the same day, new data will be appended to the original file. A new data file is automatically started when the day changes (i.e. 0000 GMT).

The Command/Display Module can export the acoustic fix data in a number of different formats. For historical reasons, Trackpoint data is customarily sent to the AGCNAV computer in a non-NMEA format known as “Std-EC w/pr”. AGCNAV recognizes this data string and converts it to an NMEA formatted string with the identifier $POREB. Unfortunately, the time code within this string is that produced by the Trackpoint Command/Display Module’s internal clock rather than GPS’s Universal Time Code (UTC) so it should be ignored. AGCNAV also computes the corresponding geographic position of the Trackpoint beacon and encapsulates this in the NMEA formatted string $POREP. Alternately, the NMEA data string $PORE produced by updated Trackpoint receivers can be used with AGCNAV. However, this data string is not currently compatible with REGULUS (to be described below). At a minimum, it is recommended that the following strings should be logged:

- $GPGGA – GPS ship position
- $HEHDT or $AGHDT – vessel heading from gyro or autopilot respectively
- $POREB – Trackpoint data

It is also useful to log other strings such as echo sounder ($SDDB?) if available. A fragment of a logged navigation data file is illustrated below:

```
:
$GPGGA,060007,4426.2229,N,05754.2906,W,2,06,01.2,18.9,M,-13.2,M,04.3,0336*64
$HEHDT,260.1,T
$GPVTG,266.7,T,288,M,003.6,N,006.7,K*53
$VDVHW,0.0,T,0.0,M,03.6,N,0.0K
$WIMWV,348,R,11.4,N,A*06,
$POREB,2,060014,,185.7,171.4,-16.3,-163.1,50.0,0.0,56,-1.2,-1.3*75
:
```

A comprehensive operating manual accompanies the AGCNAV program. Abbreviated operating instructions are provided in Appendix B of this report.

REGULUS

REGULUS is a Windows-NT based navigation display and logging program developed by ICAN Ltd, St. John’s, NL. With the Survey Module added to the basic program, it not only duplicates all the features of AGCNAV already described above, but also offers a number of additional ones. For example, the user can overlay the target location and sampler position onto an electronic

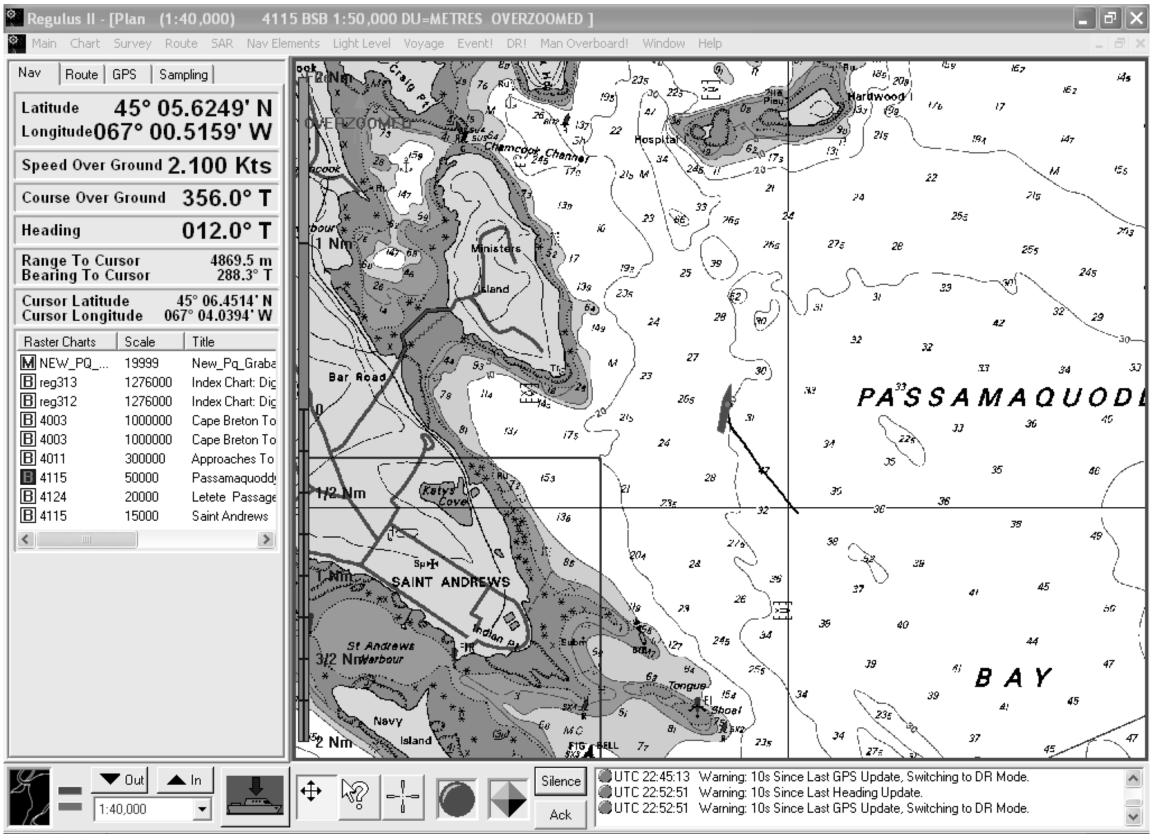


Figure 7. Example of REGULUS ship position display overlaid on a hydrographic chart.

chart (Fig. 7) or multibeam bathymetry image (Fig. 8) of the target area (which appear in colour on the actual navigation display unit). This latter format is especially valuable during benthic sampling programs as it can provide a real-time display of the sampler location relative to the seafloor target feature of interest providing it has some topographic relief or acoustic contrast with the surrounding area. However, these extra capabilities result in additional operating complexity that can lead to loss of valuable data and survey time in the hands of an inexperienced operator. REGULUS is currently fitted as standard equipment on science research vessels operated by the Maritimes Region, Canadian Coast

Guard but is being replaced by ICAN's Aldebran product which employs both raster and vector charts.

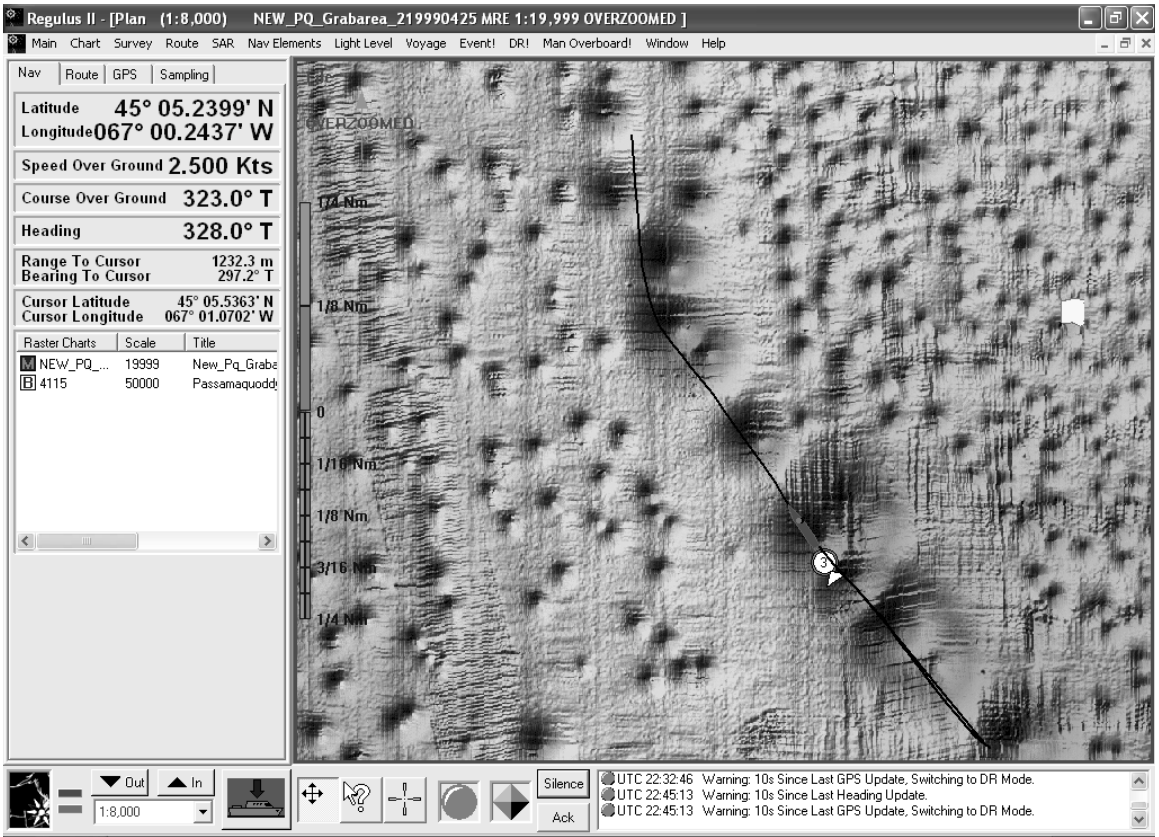


Figure 8. Example of REGULUS ship position display overlaid on a multibeam image of the sea floor.

A word of caution is in order when mixing real-time dGPS fixes, hydrographic charts and multibeam images on the same display system. The datum for dGPS is currently WGS84 (NAD83). However, hydrographic charts and multibeam images may have been produced using some other datum. Furthermore, the process of converting a geo-referenced multibeam image to a format suitable for display on some early versions of REGULUS often introduces position errors. Therefore, before attempting to sample a particular feature by manoeuvring the ship and/or sampler icon over it, the user is advised to do a simple bathymetric survey to establish the actual target location on the display screen.

Features of REGULUS that make it attractive for use with GAPS include:

- Navigation (NMEA) data can be accessed either via a serial (RS-232) or Ethernet network connection.
- Each unit can exchange waypoint, survey, etc. files with other REGULUS installations via a network connection.

- Should a power failure occur, only the last few seconds of the incoming navigation data will be lost.
- The software automatically accepts positions entered in a number of common formats.
- The right mouse button generates context-sensitive menus. This is often very helpful as the program is rich in features and it is often not obvious how to navigate its menu structure to achieve the desired objective.
- It is possible to zoom in to an unrealistically large scale on an electronic chart but the system warns the user when this is occurring.

On the other hand, the system lacks an equivalent of the AGCNAV Bullseye mode. This is an unfortunate omission as this mode is ideally suited to doing precision-targeted bottom sampling with a Trackpoint positioning system.

The display screens of Figures 7 and 8 consist of five elements:

- Main Menu Bar – This is a typical Windows-type tool bar across the top of the screen containing drop down menus.
- Info Panel – This is the large area at the left hand side of the screen. It contains multiple pages that are accessed by clicking on tabs. The pages are user configurable and can contain information components such as:

  Vessel – lat/long, SOG, COG, LOG, Heading, Sounder
  Cursor – lat/long, range/bearing, ETA
  Route – distance and time to go, ETA, numerical and graphical XTK
  Miscellaneous – data logging, wind speed and direction, graphical sounder, Point of Interest
  Time/Date – UTC and Local
  Chart Info – list of charts, pan window

  The temptation to fill each Info Panel page with all sorts of "goodies" should be resisted, as it tends to be a distraction during most operations. It is better to create multiple special purpose and simple pages. The pages can be saved and later copied onto other REGULUS units.
- Chart Window – This is the area where the ship, charts, multibeam images, markers, waypoints, etc. are displayed. Multiple charts can be viewed simultaneously and overlapped seamlessly. This area may be "True Motion" or "Planning Mode". In "True Motion" mode, the current position of the ship is always on the screen and appropriate chart(s) are loaded automatically (Note. Auto loading can be turned off if

desired). In the "Planning Mode", the user can move the display window anywhere on the active chart(s).

- Chart Window Control Panel – The area at the lower left corner of the screen containing the following elements:
    - Animated Logo – if it is not moving, the computer has "locked up".
    - Chart Loading Indicator
    - Chart Zoom Control Buttons
    - Chart Scale Selection Drop Down Box
    - Centre Ownship Button – click this to centre ship in active Chart Window
    - Cursor Icons
        - Pan/Scroll (4 Arrow) Cursor – used in Planning Mode to centre the chart at the cursor location.
        - Query Cursor – makes mouse left button imitate right button.
        - Point Selection (Cross-Hair) Cursor – used to
            - Construct/place routes, waypoints
            - Temporarily display range and bearing from ship to cursor location.
- Alarm Indication Message Bar - Contains indicator and acknowledgement icons and a message window.

A brief list of the terminology used by REGULUS includes:

- Nav Element – a general term for waypoints, markers, fixes, routes, etc.
- Marker – an icon which is placed at specific point on the screen to mark the location of a particular feature or event
- Event Marker – fix created by operator at current ship position
- Point of Interest – used when performing some useful task at a single point, e.g. to set a temporary mark on the screen for station keeping
- Route – a pre-planned track that the ship is to follow from waypoint to waypoint
- Quick Route – a route from ship's current position to a selected waypoint, marker, etc. visible in the Chart Window
- Voyage – the actual track the ship followed

Logging of navigation data is activated via the menu path "MAIN/COMMUN/DATA LOGGING". The program creates log filenames identical in format to AGCNAV. The user can specify that all incoming data is to be logged or can select specific NMEA address codes for recording. However, the correct Julian day is only included in the filename if the internal computer time and date are set to the Greenwich time zone and the program is told to synchronize time with the $GPZDA string from the GPS receiver (See Appendix C for details). It is important to note that the voyage file generated by the program is not a logged

NMEA data file. It is only a condensed version of the ship's track as a function of time.

For historical reasons, Trackpoint data is customarily sent to the REGULUS computer in a non-NMEA format known as "Std-EC w/pr". REGULUS recognizes this data string and converts it to an NMEA formatted string with the identifier $POREB. REGULUS also computes the corresponding geographic position of the Trackpoint beacon and encapsulates this in the NMEA formatted string $POREP. In contrast to AGCNAV, the NMEA data string $PORE produced by updated Trackpoint receivers cannot be used with REGULUS.

A limited on-line help file accompanies the program. Abbreviated operating instructions are provided in Appendix C of this report.

Position Accuracy

From the perspective of an error analysis, a GAPS fix has four components:

1. Geographic position of the hydrophone;
2. Horizontal range from hydrophone to beacon;
3. Azimuth of vector from hydrophone to beacon.
4. Computational errors.

The accuracy of determination of the hydrophone's geographic position is dependent upon the accuracy of the:

1. Differential GPS vessel fix;
2. Antenna/hydrophone offset determination;
3. Heading indicator;
4. Hydrophone alignment.

The horizontal range is affected by sound velocity variations in the water column and errors in measuring slant range and beacon depth. The azimuth is affected by errors in measurement of vessel heading and bearing of the beacon relative to the Trackpoint hydrophone reference direction. The dGPS error is constant over the entire working area. However, the effects of range and azimuth errors vary with the horizontal distance between the hydrophone and beacon as illustrated in Figure 9. Computational errors may be of either type.

