In-situ Underway Sound Velocity Profiling for Calibration of Multibeam Sounders Using a Moving Vessel Profiler (MVP)

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The Canadian Hydrographic Service (CHS), as with many other organisations involved in ocean based research, is faced with the requirement to collect water column data profiles for a variety of reasons. The CHS's specific need is the collection of sound velocity profiles for the day-to-day measurement of the changing water column while operating multi-beam sounders. Increasing pressures to improve the economic efficiency of survey operations and the quality of the data collected have led to the development of a family of tools to collect near vertical water column profiles from a moving vessel. These systems consist of a computer controlled hydraulic (or electric) winch, overboarding system and free fall fish capable of carrying a variety of instrumentation.

The MVP is capable of collecting profiles at ship speeds up to 12 knots and includes two modes of operation, a repetitive mode with adjustable time delay between casts or manually initiated mode. The control system includes bottom avoidance and real time feedback of free fall fish depth.

Although the CHS's primary need was for Sound Velocity (SV) profiling, other payload capabilities that have been developed for the fish include instrumentation such as CTD, Fluorometer and a prototype Laser Optical Plankton Counter (LOPC). Once deployed in the towed position, operations can continue without staff on deck. In the case of SV data, the profile is presented to the operator in real time for immediate visualisation, editing and subsequent upload to the multibeam sounder; data is also logged in a user defined directory.

Examples of data collected during recent operations on the Scotian Shelf with several systems are presented for both CTD and sound velocity profiles. The general system design, specifications and cruise results of the sea trials are presented. Methods of improving data quality and survey economics are discussed through operational examples.

***Figure 1**: Moving Vessel Profiler Family*

MVP Family - System Description

The MVP is operated under computer control by the system controller that allows the free-fall fish to drop from the moving vessel with the winch in free-wheel mode. Upon reaching the bottom of the cast the brake is applied and the free-fall fish is stopped and immediately becomes a towed body. This braking action causes the fish to ascend through the water column as it follows the path of the cable catenary. The fish is recovered to the towed position aft (distance aft and depth are user defined and adjusted for each vessel) of the vessel and the cycle is repeated if desired.
The free-fall fish can be equipped with a variety of instruments for real-time data collection. The system requires the use of a Data Telemetry Module (DTM) for cable lengths above 600 m. Graphical data is presented in real time for the operator to view and logged for future use.
The MVP is available in several different sizes each designed to meet different user criteria ranging from vessel size and weight restraints, depth of cast requirements and speed of operations. A photograph of the MVP family is presented in Figure 1. The system name identifies depth of cast capability at 12 knots. As an example, the MVP200 system can achieve a cast depth to 200 m at 12 knots. The larger MVP300 systems are configured with extra cable to allow significantly deeper casts at slower speeds.
Each MVP system consists of the following sub-systems:

1 Hydraulic or electric powered winch and overboarding boom system
2 Free-fall fish available in two configurations: Single-sensor and Multi-sensor
3 Sensors: sound velocity, CTD, fluorometer and prototype laser optical plankton counter
4 System controller

Background: - the Need for MVPs

Advances in Multi-Beam (MB) technology in recent years have dramatically reduced the traditional problems in quality of data collected.

- Heading: - integrated GPS systems and/or affordable, accurate gyros made this one of the first external parameters to not be an issue
- Positioning: - differential GPS and Selective Availability (SA) being turned off on 1 May 2000 has, for the most part, made this an historical issue
- Attitude: - inertial navigation and integrated motion compensation systems with 0.05 degree accuracy and 100 Hz output rates have minimised this as a significant source of error
- Evolution of MB systems with increase in number of beams, angle of swath coverage, increase in ping rate and the subsequent reduction in beam footprint have all contributed to this being a significant constraining factor in the quality of data collected

This left the proper measurement of the water column, (specifically Sound Velocity and Temperature) as next challenge on the list for CHS overcome. The challenge is to initially calibrate the MB system and then to maintain the proper beamforming and predicting of each beam path through rapidly changing water columns while maintaining the quality specifica-