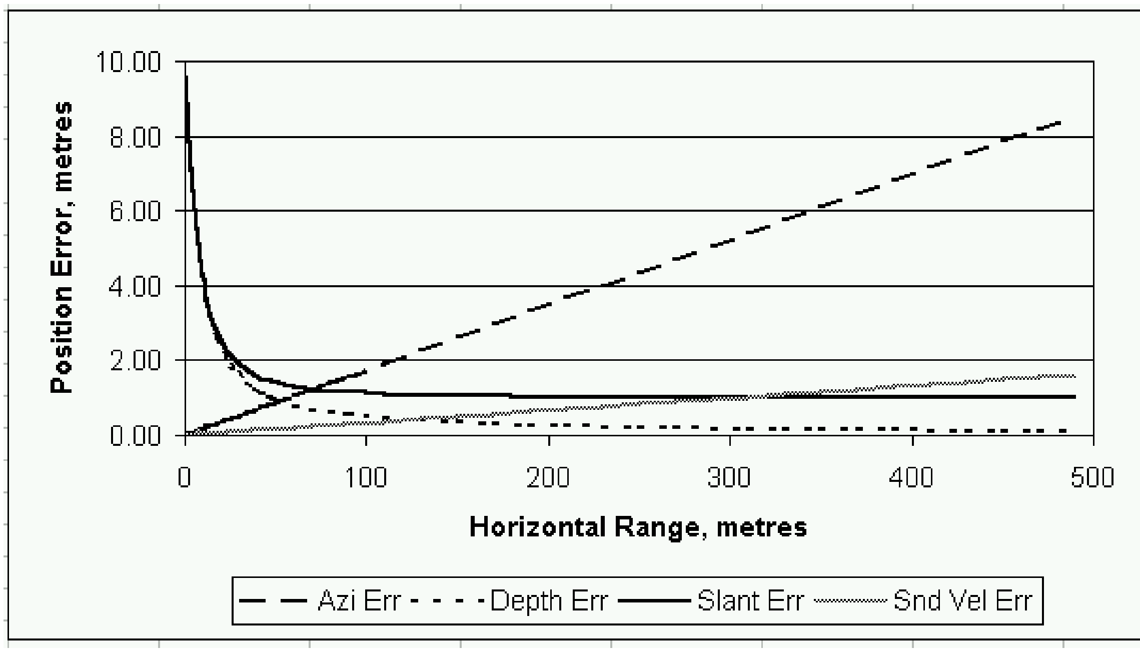


Figure 9. Sensitivity of the Trackpoint/dGPS fix accuracy to a 1^0 azimuth error, a 1m beacon depth error, a 1m slant range error or a 5 m/s sound velocity error for a beacon at a depth of 50m.

Hydrophone Geographic Position Error

The geographic position of the hydrophone is established by first locating the position of the vessel's GPS antenna then translating that to the hydrophone location. Suppliers of dGPS position corrections (e.g. Government of Canada's Ministry of Transport) guarantee 10 m positioning accuracy at sea. Expert users of the dGPS system on the east coast of Canada estimate the actual position error to be better than 3-4m (Grant 1996). In justification of this estimate, Grant (1996) reported that CN Marine have used dGPS for some years to turn their ferries in the confined area of Port aux Basques Harbour, Newfoundland and then dock them in zero visibility. Through careful use of a tape measure the location of the hydrophone relative to the GPS antenna can be determined with negligible error.

Horizontal Range Errors

The Trackpoint II system determines slant range between beacon and hydrophone by measuring the round trip travel time then converting this to a distance using a constant value for the speed of sound through the water. The receiver has provision for allowing the user to adjust the sound speed. However, to avoid uncertainties and possible mistakes when post-processing fix data, it is recommended that the receiver always be left at a setting of 1500 m/s and the correction be applied later. The sound velocity profile in the water column can be measured directly with a velocimeter or calculated from a conductivity-temperature-depth profile. This is then converted to a single mean harmonic sound velocity value (Maul, 1970) for entry into the fix computation algorithm. Careful attention to this matter should ensure that sound velocity errors do not significantly affect the fix accuracy.

The Trackpoint II system measures slant range with an accuracy of $^+$/-0.39m providing that the sound velocity structure in the water column is known (McKeown et. al., 1991). For practical purposes, the effect of an error of this magnitude on the position fix can be ignored compared to the other error sources.

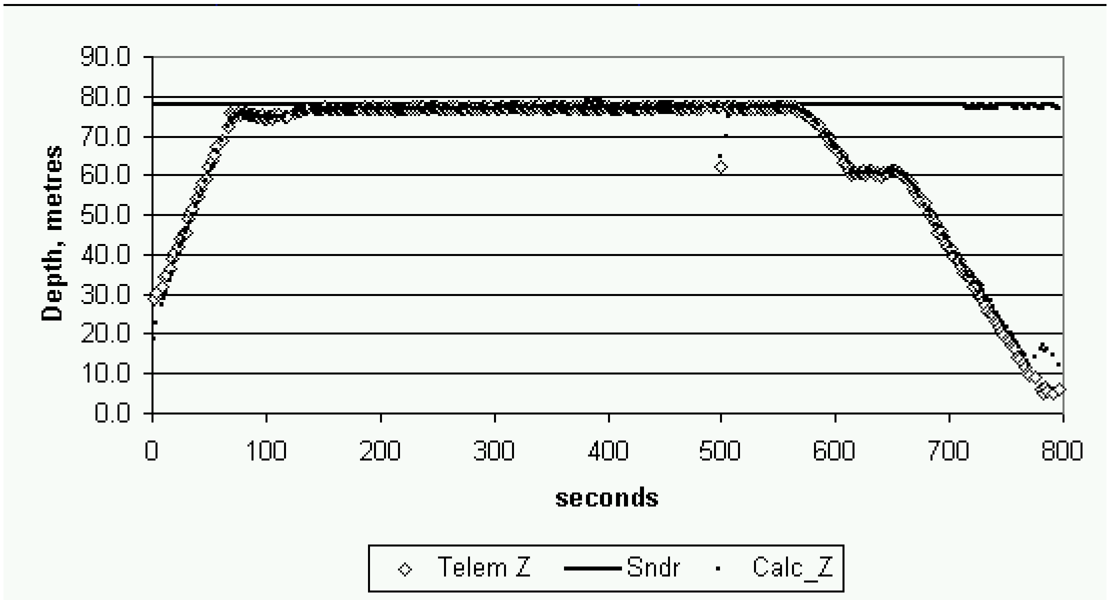
This measured slant range must be converted to a horizontal offset before the beacon position can be computed. Therefore, knowledge of the beacon depth is required. If the depression angle or direction of the beacon below the horizontal is greater than 45^0, the Trackpoint II system will measure it. This is known as the "Calculated Depth" mode. As the depression angle decreases to less than 45^0, the measurement is degraded to the point of not being useable. Under these circumstances, beacon depth must be established by some other means such as using a depth-telemetering beacon or using depth from the ship's sounder if the beacon is close to the bottom.

The "Calculated Depth" is the product of the slant range and the sine of the measured depression angle. The theoretical accuracy of the latter varies from approximately 0.12^0 RMS at a depression angle of 90^0 to about 0.17^0 at a depression angle of 45^0 (Fraser, 2005) when the hydrophone is motionless. At sea, the accuracy will be somewhat worse. To try to arrive at a workable estimate of "Calculated Depth" accuracy, a telemetering beacon was lowered to the sea floor, held there for a while then recovered while recording the telemetered depth, the "Calculated Depth" and the sea floor depth as determined by the ship's echo sounder. Multibeam data indicates that the bottom was flat to within 0.1m over the area of interest so the fact that the two transducers where at different locations on the ship can be ignored. The results are illustrated in Figure 10. Both the telemetered depths and "Calculated Depths" are about 1.0m less than the bottom depth by the ship's sounder during the period when the sampler was sitting on the sea floor after correction for the difference in draft of the two transducers. This corresponds to the distance the telemetering beacon was mounted above the bottom of the sampling device. The "Calculated Depth" and telemetered depth agree within 0.06% during the period and the depth determined by using a telemetering beacon is approximately 0.5% (Fraser, 2005). Therefore, it is reasonable to assume that a similar accuracy applies to the "Calculated Depth" over the range of depression angles of 45^0 to 90^0.

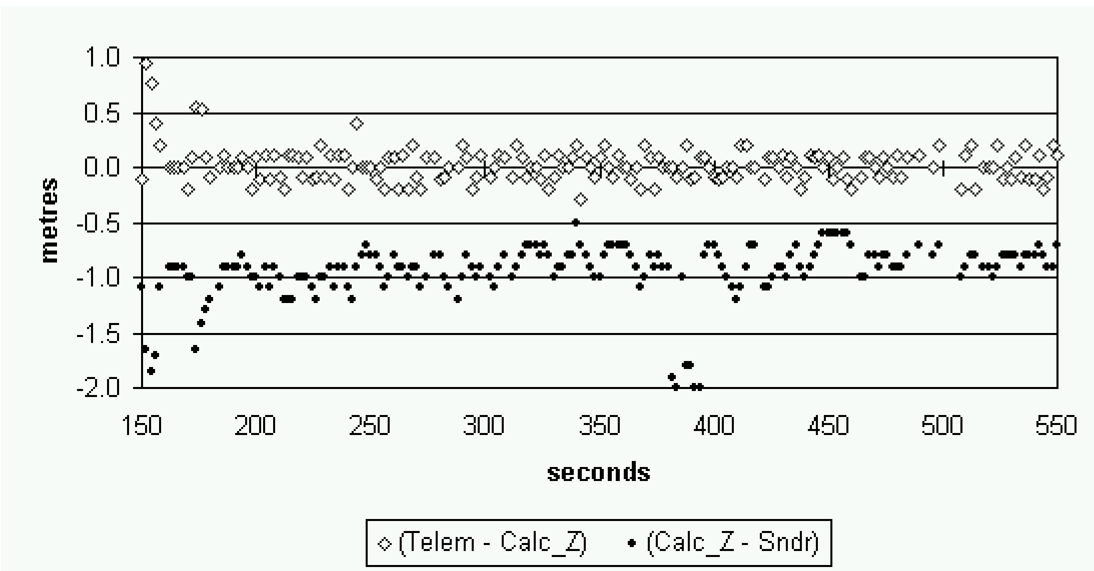
When the depression angle is substantially less than 45^0, which would occur when positioning a towed survey vehicle, or diver who is carrying a sampling device, the “Calculated Depth” is unusable. In such cases, the depth must be determined by some other means. Towed survey vehicles usually incorporate a pressure (depth) sensor and its output is normally recorded as a function of GPS time so the only challenge is to synchronize this depth record with that of the navigation data. A diver could carry a recording depth transducer in addition to the beacon and sampler. While feasible, this diver option adds a considerable complication to the field activity, as it requires the maintenance and operation of an additional piece of equipment and the depth record must be carefully synchronized to the logged Trackpoint data when computing the position. A simpler approach is to use the charted water depth at the sampling site as this introduces very little position error at ranges substantially in excess of water depth. For example, at a horizontal range of 100m, a 1% error in identifying the beacon depth at 50m only results in a 0.25% error in horizontal range and at a depth of 100m the error only increases to 1% (Fig. 11).

Hydrophone - Beacon Azimuth Error

There are three factors that affect the accuracy of the azimuth of the vector from the hydrophone to the beacon. The first is that introduced by the ship’s marine gyroscope or flux gate compass, which is typically about +/-0.5^0. The second is an offset between the reference direction of the hydrophone array and the ship’s fore/aft axis. This can be eliminated by doing a careful calibration at the time the hydrophone is installed (See Appendix A). The third component is the error in the relative bearing measurement made by the Trackpoint system. A previous study has shown that the Trackpoint receiver measures relative bearing with an accuracy of $^+$/-0.87^0 (McKeown et. al., 1991).



a) Depths by three different measurement methods.



b) Time series of depth differences while the beacon is sitting on the sea floor.

Figure 10. Comparison of beacon depths as determined by several means during the deployment and recovery of a bottom-sampling device.

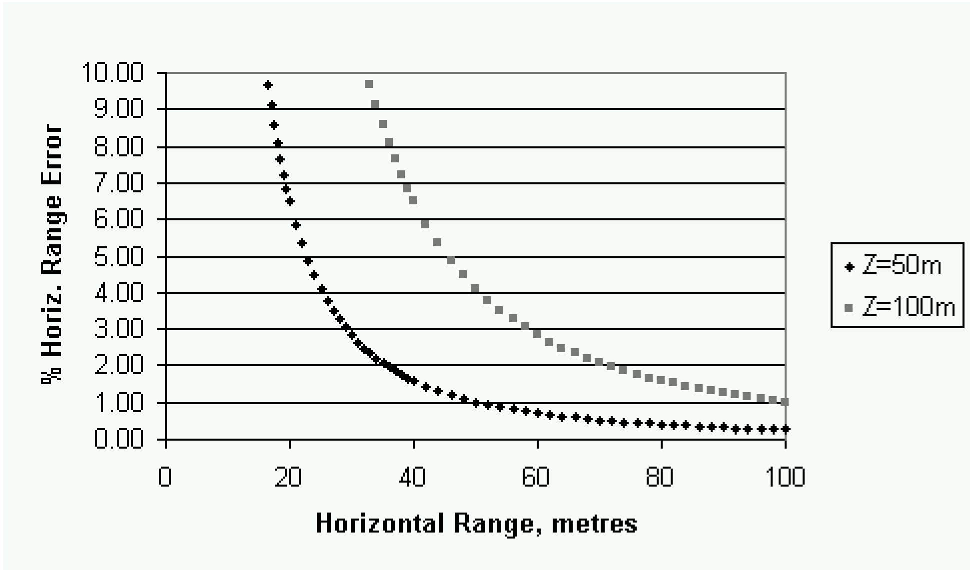


Figure 11. Horizontal range error introduced by a 1% error in beacon depth for a beacon at 50m and 100m depth.

Computational Errors

Care has been taken in structuring the position computation programs in Appendix E to ensure that the times of the GPS fix, the vessel heading and the Trackpoint data are coincident. Their computational accuracy and that of AGCNAV, REGULUS has been verified. There is one known “bug” in the AGCNAV program. The GPS antenna and Trackpoint hydrophone offsets relative to a common reference point on the vessel must be entered with opposite signs, that is:

- GPS antenna offsets are entered as starboard and forward negative;
- Trackpoint hydrophone offsets are entered as starboard, forward and down positive.

Also, caution must be exercised when using AGCNAV to compute Trackpoint II positions. It uses a constant value for the number of metres in a minute of latitude and converts longitude to easting by using the cosine of the latitude of the first ship position received after the program is started rather than computing correct geodetic conversion factors. These approximations are of little consequence when the work area is restricted to a few 10’s of kilometres in extent. REGULUS and the post-processing programs to be described below use correct geodetic conversion factors computed specifically for each ship position.

Overall Position Error

A GAPS position is determined by a polar measurement, that is, horizontal distance and direction in the vertical and horizontal planes. Slant range and depth errors contribute to a position error in the radial direction. At horizontal distances less than the water depth, slant range and beacon depth errors are the critical elements in the error budget. Horizontal bearing errors produce a tangential fix error that increases with distance so these errors tend to dominate at horizontal offsets greater than the acoustic beacon depth (e.g. when diver deployed). At substantial horizontal distances, sound velocity errors can also have an impact.

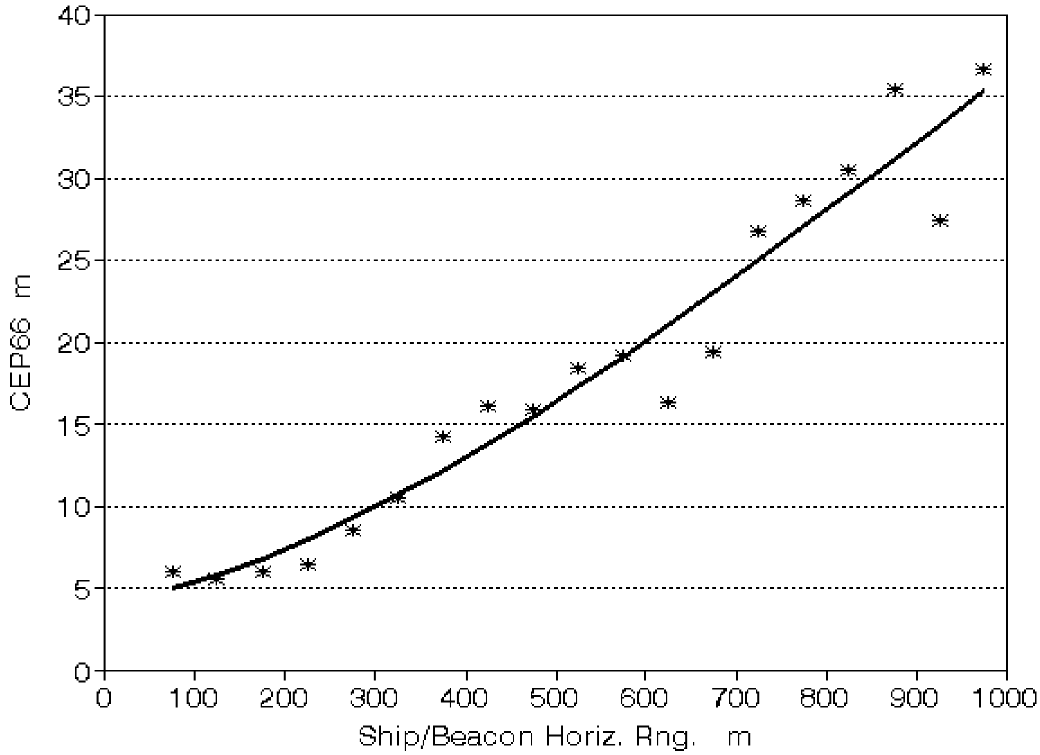


Figure 12. Overall Trackpoint/dGPS fix accuracy (CEP66 radius) as a function of beacon/ship horizontal separation (McKeown and Gordon, 1997).

While it is important to know what the nature and magnitude of each of these error components are, the user tends to be more concerned about the cumulative accuracy of a fix produced by the system. While there are several ways to quantify the overall positioning system accuracy, the one that best describes a polar positioning system such as GAPS is the Circular Error Probable radius, CEP66 (Harre 1990). Figure 12 summarizes the results of an experiment designed to establish this overall error as a function of horizontal range for a beacon moored in a depth of about 150m (McKeown and Gordon, 1997).

GAPS Trial Environment

The positioning system, operating methodology and post-processing software were tested during a benthic ecological investigation of a sea floor feature where the precise positioning of the sampling and survey equipment was a crucial element (Wildish, et al, 2007). These field trials were conducted on board *CCGS Pandalus III*, a 12.8 metre workboat based at the St. Andrews Biological Station, St. Andrews, New Brunswick and the *CCGS J.L.Hart*, a 20 metre research vessel based at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia. Both vessels are single screw and lack bow thrusters.

The study site, Passamaquoddy Bay, is a large (575 km^2) embayment located in southwestern New Brunswick, Canada (Fig. 13). One of its more remarkable features is the multitude of depressions or “pockmarks’ on its floor (Pecore and Fader, 1990). These pockmarks are believed to be formed when a sub-surface fluid percolates to the surface lifting sediment into the water column where it is swept away by currents. This formative fluid is usually methane gas although in some cases it is thought to be fresh water. In the near-shore zone the methane gas is usually produced biogenically although a petrogenic process is also a possibility.

According to Fader (1990) “…pockmarks have been found in many continental shelf environments of the world and their role as foci of intense chemosynthetic activity has attracted considerable attention”. There are estimated to be approximately 11,000 pockmarks in Passamaquoddy Bay covering an area of approximately 87 km^2. They occur on Holocene clay, the uppermost unit of the seafloor in two patches separated by a ridge of till-covered bedrock. Some are aligned in parallel rows while others occur in clusters and, in some cases, smaller pockmarks occur inside larger ones (Fig. 14). Their diameter ranges from 1 to 300 m with an average diameter of 29m and they occur in water depths of 20-40m. While their average depth is 3.5m, the range is substantial, the deepest being 50m, one of the largest ever discovered Wildish et al. 2007).

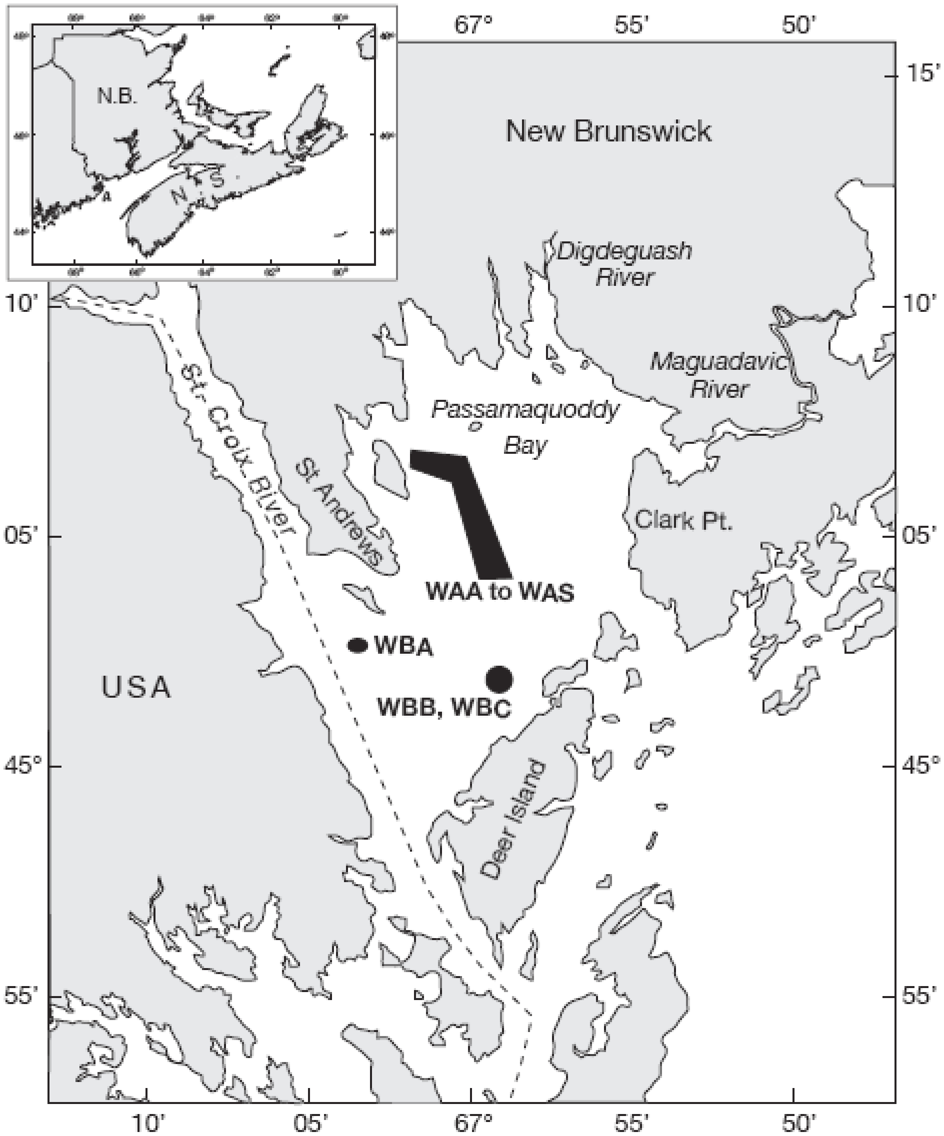


Figure 13. Location of Passamaquoddy Bay, New Brunswick.

The pockmarks in the southern area of the bay are “eyed” that is, they exhibit a strong acoustic backscatter from the central bottom area even though the depressions do not penetrate entirely through the entire section of Holocene mud in which they form. The cause of this acoustic feature is unknown but may be a consequence of acoustic focusing or result from a dense accumulation of benthic organisms or carbonate deposits. A few of the pockmarks, mainly in the southern area of the bay are buried or ancient.

Figure 14. Multibeam image of Passamaquoddy Bay pockmark areas.

The seafloor in the vicinity of these pockmarks may undergo a temporary decrease in biological productivity during their formation. As the bay houses a few salmon farms, it is important to arrive at a better understanding of the biological and geochemical nature of these features and to determine whether or not they are relic features or of recent origin. In order to accomplish this, a field program of seafloor surveying and sampling was undertaken using GAPS. This program was concentrated in the areas labeled WAA to WAS, WBA, WBB and WBC.

Typical GAPS Operations

Positioning a Grab Sample

The main motivation for creating GAPS was to enable benthic biologists to obtain bottom samples that were accurately located with respect to each other spatially. These samples are collected using the bottom grab illustrated in Figure

4 b). The first step is to identify the target locations and prepare a waypoint file. While helpful in delineating the general location and configuration of the pockmarks in Passamaquoddy Bay, the resolution of the available multibeam bathymetry (5m per pixel) was not of sufficient accuracy to allow the precise selection of target sample sites. Furthermore, the possibility existed that the vessel coordinates displayed on the workboat might contain minor errors or unknown offsets. Therefore, a preliminary list of target locations was established then, at the work site, echo sounder transects were made across the feature of interest before beginning the sampling operation in order to verify the exact locations of the target sites. The final target sites were selected from this survey information and entered into the real-time navigation system.

While either AGCNAV or REGULUS can be used for grab sample positioning, the authors have found that the former is more effective because of its simplicity of operation. The following operating procedure has proven to be very effective when attempting to sample specific sea floor targets.

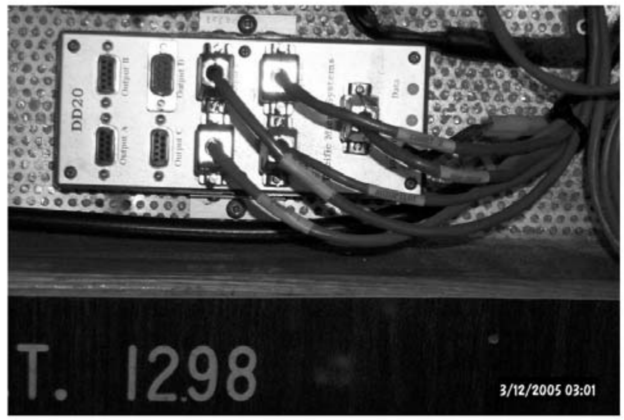
First the Trackpoint system is set up as follows:

1. Charge the battery in at least one of the beacons.
2. On *CCGS Pandalus III* and *CCGS J.L.Hart*, install the hydrophone on the side of the vessel. On CCGS Hudson, the installation will be done by Geological Survey of Canada (Atlantic) technicians. (Contact: Head, Program Support, GSC(A), Bedford Institute of Oceanography, Dartmouth, N.S.).
3. a) On *CCGS Pandalus III*, connect a cable from RS-232 port 1 (large, 25 pin connector on the back of the control/display unit) to the multiplexer (MUX). The MUX is mounted on the starboard side of the companionway. Any available connection can be used (Figure 15 a)).
   b) On *CCGS J.L.Hart* and *CCGS Hudson* the installation will be done by Geological Survey of Canada (Atlantic) technicians.
4. Turn on the Trackpoint receiver and let it "boot" itself up. Do not press the F5 key.
5. Once the graphics screen has established itself, check the configuration of the receiver by pressing the key sequence "DISPLAY(F1)/CONFIG(F2)/SYSTEM(F1)" and verify that the following settings are correct:
   Transmit keying on
   RS-232 COM port 1 = 4800 baud, 8 bit, no parity
   All offsets set to zero then press "Cancel" to reset the display
   Then press "Cancel".
6. Check the configuration of all targets (beacons) via the key sequence "DISPLAY(F1)/CONFIG(F2)/ALLTARGETS(F2)". Confirm that "Track" for the beacon being used is ON and all others are OFF and that the "Xmit"

(Interrogate) and “Recv” (Reply) frequencies displayed correspond to the specification on the beacon case then press “Cancel” to clear the screen.

7. Verify that the chosen beacon is in the “Calculated Depth” mode via the key sequence “TARGET/REPLY DATA/DEPTH/MODE

a) Multiplexer



b) Amplifier

Figure 15. a) Serial data multiplexer (box circled at upper right) and b) distribution amplifier installations on *CCGS Pandalus III*.

AGCNAV is set up as follows:

1. Connect the COM port on back of the navigation computer to any available connector on the navigation data distribution amplifier box. On *CCGS Pandalus*, this unit is mounted at the head of the companionway (Fig. 15 b)). On the *CCGS J.L.Hart* it is on the chart table in the wheelhouse. On *CCGS Hudson* distribution amplifiers are located on the forward bulkhead of the Forward Lab and in a rack at the aft end of the General Purpose Lab.
2. Start AGCNAV.

3. Click on “NAVSOURCE/SERIAL PORT SOURCE” to start the COM port reading incoming navigation data.
4. Check that serial data is being received by clicking on “NAVSOURCE/VIEW RAW NAVIGATION”. If no data is visible, try step 3 again. Check cable connections. Check that red LED’s on distribution amplifier of step 1 is flashing. Check that the green LED’s on the MUX are flashing. The one associated with the GPS receiver should blink almost continuously. The one associated with the gyro (heading) should blink briefly once a second. The one associated with the Trackpoint system will only flash if a beacon is turned on and in the water.
5. Press the space bar. The screen should display a navigation plot. See the AGCNAV manual or press the “H” key for further instructions.
6. Verify that time, ship position and heading at the upper left quadrant of the screen are updating regularly. If the vessel is secured to a wharf, only the least significant digits of position will change and heading may not change at all.
7. Verify that the latitude and longitude are being received and displayed to four decimal places.
8. Verify that the heading is correct.
9. Click on “LOGGER/LOG INTERVAL” and verify that following settings are correct
   - $GPGGA - All
   - $GPZDA – every 60 sec
   - $HEHDT - All
   - $SDDB? – All (if available)
   - $POREB – All

     Note:

     The $POREB string may not be listed at this point. Should that be the case, it is essential to return to this step after doing the system functional test described below to complete the logging setup.
10. Turn on data logging by clicking on “LOGGER/START LOGGING”
11. Click on “GRAPHICS/DISPLAY ITEMS” and turn on “Fish” and then the number corresponding to the beacon being used.
12. Set the Range Ring radius to a suitable value, e.g. 20m by clicking on “GRAPHICS/RANGE RING SIZE” and entering the value.
13. Return to graphics screen. If it is not in “Bullseye” mode press M key until it is.
14. Verify that there is a line with a green background in the lower right corner of the screen indicating that the data is being logged. If the message indicates the data is not being logged, repeat step 10.

The final set up step is a functional test of the system that is carried out as follows:

1. Put the beacon in the water off the stern at about the same depth and distance outboard as the hydrophone so that its relative bearing with respect to the fore and aft axis of the vessel is 180^{o}.
2. Verify that the Trackpoint Command/Display unit is receiving the beacon signal and displaying it at approximately the correct position on the screen relative to the vessel icon.
3. Verify that AGCNAV is receiving the Trackpoint data and displaying the fish icon at the correct location relative to the ship icon. If not check that the green LED on the MUX associated with the channel the Trackpoint receiver is plugged into flashes every time the beacon signal is received. On *CCGS Pandalus* this can best be done by turning up the Audio on the Trackpoint receiver and listening to the distinctive "boink" of the received signal while watching the MUX LED. On other vessels imaginative use of the vessel's internal communication system may be required.
4. If the string $POREB was not present during step 9 of the AGCNAV setup described above, click on "LOGGER/LOG INTERVAL", select $POREB and set its log interval to "All".
5. Record about one minute of data with the beacon in the water and note the start and end times. This data set will be used to define the Relative Bearing offset correction that will need to be applied during post processing.
6. Exit from AGCNAV, load the short logged data file into WORD or some other word processor and verify that the following sentences have been logged:
   - $GPGGA every one or two seconds
   - $GPZDA every 60 seconds
   - $HEHDT every second
   - $SDDB? If available
   - $POREB every two seconds although an occasional miss is OK.

The equipment is operated as follows during each sea floor sampling activity:

1. Place the AGCNAV laptop in front of the helmsman so that he can use it to maneuver the fish (grab) onto the target location.
2. Turn up the Audio on the Trackpoint receiver so that, when the grab is in the water, the correct operation of the Trackpoint system can be verified
3. In AGCNAV, set the next target position "Active" so that it's identifier appears at the top left corner of the plotting area. This can be done by pressing the "+" or "–" key repeatedly until the correct target waypoint is selected.
4. Press the "Home" key to centre the display on the target waypoint.

5. Zoom in/out with the “Page Up/Page Down” keys as required creating a suitable display for the helmsman.
6. As the workboat approaches the target site, the grab and acoustic beacon are lowered into the water and suspended a few metres above the bottom.
7. Using the real-time navigation display of vessel and grab positions, the helmsman manoeuvres the vessel in such a way as to bring the grab (Fish icon) over the target site.
8. When the helmsman judges that the grab is about to enter the target zone, he orders the winch brake released.
9. At the instant the deck crew judge that the grab has triggered, press the “F” key to record a fix and simultaneously note the water depth on the sounder.
10. Press the “W” key to display the waypoint file and record in the logbook the time of the fix and the water depth from step 6 then press “Esc” to exit from this display.
11. Press the C key to clear the ship’s past track off the screen.