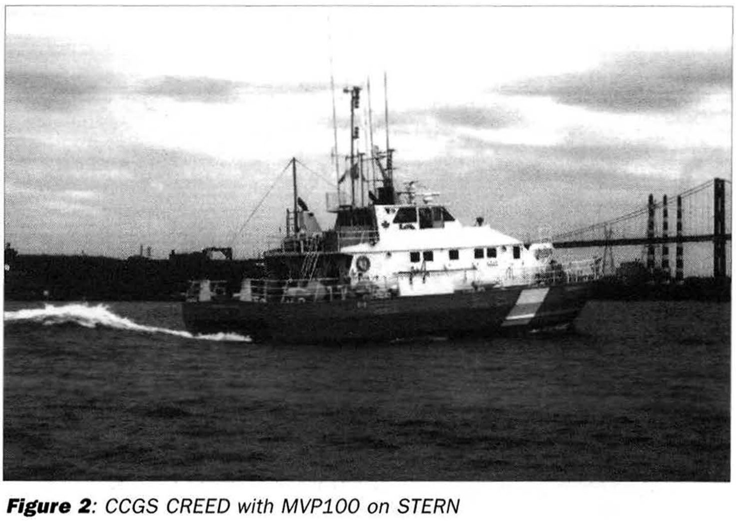

***Figure 2**: CCGS CREED with MVP100 on STERN*

tions of a hydrographic MB survey.

The ultimate goal is to solve and/or to properly compensate in 'real-time' while acquiring the data. However, very dynamic water masses, such as those encountered in the Bay of Fundy (15 metre plus tides) and limitations in MB systems to input the new profiles in as soon as they are collected (without having to stop logging) force a change of focus in this environment. As a first step in such situations, CHS concentrates on collecting sufficient data for the surveyor to objectively correct the data in the data processing stage (reference Clarke, John Hughes et al in addendum). The MVP family has allowed CHS to achieve these objectives.

MVP100 aboard the CREED

In 1997 the prototype MVP-100 was first installed (initially for temporary evaluation only) on the CCGS FG Creed. Since she is a small vessel (20m) and weight is an issue, it was necessary to remove the small A-frame on this SWATH (Small Waterline And Twin Hulls) vessel. Her normal operating speed is 13-15 knots, so for operational purposes, the vessel has to slow down to obtain an MVP cast, this soon proved to be a non-issue as so much time was gained by not having to do stationary casts. So well was it received by all staff, that initial skepticism by the bridge was soon replaced by lobbying to make sure the MVP-100 stayed aboard as a permanent addition to the ship's equipment!

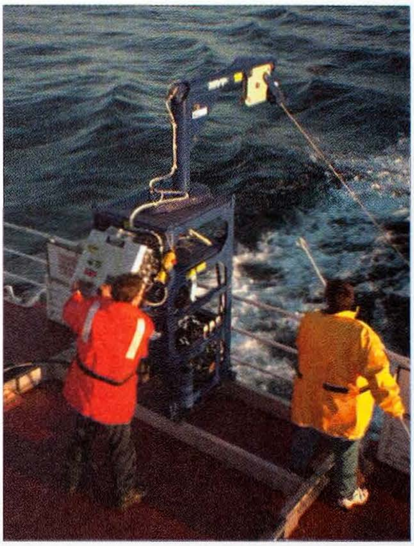

***Figure 3**: MVP100*

After initial training and familiarisation the procedures for operation of the MVP-100 were soon worked out. What follows, is an extract from these procedures to give the reader a sense of the operational procedure followed.

- 'Discuss decision to deploy MVP (Moving Vessel Profiler) with the Bridge; request speed for deployment. Maximum speed the MVP is rated for is 12 knots, there are occasions when the weather is adverse and deployment is not recommended. Although, if the fish is already in the towed position this is not an issue. Safety of staff on deck should always be the priority. Slower speeds will allow deeper casts
- Go to MVP computer and double click MVP icon. Ensure that the bridge/survey sounder is turned on and displaying the correct depth (to give depth under keel). The Controller will display this depth and will trigger the stop of deployment when the fish reaches requested depth above the bottom. Also ensure that GPS information is being received. Particulars such as time and position are written into the header of the profile
- Turn on 220-volt breaker for power pack and the 24-volt switch (beside the PC) to power the hydraulic valves on winch. Put winch in 'manual' mode, push RESET and put Free Fall Fish (FFF) in deployment position, ensure boom is pointing directly astern of the vessel. Quickly lower FFF into water and pay out cable to towed position. Lowering it in slowly while underway may result in damage due to the bridle getting twisted or undue swinging of the FFF results in contact with the ship's hull. If possible, place a protect layer of rubber mat or inflated fenders over the side of the vessel to minimise damage should such contact occur
- Make sure that tension always stays on the kevlar cable to minimise the chance of the cable becoming slack on the drum. Use bungy cord to maintain tension when FFF is stowed in its holder.
- Although the boom will travel 360 degrees this is not prudent. The boom 'position sensor' can shear if this is done. Always bring boom back in from the opposite direction it was turned out i.e. on CREED it is turned out anti-clockwise, therefore, bring it back in clockwise. If cable is brought in too far, an emergency trigger on cable (~1/2 metre before the Fish) will trigger an emergency stop on the winch. If this happens push in and hold the RESET button while SLOWLY letting paying out the cable. It is advised to do this over the water rather than inboard if this happens as cable can pay out very quickly. Damage to the sensor or personnel is possible if the FFF hits the deck. The joystick controls are