Sometimes everything will go as planned (Fig. 16) and sometimes it doesn’t (Fig. 17). Only three minutes elapsed from grab deployment to sample collection in the operation illustrated in Fig. 16 and the sample was collected 10m off target. Eleven minutes and several passes were required to collect the bottom sample illustrated in Fig. 17 but, when it was finally obtained, it was only 4m off target.

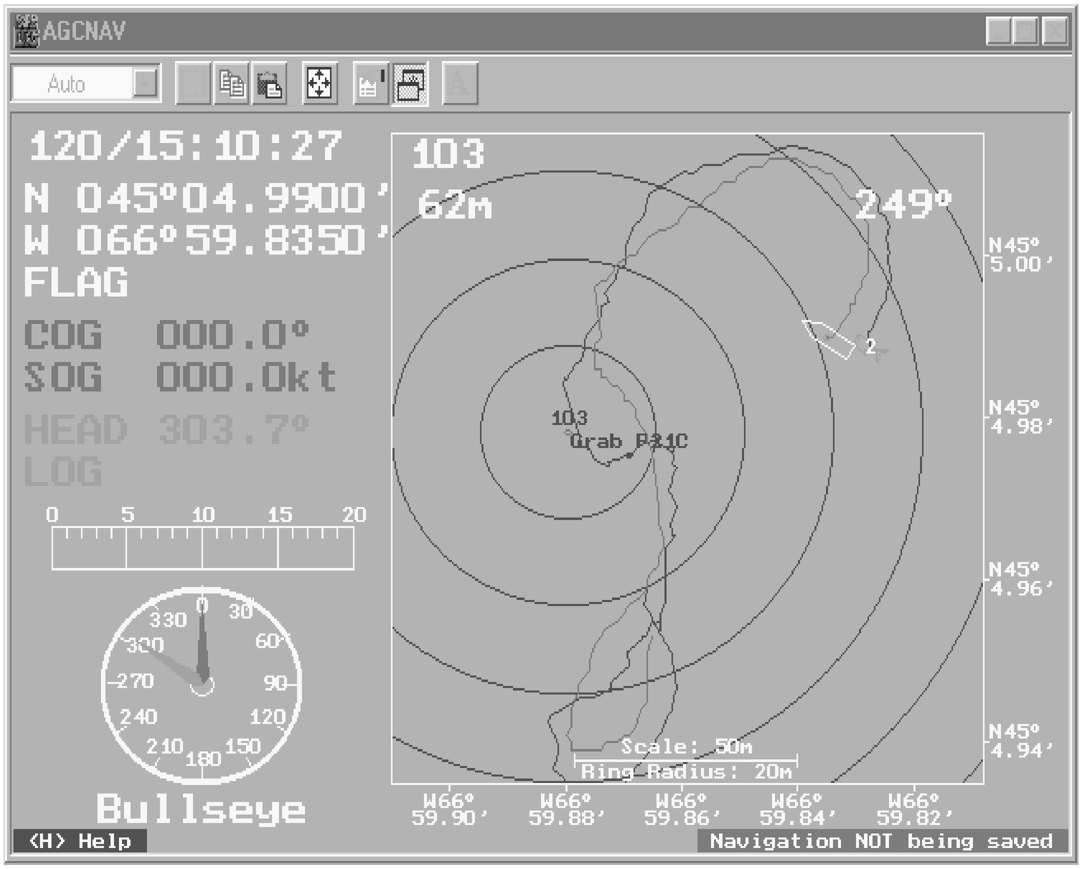


Figure 16. Workboat and grab (multi-beacon) tracks while maneuvering to sample a pockmark

The coordinates of the multi-beacon relative to the hydrophone are determined from acoustic information that is very sensitive to the presence of ambient noise. The effect of such a disturbance on the multi-beacon positions is usually, but not always, apparent from the behaviour of the fish on the AGCNAV display during the sampling operation. Furthermore, the operation of the system is sufficiently complex that even experienced users can sometimes omit a critical step or be deceived by the apparent quality of the Trackpoint navigation data as displayed by AGCNAV. Therefore, it is strongly recommended that the quality of the logged data be checked periodically during a field operation. The program NMEA_TESTER (see Appendix E) permits the user to do this. Figure 18 is an example of an entire day of logged data. The relative bearing trace varies substantially because the grab is nearly under the hydrophone as it swings about on the end of the cable. The slant range and "Calculated Depth" traces almost overlap because the grab-hydrophone horizontal offset is small.

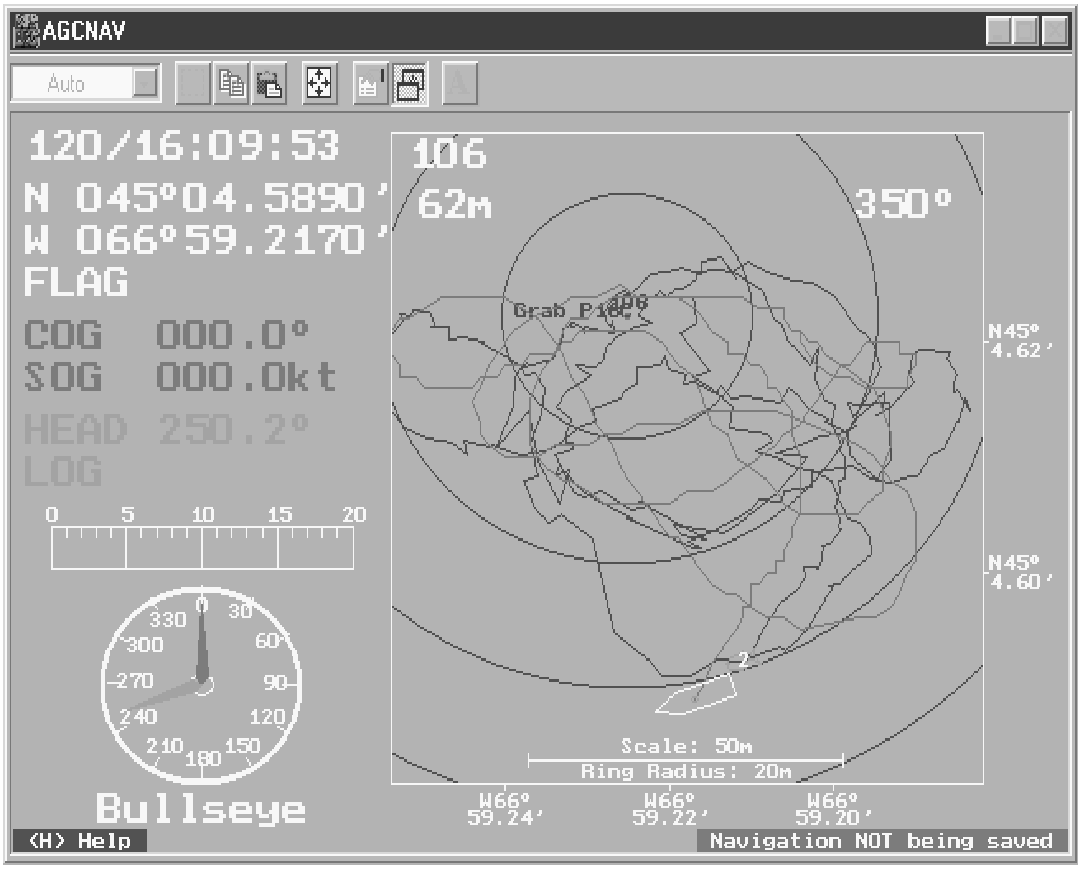


Figure 17. Workboat and grab (multi-beacon) tracks while maneuvering to sample a pockmark.

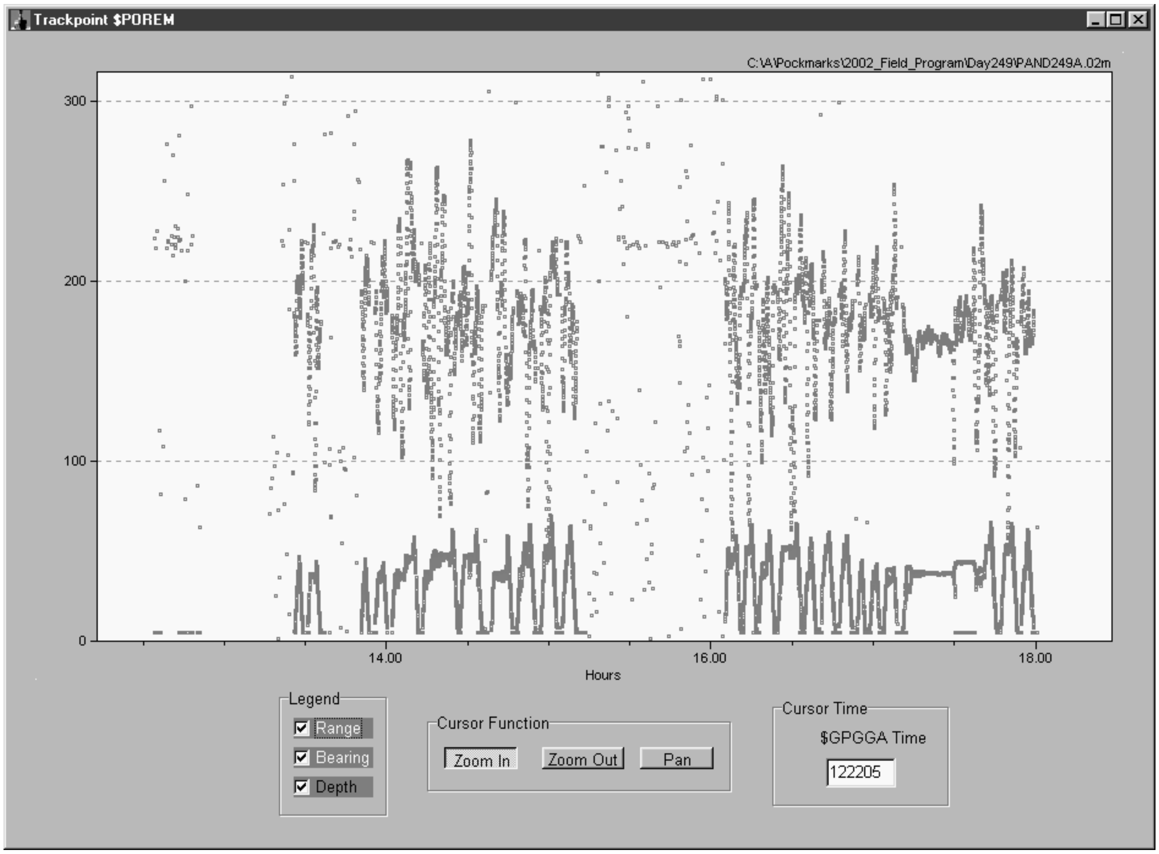


Figure 18. Several hours of logged Trackpoint data via NMEA_TESTER. The slant range, relative bearing and "Calculated Depth" traces are colour coded and can independently be turned on or off.

Positioning an Underwater Survey Platform

Benthic ecologists also make use of towed survey vehicles to survey areas of the sea floor that are of interest. These include acoustic survey systems such as sidescan sonar and video and still photograph imaging systems such as Towcam (Gordon, et al, 2004). The GAPS system can be used to accurately locate the sidescan or imaging tow fish track in order to construct an acoustic or video mosaic or to locate still photographs relative to sea floor features of interest. While the GAPS operating details are in most respects very similar to the bottom sampling procedure described above, there are some notable exceptions.

As the objective is to follow survey lines rather than proceed to specific targets, the endpoints of each line are identified as waypoints and entered into the file. Then, within AGCNAV or REGULUS, a survey pattern is generated for the guidance of the helmsman. While either navigation program can be used to conduct the survey, the latter is preferred as it permits the user to overlay the survey track on a multibeam image of the area to be studied.

The track of the towing vessel at slow survey speeds is severely affected by wind and surface currents. Meanwhile the track of the towed body is affected by underwater currents and its hydrodynamic characteristics, Consequently, the track of the survey platform over the sea floor is rarely coincident with that of the ship. If the survey objectives can be met by simply running the vessel along straight lines then the helmsman could use either navigation program in the Line Running mode. However, if the objective is to have the survey platform pass over specific objects, e.g. a pockmark, then the Chart mode is the preferred display option. This allows the helmsman to manoeuvre the vessel in such a way as to cause the fish (multi-beacon) to follow the planned track rather than the ship.

In order to compute a multi-beacon position, its depth must be known. The Trackpoint receiver's "Calculated Depth" mode is only usable if the horizontal distance to the towed body is less than its depth but this is usually not the case with towed survey vehicles. Alternative depth sources include using a telemetering multi-beacon, merging the Trackpoint data with the output of a pressure sensor in the towed vehicle during post-processing or, if the platform is near the sea floor, the charted depth can be used. While the use of charted depth will introduce some error, the effect is negligible at horizontal distances substantially in excess of the vehicle depth (Fig. 11).

Even experienced GAPS users have been deceived by the apparent acceptability of the Trackpoint data during a tow only to discover later that the logged information was faulty. To avoid such an occurrence, it is recommended that an additional computer be attached to the distribution amplifier and the program NMEA_TESTER (see Appendix E) be run in the "ANALYZE/ONLINE" mode to monitor the Trackpoint data as it is collected. Figure 19 is an example of such a process.

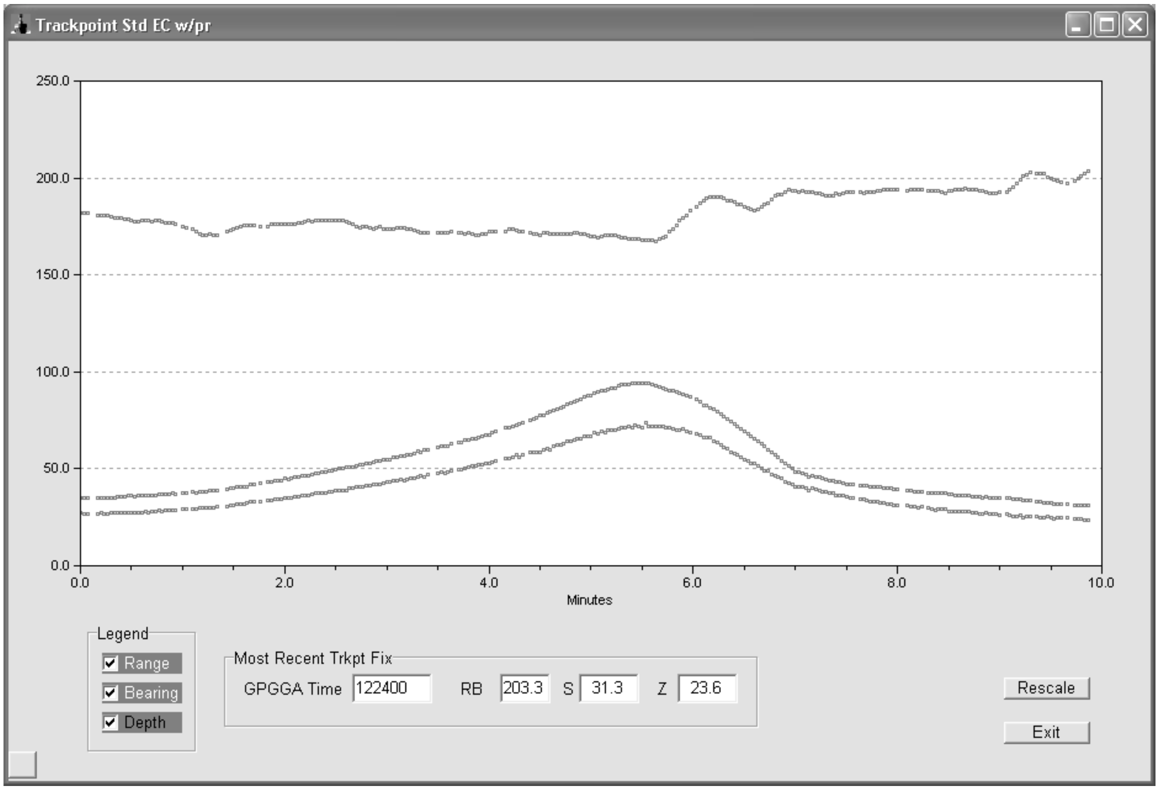


Figure 19. Real time monitoring of Trackpoint data quality during a survey operation. The slant range, bearing and depth traces are colour coded.

Figure 20 is an example of a study that was done of a pockmark in Passamaquoddy Bay using GAPS and the procedures described above to position the towed survey vehicle Towcam and a grab sampler. Target grab sites were selected at a point well outside the pockmark to the north, at several points down the walls and into the bottom of the pockmark and then outside the pockmark to the south. Three replicate samples were collected at each target site. Two video and still photo transects were also conducted with the Towcam underwater survey vehicle.

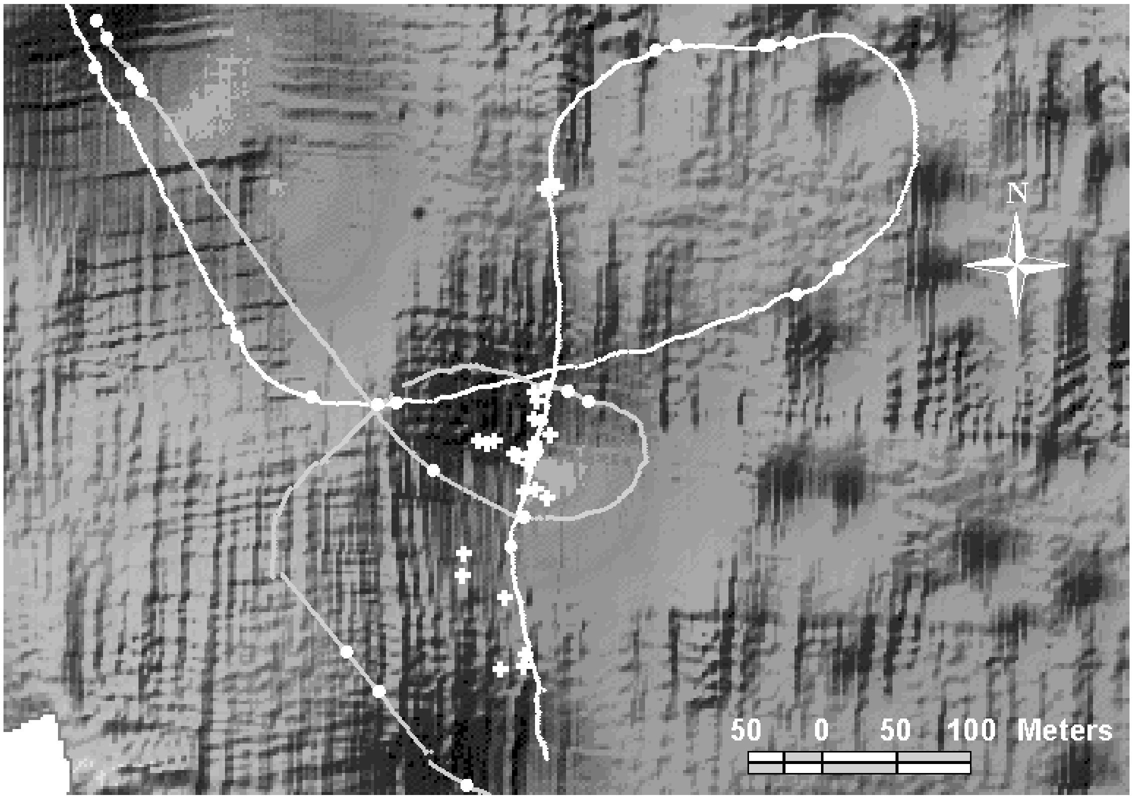


Figure 20. Grab sampling transect (white crosses) and survey vehicle tracks (white and grey lines) across pockmark WAI. The dots represent points where still photographs were taken.

Positioning a Diver

The GAPS system can also be used to accurately locate a diver conducting an underwater survey or sea floor sampling operation. While the GAPS operating details are in most respects very similar to the bottom sampling procedure described above, there are some notable exceptions. The objective of using GAPS is usually to verify that the diver followed the required track or collected samples at the specified locations. While either AGCNAV or REGULUS can be used, it is probably preferable to use the latter as it permits the observer to overlay the diver's position on top of a nautical chart or multibeam image.

Determination of the multi-beacon depth must be carefully considered when positioning a diver. From a positioning accuracy perspective, the best solution would be to have the diver carry a depth-telemetering version of the multi-beacon. However, this unit is substantially longer (527 mm vs. 298 mm) and heavier (1.70 Kg vs. 0.82 Kg in water) than the simple multi-beacon so this may not always be an acceptable solution. If the diver is operating close to the support vessel, the Trackpoint receiver's "Calculated Depth" mode may be usable. If the diver is near the sea floor and at a horizontal distance from the hydrophone that is substantially greater than the depth, the charted depth can be used. While this will introduce some error, the effect is negligible in such a circumstance as indicated in Figure 11. Another alternative would be to fit the diver with a time-depth recorder so that this data can be merged with the Trackpoint data during post-processing.

Data Processing

Waypoint Files

Prior to conducting a bottom sampling or sea floor survey operation using GAPS, a waypoint file must be prepared. This data file contains the locations of the sampling sites or survey lines. It is a text file especially formatted for AGCNAV or REGULUS. Figure 21 contains an example of an AGCNAV waypoint file and Figure 22 the corresponding REGULUS version. The waypoint file can be created by using a special purpose editor included in each of those navigation programs or by using the program WAYPOINT described in Appendix E. In addition to creating waypoint files, the program WAYPOINT can also be used to convert files between various formats. These files are normally given the extension WP in the filename.

```
AGCNAV Survey / Waypoint file
Version 3.04
Waypoints:
bio jetty      ,44.679445,-63.613888
Bear Cove 1    ,44.5404,-63.531678
Bear Cove 2    ,44.520845,-63.508908
279/05:35:21   ,44.68133,-63.612063
280/12:21:02   ,44.67916,-63.597865
Survey Lines:
BC1 – BC2      ,Bear Cove 1    ,Bear Cove 2

BC2 – BC1      ,Bear Cove 2    ,Bear Cove 1

END OF FILE
```

Figure 21 Example of an AGCNAV waypoint file.

```
Waypoint,SOL        ,45.085,-7.001355,150.0,225.0,1,Comment
Waypoint,EOL        ,45.091727,-67.008278,150.0,225.0,1,Comment
```

Figure 22 Example of a REGULUS waypoint file.

M-type Files

A number of programs described in Appendix E have been developed to manipulate, process and display GAPS data. To simplify data transfer between these programs a file format known as M-type has been created. This consolidates into a single comma delimited record of the dGPS ship's position, vessel heading and Trackpoint fix information related to a single multi-beacon fix as follows:

ID code, i.e., $POREM
GPS fix time from dGPS receiver $GPGGA string
GPS ship position from dGPS receiver $GPGGA string
Flag – type of GPS fix
Vessel heading from gyro or autopilot
Trackpoint

- o Beacon number
- o Relative bearing, slant range and depth
- o Latitude and longitude
- o X and Y coordinates relative to hydrophone
- o Telemetered depth
- o Error code
- o Echo sounder depth

For example:

```
$POREM,130038,4426.2609,N,5753.389,W,0,329,5,11,83.2,69.6,4426.267807,N,5753.389543,W,8.2,42,70.7,,70
$POREM,130040,4426.2609,N,5753.3888,W,0,329.5,5,12.8,84.1,70.1,4426.26888,N,5753.38858,W,9.7,42.7,70.3,,70
```

A-type Files

The Geological Survey of Canada (Atlantic) has created a fixed format of navigation data files known as A-type. The first field in the record is a time field consisting of a combination of the Julian day (DDD), hour (HH), minute (MM) and second (SS) to create a string DDDHHMMSS. Latitude and longitude fields in decimal degrees follow this to six places. For example:

168220316 43.289283 -65.120535
168220318 43.289290 -65.120518
168220320 43.289295 -65.120507

REGULUS Data Files

REGULUS records all data other than the logged NMEA navigation data in an Access database file with the name MAIN_DB.MDB. Tables 2, 3 and 4 illustrate the Access database tables of particular interest.

Table 2. Marker (Event) Table

Field	Description
ID	AutoNumber
Shape	Number
Lat	Number
Long	Number
Colour	Number
Description	Text
Reciprocal_Scale	Number
Name	Text
Range	Number
Bearing	Number
Label_Visible	Yes/No
Memo	Text
Locked	Yes/No
Data Item	Number

ID	Shape	Latitude	Longitude	Colour	Description	ReciprocalScale
2	6	43.8107328772868	-60.7333434842165	32767	Generated at UTC 2000.06.13 14:09:27	10000

Name	Range	Bearing	LabelVisable	Memo	Locked	Data_Item
Event 2	75	135	Yes		Yes	0

Table 3. Routes Table

Field	Description
ID	Autonumber
Route Name	Text
Description	Text
Memo	Text
Type	Number
Data Item	Number

ID	Route_Name	Description	Memo	Type	Data_Item
29	Sidescan	Generated at UTC 2000.07.06 15:01:42		0	0

Table 4. WP_Library Table

Field	Description
ID	AutoNumber
WP_Name	Text
Latitude	Number
Longitude	Number
Locked	Yes/No
Label_Range	Number
Label_Bearing	Number
Memo	Text
Transparent	Number
Data_Item	Number

ID	WP_NAME	Latitude	Longitude	Locked
12	PW6	43.8111666666667	-60.85805	Yes

Label_Range	Label_Bearing	Memo	Transparent	Data_Item
150	225	Generated at UTC 2000.06.13 10:13:37	0	0

Plotting Ship's Track

The first step in processing the logged navigation data is often to display the ship's track. Differential GPS ship positions do not usually require any editing since spurious values are rare. Both AGCNAV and REGULUS can be used to replay logged NMEA data contained in E-type files in order to display the track. This is accomplished by specifying the data file as the navigation data source via the menu path "NAV SOURCE/FILE SOURCE" in AGCNAV and

“MAIN/COMMUNICATIONS/CONFIGURE PORTS/INPUT FROM FILE” in REGULUS. Unfortunately, this process can be rather slow and unwieldy. An alternate approach is to plot the track via APLOTWIN (see Appendix E) as this plotting program has some features that are of use when exploring details of the ship’s track such as a latitude/longitude cursor, a distance ruler and an ability to search for a position on the track that corresponds to a user specified time. Another alternative would be to use PROCNMEA to export the times and ship positions as decimal degrees to a comma delimited file. It is then possible to use a Geographic Information System (GIS) program such as ArcView, a commercial package from ESRI (www.esri.com), or the freeware package such as fGIS (www.digitalgrove.net/fgis.htm) to plot the track.

Processing Grab Sample Data

A computer program (SAMPLR_POSN, see Appendix E) has been developed to process the logged NMEA navigation data and calculate the position of the grab or diver at the instant a sample was collected. Acoustic data of the type produced by the Trackpoint II system often contains anomalous range or direction readings. The program contains a graphical editing module to eliminate these anomalies before computing multi-beacon positions. The logged slant range, relative (horizontal) bearing and depth of the sampler are displayed as time series and smoothed lines are fitted through the measured points. Figure 23 is an example of a depth time series for a grab sample from about 50 seconds before to 50 seconds after the recorded time the grab struck the sea floor (58842 seconds after midnight). After anomalous readings have been removed, the vertical cursor is moved to the maximum depth, which corresponds to the instant the grab struck the sea floor. In this case, it appears that the grab actually struck the seafloor about 5 seconds before the time that was logged during the experiment. The program then computes and records the grab position based on the measured slant range, relative bearing and depth at the time corresponding to the cursor position. If, as sometimes happens, there is no actual Trackpoint fix at the instant the grab appeared to strike the sea floor, the position is calculated from smoothed curves passing through the available measured slant range, relative bearing and depth measurements.

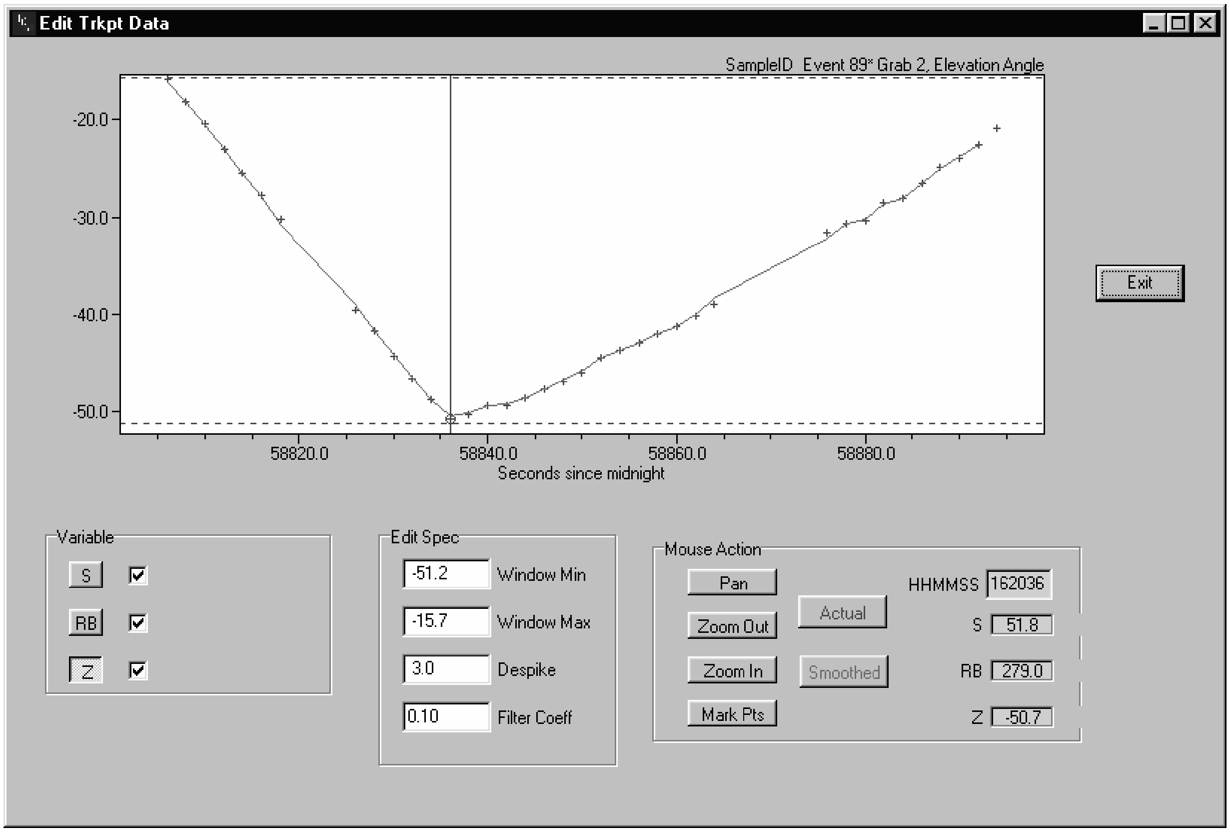


Figure 23. Trackpoint depth time series for a grab station. The vertical cursor is located at the instant the grab struck the seafloor.

Processing Survey Vehicle and Diver Track Data

AGCNAV and REGULUS can be used to compute and display the track of a survey vehicle or diver in the same way as they can display ship's track. However, this is not recommended as the process is slow and bad Trackpoint fixes sometimes render the result unusable. A better approach is to first edit the multi-beacon data set to remove errant readings before plotting the track. This can be accomplished by using the processing program TRKPT_EDT (see Appendix E). It sequentially displays segments of the slant range, relative bearing and depth time series. Individual values that fall outside user specified limits are automatically identified and flagged as bad fixes (Fig. 24). Using the mouse, the operator can reverse this decision if appropriate and also flag additional outliers that were missed by the automatic process. Once the slant range, relative bearing and depth values for the displayed time block have been edited, a smoothed version of each is computed then beacon positions are calculated and the results saved to an output file. To display the multi-beacon track, one could use the track plotter module of

TRKPT_EDT or use PROCNMEA to export the times and multi-beacon positions as decimal degrees to a comma delimited file then use a Geographic Information System (GIS) program such as ArcView or fGIS to plot the track. Alternately, APLOTWIN is capable of plotting the track directly from the output data file produced by TRKPT_EDT. Two underwater survey vehicle tracks created via TRKPT_EDT and overlaid on a multibeam image of a pockmark area are illustrated in Figure 20.