variable speed and require practice to use properly

- Put the switch in STOP mode, wait ~3 seconds then put in AUTO mode, push RESET. FFF is now be ready for deployment. Check the main screen on the computer to ensure that there are valid numbers being received from the MVP 'depth' and 'cable out' sensors. The button will be red and 9's shown underneath, if no information is being received. Turn the switch on the winch to STOP, wait again and then turn back to AUTO and push RESET. Repeat until both sensors are being displayed on the screen. (NB when in air the depth sensor should be reading approx. –0.15m/s, and changing each second). When all sensors are working, you can now set the parameters for the cast. The deployment of the FFF will automatically terminate when the first of the following conditions is met:-
- Depth set above bottom, this is usually 10 m but can be set less in good conditions i.e. 6m (this is the depth AT TIME OF DEPLOYMENT, do not try to change the cut-off depth of FFF while it is dropping)

OR

Specified depth of cast is reached

OR

Maximum cable is released (it is not recommended to set this to greater than 275m)

- The maximum depth of the chart display can be set using toggle keys or double-clicking and using keyboard (this is true for all values) turn logging on and name file to be saved on the hard drive. The convention in use is:- SVP###.@@@ where ### is Julian day and @@@ is number of cast for the day 'e.g. SVP139.002

*Note that the extension must be 3 digits, the program will automatically increment the number by one before cast. This ensures that a cast will not be overwritten. You can select the last cast you did rather than typing in a new name each time. Therefore, the first cast of Feb 10 would be entered as SVP041.000 in order to be logged as SVP041.001. This file contains ALL the depths sent up by the 'SmartProbe' sensor, whereas the file sent on to sounder will only have one velocity per metre up to 50 metres then one every five metres after that. This is because the Simrad EM1000 system will only accept the first hundred lines of the profile and ignore the rest.'

All the groups that have operated hydrographic operations from the Creed since 1997 have used the MVP with great success and acceptance. These include CHS Atlantic and Laurentian regions as well as the Geological Surveys of Canada. In fact, over the winter of 1999/2000 these three groups pooled their funds to refurbish the original prototype MVP-100 to the new standard version that was being currently shipped. Improvements in the controller software, the winch system and overall robustness were welcomed by all.

The Creed has been saving 2-3 hours per day during 24-hour survey operations in areas of high water column variability.

MVP200 aboard the MV ANNE S PIERCE

In 1999 the CHS-Atlantic entered into a Joint Project (JP) with the Geological Survey of Canada (Atlantic) and a number of offshore scallop producers, the Nova Scotia fishing company Clearwater Fine Foods Inc. took the lead for industry. Five of these companies have now formed their own organisation the Canadian Offshore Scallop Industry Ocean Mapping Group. The objective was to collect multibeam data and produce derived imagery (four layers of information -bathymetry, backscatter, habitat & benthos) for use in their Electronic Chart Systems (ECS) in support of fishing operations. This was initiated due to the tremendous success of CHS's test project on Browns Bank (in the Gulf of Maine) the previous year.

In the spring of 2000 an MVP200 system was installed on the after deck and is used to collect sound velocity profiles in support of multibeam

***Figure 4**: ANNE S PIERCE with MVP200*

mapping operations. This was a significant step, as she is the first privately owned and operated multibeam equipped vessel in Canada. The JP covered the surveying of the Canadian side of Georges Bank (7600 kms^2).

Another interesting aspect of this installation was the inclusion of a sound velocity (SV) probe in a (BOT designed) enclosed chamber in the Transducer Ram area. The serial output from this sensor is fed into the Simrad EM1002 operator console. This data is used to properly steer the acoustic beams of the sounder. It has been documented that the accurate knowledge of the sound velocity at the water/transducer face allows for more accurate 'steering' of the pulses.

There is a pump that pulls water from the outside of the hull near the transducer, passes it over the sensor and dumps the water overboard. In the case of the EM1002 transducer, (after installation) we were advised that it is required to know the temperature of the water at the transducer (Td) face as well. The existence of this chamber made it an easy matter to integrate the required solution. By having the fixed sensor in an enclosed chamber it is easy to service and thus also to retrofit the (Simrad supplied) sound velocity and temperature probe (SV&T).