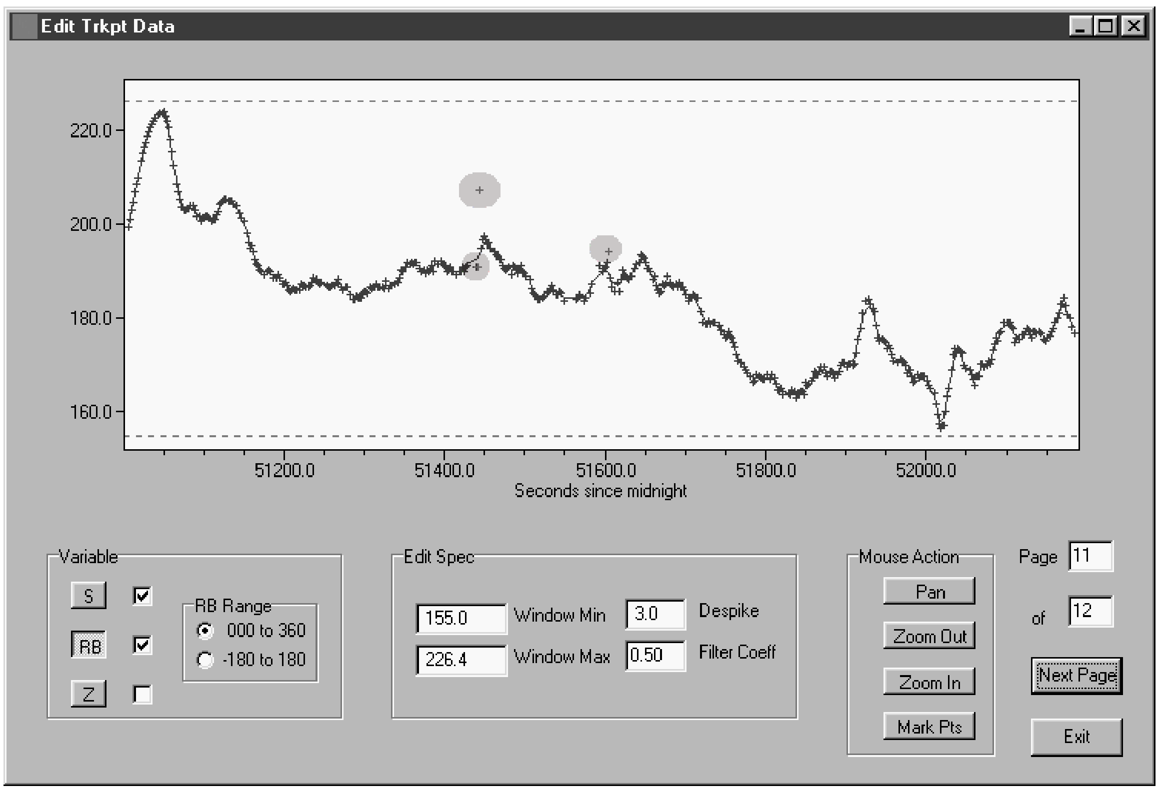


Figure 24. Example of Trackpoint slant range data being edited using TRKPT_EDT. The points marked with grey circles were automatically detected as outliers by the program.

Summary

The Grab Acoustic Positioning System (GAPS) was developed as part of a program to study the nature of pockmarks in Passamaquoddy Bay, Canada. It is an integrated system of hardware; software and methodology that has been created to provide benthic ecologists, geologists and engineers with accurate, real-time information about the location of grab and diver-held samplers and towed survey platforms. It enables users to predetermine a detailed sample transect across an area of interest and maneuver the sampler or diver to within a few metres of each target location before collecting the sample or to tow a survey platform along a pre-determined survey line.

The navigation equipment includes a differential Global Positioning System (dGPS) receiver, the ship's autopilot for heading information, and a Trackpoint II ultra-short baseline acoustic positioning system with an over-the-side transducer boom to position seafloor sampling devices and towed survey systems. Ship and survey or sampling equipment positions are recorded and displayed using navigation display and logging programs such as AGCNAV and REGULUS. The equipment is simple to mobilize and operate and does not adversely affect the functionality of the sampling devices and survey platforms it is used with.

The geographic position of the beacon and thus the actual location of the survey platform or collected sample is determined by combining the vessel’s geographic position from dGPS with its heading from the autopilot and the three-dimensional coordinates of the multi-beacon relative to the Trackpoint transducer on the support vessel. The combined effects of the following influence the accuracy of the position determination:

1. dGPS vessel position, accurate to about 3-4m;
2. Gyro or autopilot error, about 0.5^0;
3. Trackpoint slant range error, about 0.4m;
4. Trackpoint relative bearing error, about 0.9^0;
5. Multi-beacon depth, about 0.5%;
6. Geometry of the fix.

This final point requires further elaboration. If the multi-beacon is close to the hydrophone horizontally, the fix error is dominated by the slant range and depth errors. However, at horizontal distances much greater than the beacon depth, the error is dominated by the combined effect of the vessel heading and Trackpoint relative bearing errors. While the net effect does vary depending on various factors, the typical cumulative error when using the system described above at horizontal ranges of less than 200m and water depths of less than 100m is no greater than +/-5 to 7m (McKeown and Heffler, 1997).

Acknowledgement

The authors wish to express their appreciation to the officers and crews of *CCGS Pandalus III* and *CCGS J.L.Hart* for their outstanding seamanship and interest in the successful outcome of the fieldwork, to A. Duxfield, University of New Brunswick for repeatedly processing the multibeam data in an effort to maximize the effectiveness of the information and to colleagues at the Bedford Institute of Oceanography and St. Andrews Biological Station who have assisted in the successful outcome of this project .

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Appendix A: Trackpoint Operating Notes

Multi-beacon

The multi-beacons are powered by rechargeable Ni-Cad batteries which provide a working life of about 100 hours of continuous use when interrogated at the maximum rate of 2 sec. Beacons are turned on/off via an external shorting plug on the side. The battery will retain its charge for about 14 days at 10^0C. Recharging can be accomplished without opening the pressure case but the Teflon closure strip MUST be temporarily removed in case any venting from the cells occurs. Set the battery charger to 85 ma if charging one beacon and 170 ma if charging two simultaneously. Repeated shallow (partial) discharges of the battery will adversely affect its operating life. It is recommended that the battery be occasionally fully discharged to 10.0 volts by means of a 220-ohm, 1-watt resistor (see 4430B manual, page 3-3). A manganese-alkaline battery that extends the operating life to well beyond an entire cruise can replace the Ni-Cad one. The beacon should occasionally be disassembled and the O-ring cleaned and re-greased (see 4430B manual, page 3-4).

Hydrophone

Before connecting the cable, verify that the O-ring on the connector is in place and the mating surfaces are cleaned and greased.
DO NOT get any grease on the rubber surface of the hydrophone.
DO NOT exceed 6 knots with the hydrophone in the water.
DO NOT subject the rubber-covered transducer to any mechanical shock or abrasion.

Hydrophone Alignment

The Trackpoint II hydrophone measures the direction of the acoustic beacon with respect to its internal reference axis. This is converted to a geographical reference frame by adding to it the ship's heading. Therefore, each time the hydrophone is installed, its reference direction must be set as close as possible parallel to the ship's fore/aft axis and then a calibration process conducted to establish any offset that may then exist.

The most thorough calibration procedure is quite time consuming and requires two vessels but is the most accurate and is recommended. The Trackpoint system is mounted on vessel A in its normal working configuration. A is mounted on the bottom of a vertical pole immediately adjacent to the GPS antenna on vessel B so that it is about 2m below the water surface. Vessel B then circles vessel A at a distance of a few hundred metres while recording its dGPS position. Meanwhile, vessel A continuously tracks the geographic position of the beacon via the

Trackpoint system. From a comparison of the two sets of beacon positions, the hydrophone reference direction correction can be established.

A less accurate but quicker method of establishing the relative bearing correction can be done while the ship is alongside. However, it is prone to problems caused by reflections of the acoustic signals from the nearby seafloor and pier structure. An acoustic beacon is lowered to a convenient depth on a weighted line from one or more points around the vessel at known directions relative to the hydrophone. At each location, about five minutes of relative bearing measurements are recorded. While it is possible to use AGCNAV or REGULUS to log the data, it is more convenient to use a communications program such as HYPERTERM. Each of these data sets is edited to remove outliers usually caused by reflections from nearby structures. The mean of each edited relative bearing data set is computed and compared to the actual relative bearing that should have been observed according to the physical geometry. An even quicker and adequate procedure of high accuracy is not required is to make the measurement at one site only along the reference axis of the hydrophone. If the measured vs. actual relative bearing difference(s) is (are) not zero, either the reference direction of the hydrophone boom is adjusted accordingly and the process repeated until agreement is achieved or the mean offset is noted and used subsequently when post-processing the acoustic positioning data.

Command/Display Module Menu Structure

The Command/Display Module menu structure is unfortunately not entirely intuitive and is sometimes frustrating to use. For example, entering a setup parameter often causes the system to jump back to the base menu rather than one level up thus requiring repeated entries of a sequence of steps to enter closely related settings.

Display Menu
- Modify the appearance of the screen
- Display summaries of various system configuration settings such as “All Targets”

System Menu
- Adjust the internal clock
- Change RS-232 communication parameters

Target Menu
- Select a beacon
- Set up the operating parameters associated with a particular beacon such as tracking On/Off and Depth

Filtering Menu
- Setup Filtering, Smoothing and Threshold parameters

Self-Test Menu

- Run self-tests on the Command/Display Module and hydrophone

Start-Up

When turning the Command/Display Module on ALWAYS select "Previous Setup", i.e., press F1.

The internal clock drifts rapidly but this is of no consequence because all of the processing procedures described in this report ignore it and use the GPS clock time.

It is recommended that all geometric offsets in the Command/Display Module be set to zero so that the logged values of relative bearing, slant range and depth produced are unadulterated.

Very important. Set the Command/Display Module to the "Calculated Depth" mode via menu path "TARGET/REPLY DATA/DEPTH/MODE". This is the most versatile operating mode. If the Command/Display Module is not set in this mode, it may not be possible to establish beacon depth and thus position during post-processing. When the Command/Display Module is operating in this mode, the output data string contains all the information necessary to reproduce any of the other horizontal range determinations one may wish to make because it contains:

- Measured RB and Slant Range
- Manual Z (depth) as keyed in by the user
- X (athwart ships) and Y (fore-aft) coordinates of the beacon position as determined from the depression angle.

Check the system setup via menu path DISPLAY/CONFIGURATION/SYSTEM. If it does not conform to the following, change as required:

- Via menu path "SYSTEM/XMIT CONTROL", set
    - Xmit & Key On
    - Internal Key
- Via menu path "SYSTEM/HYD OFFSETS", set
    - all offsets to "0.0"
    - VRU orientation to "Normal"
- Via menu path "SYSTEM/TIME/DATE" set the date. The Trackpoint Command/Display Module clock has a high drift rate so it isn't worth setting it until the system is about to be used to generate positions
- Via menu path "SYSTEM/ACOUSTIC DATA" set
    - Temp Auto
    - Speed of sound 1500
    - Salinity 35 ppt

- Via menu path “SYSTEM/MORE/HARDWARE/RS-232”, set RS-232 communication parameters to
  - 4800 baud, 8 bit, 1 stop (9600 baud on *CCGS Hudson*)
  - Interval = 1
  - ON
- Via menu path “SYSTEM/MORE/RS-232 UNITS”, set RS-232 units to metres
- Via menu path “SYSTEM/MORE/RS-232 FORMAT”, set RS-232 output format to “STD-EC W/PR”

  NOTE: It is very important that this setting be used otherwise valid fixes may not be recorded. For example, this would occur when the beacon depth has been set to the Manual mode and the entered depth exceeds the actual measured slant range.
- Via menu path “DISPLAY/CONFIGURATION/ALL TARGETS” review the setup for each beacon being used and change if necessary by first selecting the beacon via menu path “TARGET/CHOICE” then:
  - “TARGET/REPLY DATA” to change beacon type and receive frequency
  - “TARGET/TRACKING” to turn tracking Off
  - “TARGET/INTERROGATE DATA” to change interrogation interval or frequency
  - “FILTERING/THRESHOLD” to change threshold to Low
- Via menu paths “FILTERING/SMOOTHING” and “FILTERING/FILTER LEVEL” set smoothing and filter levels for all targets to Off
- Select beacon(s) to be tracked via menu path “TARGET/CHOICE” then “TARGET/TRACKING”

Command/Display Module Operation

Each time the Command/Display Module transmits an interrogation, the green LED’s in the lower left corner of the screen will flash. When a beacon replies, the red LED’s in the upper left corner of the screen will flash. An audible tone is also generated each time a response is received.

If more than one beacon is being tracked, the Command/Display Module will interrogate each sequentially.

If responses are erratic:

- Raise receiver threshold level:
  - Select the beacon via menu path “TARGET/CHOICE”
  - Set “FILTER/THRESHOLD” level
- Set slant range gate to slightly less than the expected slant range via “TARGET/REPLY DATA/TYPE/MIN/XPNDR RANGE”

- Try a different receiver channel. A quick way to determine quiet channels is as follows:
    - Switch Interrogation off
    - Select beacon frequency (such as 22 kHz)
    - Set Min Range to 10 m
    - Set Depth to 1 m
    - Set Filter/Smoothing/Threshold to Off/Low/Low
    - Turn Tracking ON
    - Observe red LED’s at the upper left corner of the Trackpoint display screen and listen to the audio signal.

Appendix B: Operating AGCNAV

Prepare the Waypoint or Target Position File

If the target positions exist as a comma delimited text file, convert them to AGCNAV format via program WAYPOINT (see Appendix E). If no such file exists then use WAYPOINT to create a properly formatted AGCNAV waypoint file. Once the file has been created, load it into AGCNAV as follows:

1. Run AGCNAV.
2. Click on "WAYPOINTS/CLEAR ALL" and then "Yes" to clear the previous waypoints out of the program.
3. Load the waypoint file.

Operating Notes

Unlimited PC's can operate independently and share the same incoming data. DFO owns the rights to simultaneously operate unlimited copies of AGCNAV.

Before starting AGCNAV, set the computer system clock's day and time to GMT. This is important as the program gets its "day" information from the computer clock.

When the display is zoomed in to the point where the ship icon switches to a transparent outline, its dimensions are shown at the chart scale.

When the program loads, it will read in the file AGCNAV.INI that tells it how the system was configured when it was last used. The manual describes in detail how to make changes to this setup. If significant changes are made to the setup these are automatically entered into AGCNAV.INI and immediately saved to disc. It is also a good practice to save a reasonably current copy of this AGCNAV.INI as BACKUP.INI. If the former gets corrupted in some way, it is then a simple matter to exit the program, delete AGCNAV.INI and create a new one by making a copy of BACKUP.INI named AGCNAV.INI then restarting the program. The most common sign that this needs to be done is when the program starts up displaying the latitude and longitude grid centred on the earth's equator at the zero meridians.

Once the program loads, the user should verify that it is receiving serial navigation data via menu paths:

- "NAV SOURCE/SERIAL PORT SOURCE"
- "NAV SOURCE/VIEW RAW NAVIGATION"

If the screen does not fill with scrolling NMEA data strings, check that the computer serial ports are set up correctly via "SETUP/COM PORTS" and that serial data is in fact being supplied to the computer.

Next, by following menu path "SETUP/BROADCASTER SETUP", verify that the Broadcast feature is turned off. If it is unintentionally turned on and other AGCNAV computers are connected to the same serial navigation source, very odd things will happen.

The space bar switches between the graphics display and the menu screens.

The GRAPHICS menu allows the user to change units from nautical to metric, turn screen items on/off, etc.

Always save the waypoint file periodically if it contains fixes.

Always check that logging is turned on and correct strings are being logged at desired intervals.