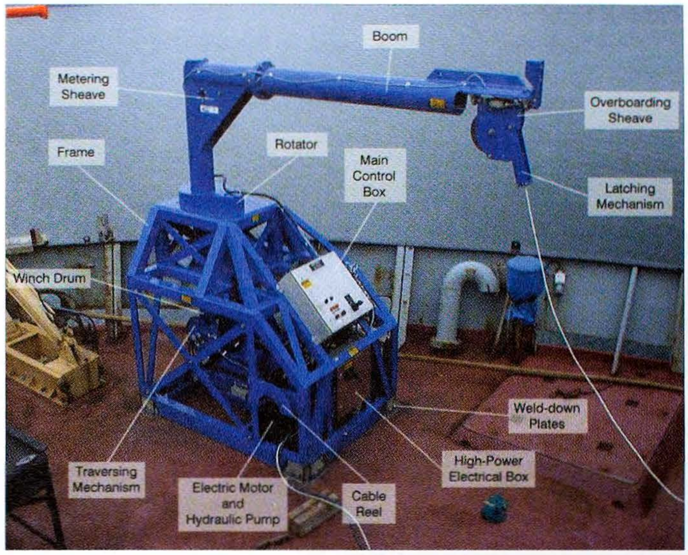

***Figure 5**: Photograph of the MVP300-1700*

It was always possible to obtain the sound velocity data from the FFF if you towed it at the same depth as the transducer, but this has a few drawbacks. One is that in a dynamic environment there is a physical displacement between the Td and the FFF aft of the vessel, so time delays when entering new water masses are experienced (this is very hard to handle in post-processing). Other drawbacks include that you will not have Td SV&T data while performing a cast, or when the FFF is inboard for servicing.

Redundancy is always desirable in these operations so this addition to MB survey operations as part of an integrated sound velocity solution has proved very beneficial.

MVP300 System Description

The MVP300-1700 is capable of collecting a cast to a depth of 300m with the vessel traveling at 12

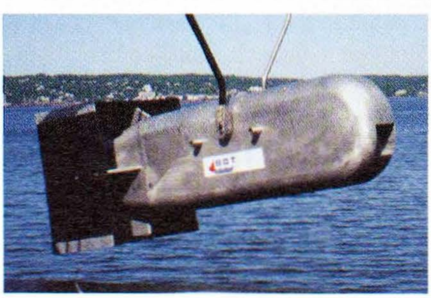

***Figure 6**: Multi-Sensor Free-Fall Fish*

***Figure 7**: Single-Sensor Free-Fall Fish*

knots. The system holds 1700 m of cable that allows the fish to achieve an even deeper cast to 850 m at 5 knots and 1700 m cast at 0 knots. It was tested on the Grand Banks in Canada and across a section of the Kuroshio Current in Japan. A photograph of the system is presented in Figure 5.

The system's hydraulic powered winch and overboarding mechanism includes a 25 HP hydraulic power pack, traversing drum and a powered rotating boom for launch & recovery. The rotating boom includes a cable metering system and flagging block.

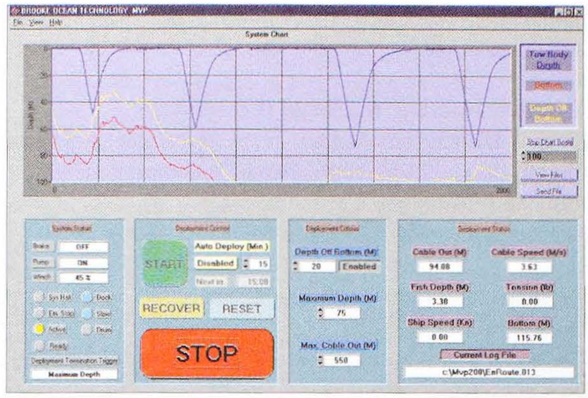

***Figure 8**: MVP control screen*

The system tested in Canada and Japan was equipped with a Multi-Sensor Free-Fall Fish and a Single-Sensor Free-Fall Fish (see Figure 6 and 7). The multi-sensor free-fall fish is presently designed to hold a variety of configurations of the accepted sensors and the required DTM. The single-sensor free-fall fish is capable of holding a single-sensor (CTD or SV) and the DTM. During these trials the sensors that were tested included a CTD and an SV&P coupled to the DTM.

The system controller runs a control program that allows the user to configure and operate the MVP. The system requires inputs of fish depth, bottom depth and a GPS feed for position and vessel speed. A view of the control screen is presented in Figure 8. The blue trace represents the free-fall fish position. The red trace represents the ocean bottom and the yellow trace the bottom avoidance safety zone.