Logged data can be re-played via "NAVSOURCE/FILE SOURCE"

A useful trick to remember is that the FLAG data line on the graphics screen can be used to display information such as sounder depth by selecting FLAG in the setup procedure, specifying the NMEA string of interest then identify the field to be displayed opposite the FLAG caption.

The manual contains excellent descriptions of all other operating procedures. It was produced in WordPerfect. If it is accessed electronically via WORD many of the captured computer screen images will be corrupted so the manual must then be used in conjunction with an actual running version of AGCNAV.

On screen help is available via the "H" key that generates the information shown in Figure A1.

```
                          AGCNAV Graphic Hot Keys

 Panning (Screen Movement)              Other Keys

 ↑   * Move screen up                   H        Display this help information
 ↓   * Move screen down                 I        Display AGCNAV information
 ←   * Move screen left                 <space>  Return to pull down menus
 →   * Move screen right                M        Switch between chart, bullseye
                                                 and line running modes
                                        C        Clear all tracks
 Centering Screen                       G        Graphic Display Options
                                        F        Create new waypoint fix at
 Home* Centre screen on active waypoint ship's latest position
 End * Centre screen on ship position   B        Broadcast messages
                                        W        Waypoint editor
                                        S        Survey Line editor
                                        +        Make next waypoint or
                                                 survey line the active one
 Zooming (Changing Scale)               -        Make previous waypoint or
                                                 survey line the active one
 PgUp   Larger scale                    F1-F6    Track Fish 1, 2, 3, 4, 5, 6 in
 PgDn   Smaller scale                            Survey Line Mode
                                        F10      Track Ship in Survey Line Mode
 * Chart & Bullseye modes only          Alt-X    Exit AGCNAV

 Press any key to return to graphic screen
```

Figure A1. AGCNAV help screen.

Reference Position

By default AGCNAV displays the centre of the ship icon at the dGPS position of the ship. The measured position of the acoustic multi-beacon beacon described by Trackpoint system is relative to the hydrophone. Therefore, one must allow for the offset between the dGPS antenna and the hydrophone in order to display the actual geographic position of beacon correctly relative to the ship icon. Table B1 lists geometries for some DFO vessels. Normal practice is to select a reference point on the ship that is meaningful operationally then describe the position of the GPS antenna and Trackpoint transducer relative to it. For example, one might chose as reference position outboard end of the crane supporting the bottom sampler.

NOTE:

The GPS antenna and Trackpoint hydrophone offsets relative to a common reference point on the vessel must be entered with opposite signs, that is:

- GPS antenna offsets are entered as starboard and forward negative;
- Trackpoint hydrophone offsets are entered as starboard, forward and down positive.

Table B1. GPS and Trackpoint Hydrophone Offsets With Respect to the GPS Antenna

Ship	Hydrophone		
	Fore/Aft	**Athwartship**	**Depth**
CCGS Pandalus III	-3.1	+2.7m	+2.0m
CCGS J.L.Hart	-1.8	+2.5	3.0
CCGS Hudson	-25.0	-2.9	6.0

Trouble Shooting AGCNAV

Program Starts Up with Bizarre Settings

If all the settings seem bizarre or problems setting AGCNAV up are encountered, proceed as follows:

1. Turn off AGCNAV.
2. Delete file “AGCNAV.INI”.
3. Make a copy of file “BACKUP.INI”.
4. Change the name of this copy to “AGCNAV.INI”.
5. In Explorer highlight this file then, via “File/Properties”, remove the tick mark beside “Read Only” if necessary.
6. Restart AGCNAV.

Latitudes and Longitudes Not Updating

1. Go to the menu screen by pressing the “space” bar then select menu items “NAVSOURCE/VIEW RAW NAVIGATION”. You should see lines of data scrolling up the screen. The dGPS data lines start with the code $GP….
2. If these lines are not present, reset the serial port by selecting menu items “NAVSOURCE/SERIAL PORT SOURCE” then return to step 1 to determine whether or not data is now getting into the computer.
3. If there is still no navigation data appearing on the screen, verify that the communication parameters are correctly set.
   a) Select menu items “SETUP/COM PORTS/SERIAL PORT 1”
   b) Verify that it is set to or reset it to

Baud Rate	4800
Parity	None
Data Bits	8
Stop Bits	1

   c) Return to step 1 to determine whether or not data is now getting into the computer
4. If the NMEA navigation data lines are present but the time, latitude and/or longitude are still not updating, the setup may be wrong. Press the space bar to change to the main menu screen then select menu items “SETUP/SHIP” display fields and set-up time, lat, long, COG, SOG, Flag by parsing the data line $GPGGA and $GPVTG correctly.

5. If there is still no data, check that the cable from the dGPS receiver to the MUX or from the navigation multiplexer to the PC has not been dislodged somehow.

Gyro and/or Autopilot and/or Log Not Updating

1. Go to the menu screen by pressing the "space" bar then select menu items "NAVSOURCE/VIEW RAW NAVIGATION". You should see lines of data scrolling up the screen. The gyro data lines start with the code $HE…., autopilot codes with $AG.. and speed Log codes with $V…
2. If these lines are not present, reset the serial port by selecting menu items "NAVSOURCE/SERIAL PORT SOURCE" then return to step 1 to determine whether or not data is now getting into the computer.
3. If there is still no navigation data appearing on the screen, verify that the communication parameters are correctly set.
   a) Select menu items "SETUP/COM PORTS/SERIAL PORT 1"
   b) Verify that it is set to or reset it to

Baud Rate	4800
Parity	None
Data Bits	8
Stop Bits	1

   c) Return to step 1 to determine whether or not data is now getting into the computer
4. If the NMEA navigation data lines are present but the heading and/or speed are still not updating, the setup may be wrong. Press the space bar to change to the main menu screen then select menu items "SETUP/SHIP" display fields and setup heading and Log by parsing the appropriate data lines correctly.
5. If there is still no data, check that the cable from the gyro or autopilot or speed log to the MUX or from the navigation multiplexer to the PC has not been dislodged somehow.

Wrong Day Number

The Julian day number is derived from the operating system clock inside the computer, not the dGPS data. If the displayed day number is wrong, the system clock within the computer must be reset.

Trackpoint Fix – Odd Behaviour

Sometimes AGCNAV will display the beacon as being located directly under the ship for some time after the beacon enters the water then, as it is lowered toward the sea floor, the fish icon will jump out to a position some distance from the ship. This behavior has a simple explanation. When the measured slant range from ship to beacon is less than the beacon depth being sent to AGCNAV by the Trackpoint receiver, the program is unable to compute a valid beacon position so it sets this equal to the ship position.

Appendix C: Operating REGULUS

Verify Incoming NMEA Data Strings

Check that serial navigation data is being received via menu path "MAIN/COMMUNICATIONS/VIEW INPUT", try configuring COM port via CONFIGURE PORTS button. The following data strings are required for Info Boxes to be fully functional. The first three are essential. If the others are not available, some display features will not operate.

Vessel lat/Lng	GGA
Heading	HDT
Date/Time	ZDA
Datum	DTM
Depth	DBK or DBT
COG/SOG	VTG
Log	VHW

Synchronize PC Clock

Access the synchronization feature via menu path "MAIN/CONFIGURE - TIME". It is recommend that the synchronization period be set to 5 minutes.

Units

The display units are set via menu path "MAIN/CONFIGURE - UNITS".

Ship Configuration

Via menu path "MAIN/CONFIGURE - VESSEL" set up the correct vessel size, shape, name, conning position, GPS antenna position, and Trackpoint hydrophone position.
Set the reference or conning position as desired.
Select an appropriate vessel icon.

> Note: On *CCGS Hudson*, ship icon will briefly switch to north every 18 seconds. This is caused by the presence of 0.00 in the heading field of the VHW speed log string. This field needs to be blank to eliminate the problem.

Date/Time

If the graphic display is to show UTC time, the program must be setup to use the $GPZDA string. Otherwise it will display the internal PC clock system time.

When creating Events, REGULUS tags them with date and time. The time will be UTC if the program is set as above but the date is derived from the system clock. Therefore, one must set the computer operating system time zone to GMT to make the date appear correct near midnight. This is done via the Windows path "START/CONTROL PANEL/DATE AND TIME". When doing so, make sure that the "Automatically adjust to daylight saving time" box is not ticked.

Main Menu Defaults

Active leg red
Inactive leg light blue
Inactive route yellow
End of leg detection – "End of Line Perpendicular"

Length of Past Ship's Track

Set this via menu path "Window\Overlays\Track"

Routes

There appears to be a "bug" in the program with respect to the Routes function. If the actual vessel position is closest to end of a specified route when it is made active (not uncommon in scientific operations but rare in commercial world), the ship will identify the end of the route as its planned starting point. The solution is to put a false start of line nearer the current ship position and connect this to true start of line as the first leg in route.

Markers and Events (Fixes)

Markers and Events are basically the same thing. Events correspond to AGCNAV fixes in that they can be created by clicking on the EVENT in menu at the top of screen.

Opening a window via path "NAV ELEMENTS/MARKER/NEW MARKER" and entering a latitude and longitude create markers.

Both will be annotated with UTC date/time of creation.

If they clutter up the screen, individual labels can be turned off and symbols hidden.

Markers and Events can be viewed, edited, deleted, hidden etc. by placing the mouse cursor over the symbol and right clicking.

To export Markers and Events, select menu path “NAV ELEMENTS/NAV MANAGER” then highlight all to be exported then save to a comma delimited file. Figure C1 is an example of such a file.

```
Marker,Event 2,43.810732877287,-60.733343484217,6,32767,Generated at UTC
2000.06.13 14:09:27,10000,75.000000000000,135.000000000000,1,
Marker,Event 3,43.810790266604,-60.732974077514,6,32767,Generated at UTC
2000.06.13 14:12:23,10000,75.000000000000,135.000000000000,1,
Marker,Event 4,43.810813333265,-60.732960286235,6,32767,Generated at UTC
2000.06.13 14:12:36,10000,75.000000000000,135.000000000000,1,
```

Figure C1. Example of a REGULUS Marker/Event file

Point of Interest

Place cursor at point of interest.
Right click.
Identify cursor location as “Point of Interest”.
This activates “Point of Interest” box.

Waypoints

<u>WP Management</u>
REGULUS maintains waypoints in an ACCESS database table in the database. MAIN_DB.MDB. Waypoints can be tagged to Hide or Show or Export them via menu path “ROUTE/WAYPOINT LIBRARY”.

<u>Entering WP’s Manually</u>
Select menu path “ROUTE/WAYPOINT LIBRARY”.
Click on NEW button.
Enter Name, Latitude and Longitude.
Click APPLY button.

<u>Editing a Waypoint</u>
Unload any Route that uses the waypoint of interest.
Right click on it in the Chart Window or enter the Waypoint Library and select the waypoint to be changed.
Edit it in the box at the top of the Waypoint Library window.
Click on SAVE button.

Re-load the Route(s).

Importing AGCNAV WP Files Into REGULUS

<u>Method A</u>

Convert the AGCNAV waypoint file to REGULUS format using program WAYPOINT. Filename of converted file must have CSV extension.

In REGULUS activate menu path "ROUTE/WAYPOINT LIBRARY" then click on "Import" and open file.

<u>Method B</u>

Load the AGCANV.WP file into EXCEL via "Delimited" then click on "Comma" and "Space".

Delete first three lines plus lines at end from "Survey" to "EOF"

Insert a blank column before the WP label and fill each row in this column with the text string "Waypoint". Note that upper and lower case as shown are essential.

After the Longitude column add columns filled as follows:

150
225
1
AGCNAV

Copy last row into next row, i.e., make it appear twice. If this is not done, the last correct WP is not entered into the library.

Save as a CSV file

Import via "ROUTE/WAYPOINT LIBRARY" and click on IMPORT button.

Exporting Waypoints to a File

To export waypoints, tag (highlight) all to be exported then save to a CSV file. Figure C2 is an example of such a file. If there are a large number of waypoints to export, it may be more efficient to load the REGULUS file MAIN.DB into ACCESS then export to a comma-delimited text via that program.

```
Waypoint,Panuke,43.811167,-60.733383,150.000000,225.000000,1,Generated at UTC 2000.06.13 11:46:38
Waypoint,Cohasset,43.849167,-60.627767,150.000000,225.000000,1,Generated at UTC 2000.06.13 11:45:57
Waypoint,PS1,43.808917,-60.733383,150.000000,225.000000,1,Generated at UTC 2000.06.13 11:45:21
Waypoint,PN1,43.813417,-60.733383,150.000000,225.000000,1,Generated at UTC 2000.06.13 11:44:14
```

Figure C2. Example of REGULUS waypoints exported to a comma delimited text file.

Using REGULUS to Plan a Field Operation

Set Up Display

Switch Chart Window to planning mode.
Select chart of interest then pan and zoom as required.

Create Waypoint List

Select "ROUTE/WAYPOINT LIBRARY".
Create new waypoints by:

a) Click on NEW button.
b) Either enter latitude and longitude or move "inward arrow cursor" to required location and click.
c) Edit waypoint name.
d) Left click on APPLY button.

NOTE. Must do this in DDMMSS units. If DDMM.MM units are used, a bug in the program causes minutes to be rounded to the nearest whole minute. However, they can be listed in DDMM.MM format once the waypoint list is prepared.

Route Planning

Use "ROUTE MANAGER"
To create a route, select menu "ROUTE/ROUTE MANAGER/CREATE" then either create the route directly on the chart via mouse clicks using the cross hair cursor and/or select waypoints from library.

If mouse clicks method is used, marked points do not become real waypoints until their name is changed and APPLY is clicked. Until then they are ephemeral route markers. While they remain as route markers, one cannot do much of anything with them.

Export a route via menu path "ROUTE/ROUTE MANAGER/LOAD/EXPORT".

Order of waypoints in a route can be reorganized or one or more deleted via path "ROUTE MANAGER/SELECT ROUTE/REORDER".

Survey Planning

There is nothing in the HELP file about how to do this but the process is intuitive.

Moving REGULUS Waypoints and Routes to Another PC

To move waypoints and routes from one REGULUS PC to another

a) Move waypoints first
   - Menu "ROUTE/WAYPOINT LIBRARY".
   - Click on Name header to sort by name.
   - Click on first waypoint and click/Shift on last and/or Ctrl/Click on individuals.
   - Click on "Export".

b) Move route(s) next.
   - Menu "ROUTE MANAGER/LOAD" to bring up "Route Load" window.
   - Highlight route to be exported then click "Export" or click on "Import" to get the exported route from the floppy.

Converting Geo-Referenced TIFF to MRE (e.g. Multibeam image)

In order to use geo-referenced TIFF files such as multibeam images on older versions of REGULUS, the image format must first be converted to a format known as MRE. To do this one requires:

a. Geo-referenced TIFF image in Mercator projection. UTM will do if accuracy of about 10m acceptable. Otherwise, must convert UTM bitmap to Mercator bitmap via utility program UTM2LL.
b. Latitude and Longitude of upper left corner of the image, i.e., if image is UTM must convert this to degrees.
c. Image format conversion program such as THUMBSPLUS (available from www.cerious.com/index.html)
d. UTM to Lat/Long conversion program UTM2LL (see Appendix E)

The process is as follows:

1. Convert TIFF image to BMP format via THUMBSPLUS
2. Convert UTM BMP file to Lat/Lng via UTM2LL
   - Enter Easting, Northing and Zone UTM coordinates of northwest corner delimited by spaces (e.g. 792735 4897780 20)
   - Click in grey area of box. Latitude and longitude of this corner should appear to right of entry
   - Enter desired easting (dx) and northing (dy) metres/pixel as integer values in cm/pixel with space between (e.g. 728 736)
   - Border is blank space around edge that leaves room for UTM image to rotate (e.g. 50)

Enter easting and northing metres/pixel for TIFF image as real numbers with space delimiter (e.g. 7.28 7.36)

Open BMP file

UTM image will appear in UTM window

Start conversion process via menu "FILE/START CONVERT".

When conversion compete, save resulting image. This is a BMP file at this point.

Text that appears at bottom of window will be saved to same file name but with extension TXT.