Mode of Operation

The MVP operates much differently than a towed system. It is designed to allow a streamlined body to free-fall (see position 1-2 in Figure 9) from a moving vessel. The fish is instrumented to provide real time depth information to the control algorithm, at the bottom of the cast (see position 3 in the Figure 9), the winch is stopped and the free-fall fish, (after immediately rising, initially duplicating the cable catenary) becomes a towed body. The fish is winched to the surface (see position 4 in Figure 9). The MVP can achieve a greater depth than a comparable towed system.

The MVP allows repeated deployment of the fish under computer control. The narrow red band behind the ship indicates the 'plane of operation' for the fish and cable. This is a very narrow strip approximately 1 meter wide. The nature of this operation allows it to be used simultaneously with applications that require other towed objects behind the vessel without fear of entanglement.

After deployment, the MVP fish can be left in the towed position without the worry of recovery if the weather deteriorates, (the operator should, of course, be cautious in areas with fishing gear). Through the use of computer automation, the system can be relied upon to carry out repeated casts, without the requirement for personnel to intervene in operations. The data collected at the end of each cast is written to the controller's hard-drive automatically in sequential file formats. For multibeam mapping operations, the SV profile can be viewed, edited (if required) and then sent to the multibeam sounding system via serial connection.

Sea Trials

Sea trials have been carried out over the last four years to ensure that the numerous enhancements have been properly implemented and are working as per specifications. This attention to quality and user satisfaction is part of the service that operators of MVP systems have come to expect. Calibration comparisons with traditional SV probes attached to the FFF bridle (slow, stationary deployment) have shown that this new generation of high sampling SV and SV&T sensors are up to the task.

Other Applications

The MVP can be used to collect traditional oceanographic data. The multi-sensor free-fall fish can be outfitted with multiple sensors. These sensors can include CTD & Sound Velocity (SV), Fluorometer and a prototype Laser Optical Plankton Counter (LOPC). Other sensors being investigated include Optical Back Scatter (OBS) and Dissolved Oxygen.

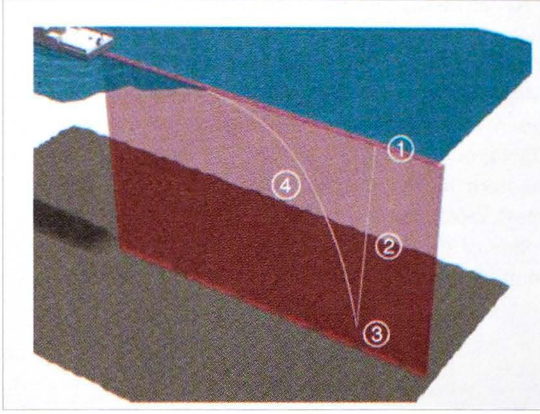

***Figure 9**: Path of Free-Fall Fish during cycle*

Several organisations are using the MVP system to collect oceanographic data including the Bedford Institute of Oceanography who collect CTD, Fluorometry and plankton, Tokyo University of Fisheries who collect CTD and Fluorometery and Nippon Kaiyou who collect CTD.

Conclusions

The MVP is a reliable system able to collect sound velocity profiles to a depth of up to 300 m at 12 knots. The MVP (and the optional sampling chamber for the water near the Td) has been well integrated with multibeam systems to provide real time SVP corrections while underway. Operator acceptance and ease of use are proven.

The MVP can improve the efficiency and economics of data collection; casts can be collected in a variety of weather conditions by a single technician. The automatic nature of the system allows it to avoid the bottom without concern of bottom contact. Even though the MB acquisition systems may not be able to handle the changes in the water mass as quickly as they occur in nature, at least the conscientious hydrographer can log sufficient data to be able to make informed decisions at the post-processing stage, if the need arises.

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Biography

Arnold Furlong is a partner in Brooke Ocean Technology Ltd. and a Senior Engineer specialising in the development and application of ocean profiling tools and payloads. These tools include the Moving Vessel

Profiler (MVP) and the Wave Powered Moored Ocean Profiler (SeaHorse). This work has included interaction with these tools and their users during field operations. Mr Furlong is presently focusing his efforts on the development of payloads for these platforms.

Michael Lamplugh is a Hydrographic Project Supervisor with the Canadian Hydrographic Service. He has been working out of the Bedford Institute of Oceanography in Dartmouth, Nova Scotia since 1977. His background is in field survey and as such, has worked on many different hydrographic platforms over the eastern half of Canada. His primary interest over the last 13 years has been 100% bottom coverage methodologies and has used a wide range of sensors such as Navitronics (multi-transducer), Reson and many of the Simrad family of shallow to mid-water multi-beam systems. His most recent project was a joint venture with industry to achieve complete coverage of Canadian side of Georges Bank.