3. Open the TXT file, delete all text down to the line starting NA= then save it

NA=Image name, up to 80 char including white spaces

ID=Image identifier, up to 16 char, no white spaces

4. Convert BMP file to TIF via THUMBSPLUS

Open the BMP file of step 2

Save it as a TIF file using the suggested default settings

5. Convert TIF to MRE via CONVERTER (ICAN supplies this utility with REGULUS)

Tag the file of step 4 in left window

Identify the MRE directory in the right window

Click on button >>

Loading BSB and MRE Files on a REGULUS System

If new BSB, geo-referenced TIFF or MRE files are loaded while REGULUS is running, REGULUS must be turned off then on again to update program's knowledge of what charts are available.

When setting paths to charts one must first click on BSB or MRE button to indicate the type of charts stored in the specified path before updating the list of paths. In other words, separate lists of paths are maintained for each of the chart types. REGULUS won't be able to find an MRE chart if its path is listed in the BSB path list. Also it appears as though REGULUS will crash if one specifies sub-directories in the BSB chart path even though they exist. Somehow program searches and finds charts in sub-directories of directory specified.

Appendix D. Multi-beacon Protective Housing

Designed by:

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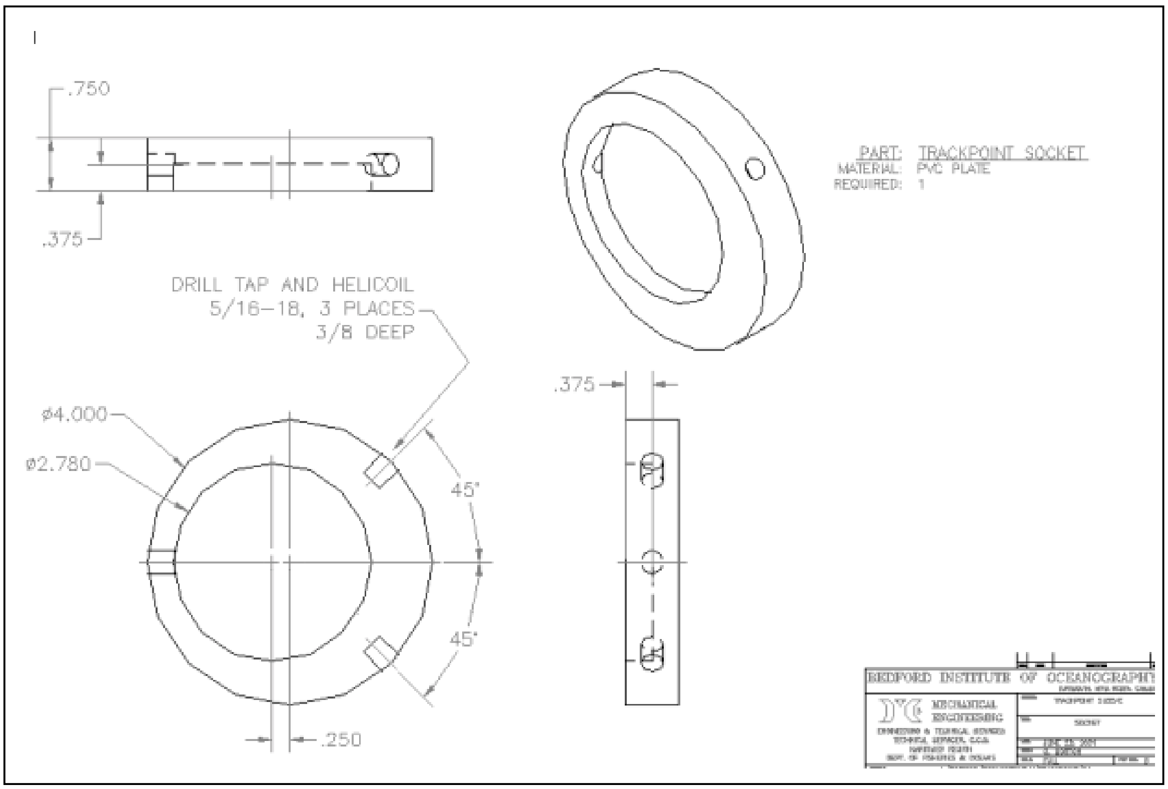
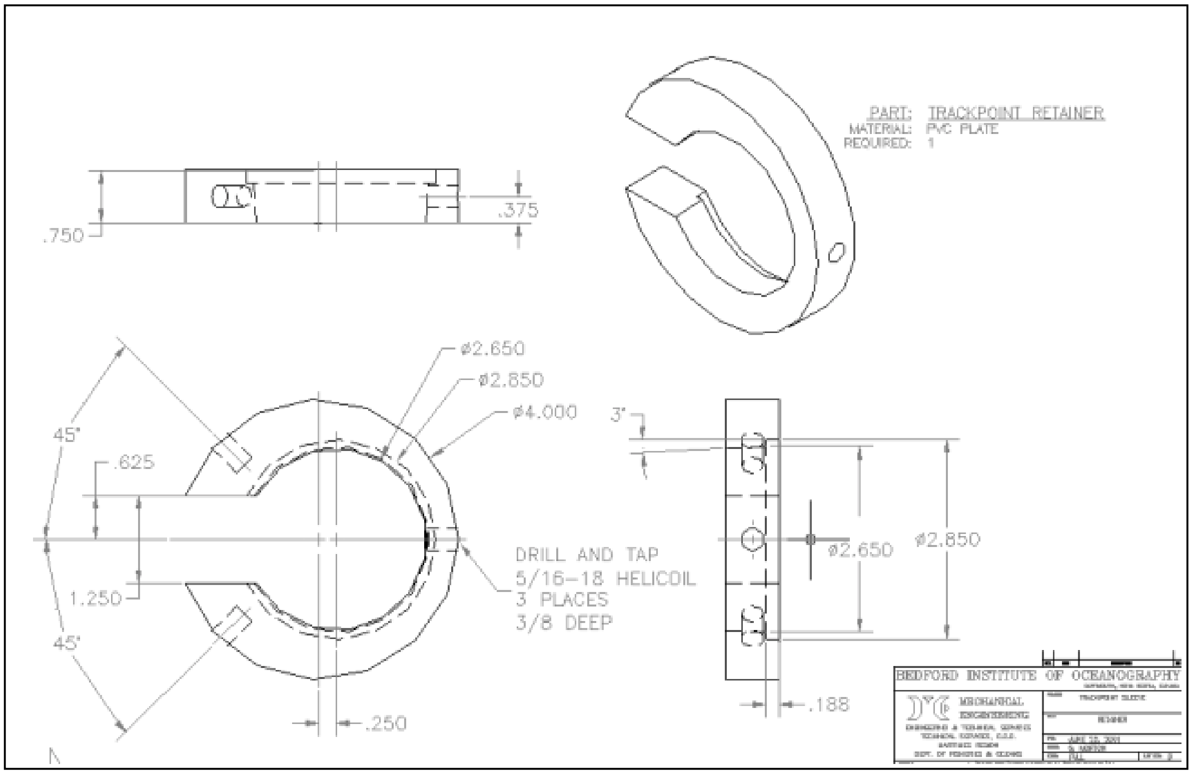
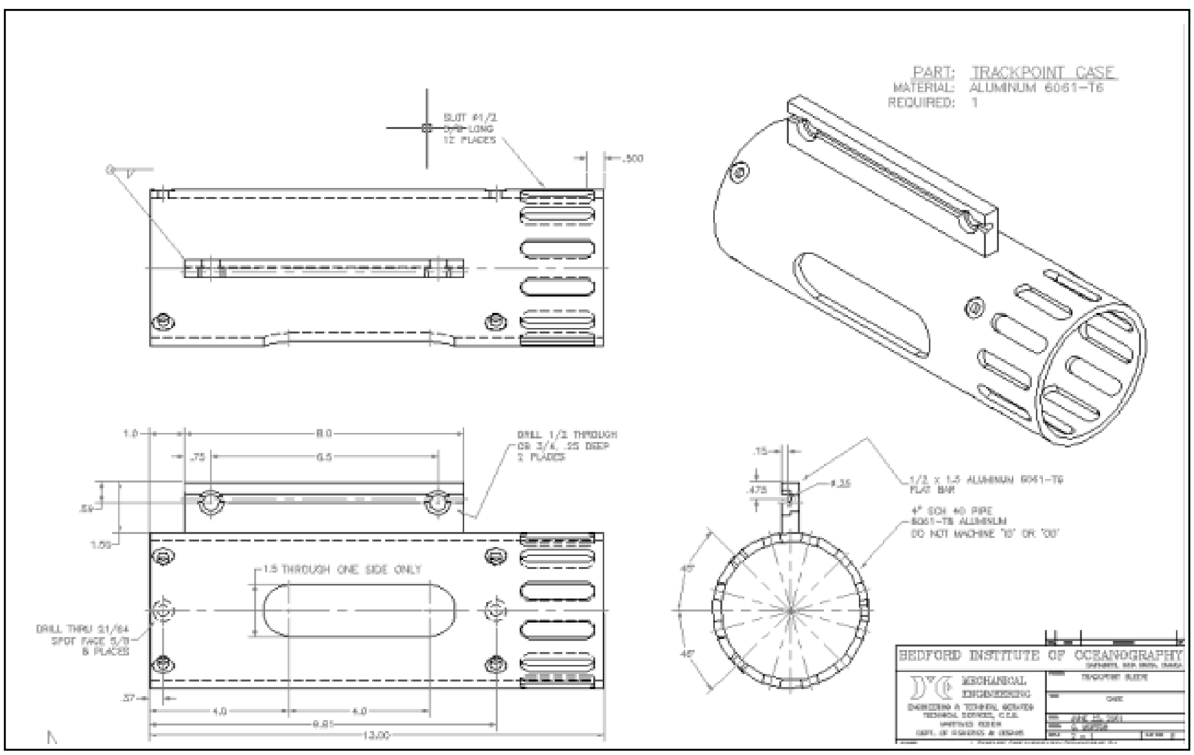
B2Y 4A2




PART: TRACKPOINT RETAINER
MATERIAL: PVC PLATE
REQUIRED: 1
.750
.375
⌀2.650
⌀2.850
⌀4.000
45°
.625
1.250
45°
DRILL AND TAP
5/16–18 HELICOIL
3 PLACES
3/8 DEEP
3°
⌀2.650
⌀2.850
.188
.250
BEDFORD INSTITUTE OF OCEANOGRAPHY
MECHANICAL
ENGINEERING


PART: TRACKPOINT CASE
MATERIAL: ALUMINUM 6061–T6
REQUIRED: 1
.500
1.0
8.0
.75
6.5
DRILL 1/2 THROUGH
1.5 THROUGH ONE SIDE ONLY
4.0
4.0
13.00
1/2 X 1.5 ALUMINUM 6061–T6
FLAT BAR
4" SCH 40 PIPE
6061–T6 ALUMINUM
DO NOT MACHINE 'ID' OR 'OD'
45°
45°
BEDFORD INSTITUTE OF OCEANOGRAPHY
MECHANICAL
ENGINEERING

Appendix E. Data Processing Programs

The following programs are available from:

D.L. McKeown
Ocean Sciences Division
Bedford Institute of Oceanography
1 Challenger Drive
Dartmouth, Nova Scotia, B2Y 4A2
Canada

Data Manager
Ecosystem Research Division
Bedford Institute of Oceanography
1 Challenger Drive
Dartmouth, Nova Scotia, B2Y 4A2
Canada

APLOTWIN

This program plots fixes contained in text files prepared in a number of different formats:

Comma delimited
  Accepts positions in any one of the following position formats
  DDD.dddd e.g. 63.5674
  DDMM.mmmm e.g. 6334.0440
  DD, MM.mmmm e.g. 63, 34.0440
  DD, MM, SS.ss e.g. 63, 34, 2.64
$GPGGA data strings
A-type, that is, fixed format day-time and decimal latitude and longitude
$POREM data strings – either ship or beacon positions can be plotted

The resulting track plot can be printed and/or saved as a BMP file.

NMEA_TESTER

Monitors real-time NMEA data streams and periodically reports on

- Which NMEA ID codes are present
- Whether or not Trackpoint Std EC w/pr formatted lines are present
- Number of occurrences of each
- Repetition rate of each

Continuously plots slant range, relative bearing and beacon depth time series of real-time Trackpoint data in either "StdEC w/pr" or "$POREB" format.

Examines a logged NMEA data file to establish:

- Which NMEA ID codes are present
- Whether or not Trackpoint Std EC w/pr formatted lines are present
- Number of occurrences of each
- Repetition rate of each

Creates a time series plot of all Trackpoint slant range, relative bearing and depth records contained in a logged data file. The Trackpoint data can be in either "$POREB" or "Std EC w/pr" or "$POREM" format.

Simulates the serial output of a number of different NMEA navigation devices including a Trackpoint system for testing other programs or NMEA equipment. This data is created:

- By synthesizing typical NMEA data records
- By playing back an actual logged data file

PROCNMEA

This program

- Converts navigation data from one format to another as indicated in Table E1
- Calculates Trackpoint beacon positions using the following multi-beacon depth options.
    - Constant Depth - User enters a constant beacon depth below the surface.
    - Logged Trackpoint Depth - Depth logged as part of the Trackpoint data. It is assumed that this depth is the depth of the beacon beneath the surface NOT beneath the Trackpoint hydrophone.
    - Telemetered Depth - Depth of beacon derived from telemetering transponder.
    - Calculated Depth - Depth logged as part of Trackpoint data string with Trackpoint Command/Display Module in “Calculated Depth” mode.
    - Sounder Depth - Bottom depth logged from ships echo sounder is used. It is assumed that this is the depth below the ships transducer. The user must enter a draft correction.

Table E1. PROCNMEA Input and Output File Formats

	Output Format									
	Logged All	Logged Selected	POREM	Cruise Track	Ship CSV	Ship Fixed	Trkpt CSV	Trkpt Fixed	Bathy CSV	Bathy Fixed
Input Format										
Logged	X	X	X	X	X	X			X	X
POREM			X		X	X	X	X	X	X
Ship CSV					X	X				
Ship Fixed					X	X				
Trkpt CSV							X	X		
Trkpt Fixed							X	X		
Bathy CSV									X	X
Bathy Fixed									X	X

SAMPLER_POSN

This program is used to compute the exact position of a bottom sample from logged ship position and Trackpoint data.

The user first specifies the time of a bottom sampler fix for which a position is required. The entry mode of this fix information may be:

- Keyboard entry
- An AGCNAV waypoint file
- A REGULUS fix file
- A comma delimited file containing information about the fix.

The user graphically edits out bad Trackpoint fixes if necessary and identifies the exact instant that the sample was taken. The program then computes the position of the bottom sampler from the logged navigation data and writes the result to an output file.

TRKPT_EDT

This program edits and computes Trackpoint positions from input data files in the $POREM format using any one of the following beacon depth sources:

- Constant depth entered from keyboard
- Depth logged by Trackpoint receiver
- Depth from telemetering beacon
- "Calculated Depth" as measured by Trackpoint receiver

- Echo sounder depth
- Campod pressure sensor
- Towcam pressure sensor
- Time/depth comma delimited data file

The program has three distinct functional parts

1. Edit and compute beacon positions as latitude and longitude in DDDMM.mmmm format
2. Reformat beacon positions into decimal degrees and UTM coordinates
3. Plot beacon positions and depth time series

UTM2LL

This program converts geo-referenced bitmapped (BMP) images in UTM coordinates to bitmapped images in Mercator latitude/longitude coordinates.

WAYPOINT

This program performs the following functions:

- Creates a waypoint file in any one of the following formats:
  Comma delimited decimal degrees - e.g. GIS, Fugawi, etc. formats
  REGULUS
  AGCNAV
  OceanVision
- Loads and edits existing waypoint files in the above formats
- Plots the waypoints and adds and deletes them graphically
- Saves the waypoint file in any one of the above formats

WINFLTRNMEA

This program:

- Reads NMEA data from a serial port
- Exports a user specified subset of the incoming data on the same or different serial port or saves them to a data file
- Creates Trackpoint $POREB strings from "Std EC w p/r" strings
- Simulates a navigation data source by reading data from a file and outputting it on a serial port.