The Ocean Technology Test Bed - From Concept to Operation

Alison A. Proctor, Jeff Kennedy, Emmett Gamroth, and Colin Bradley
Department of Mechanical Engineering
University of Victoria
Victoria, British Columbia

Darryl Gamroth
Rubus Technologies
Victoria, British Columbia

Abstract

The Ocean Technology Test Bed (OTTB) is a multi-functional underwater test facility developed by the Ocean Technology Lab (OTL) at the University of Victoria to serve military, academia, government and industry. The OTTB is located off the coast of Vancouver Island, Canada. It resides in 80m of water and covers 2-square kilometers of the seafloor. A seafloor cable provides power and communication to a recoverable platform. The platform sits inside of an Integrated cabled long baseline Acoustic System (IAS), which provides precision tracking and acoustic communication throughout the OTTB arena. The facility has the tools researchers require to develop new underwater technologies, such as: oceanographic sensors, autonomous underwater vehicles (AUVs); underwater AUV docking systems; guidance, navigation and control algorithms; multiple vehicle cooperation; acoustic communication; and autonomous remote sensors.

The OTTB project is a satellite off of the Victoria Experimental Network Under the Sea (VENUS) observatory in Saanich Inlet, and was originally proposed as an engineering laboratory to facilitate the development and testing of new underwater technology for use on cabled ocean observatories, and as a proving ground for demonstrating the suitability of existing technology for long term deployments in remote locations. The facility has subsequently come to fill a broader role, serving as a test facility for surveying, security and other ocean sensing applications.

The first phase of the OTTB installation has been completed and operational testing is now underway. This document describes the development and installation of this unique facility and presents case studies for the first few experiments to capitalize on the capabilities of the OTTB.

I. Introduction

The Ocean Technology Test Bed (OTTB) design and installation project began in earnest in 2007 by the Ocean Technology Lab (OTL) at the University of Victoria (UVic)[1]. The OTTB was originally proposed as an engineering laboratory to facilitate the development and testing of new underwater technology for use on cabled ocean observatories, and as a proving ground for demonstrating the suitability of existing technology for long term deployments in remote locations. However, the facility has subsequently come to fill a broader role, serving as a test facility for a myriad of underwater applications including defense and security, surveying, and other ocean sensing.

The OTTB is located off the coast of Vancouver Island in Patricia Bay and resides in 80m of water. Power and communication for the OTTB are provided by the Victoria Experimental Network Under the Sea (VENUS) node in Saanich Inlet[2]. An integral part of the OTTB facility is the Integrated Acoustic System (IAS), which enables precision tracking and acoustic communication throughout a 2-square kilometers area around the OTTB site. This test range can be used to support underwater vehicles, sensing platforms and operational training scenarios.

The facility has the tools researchers require to develop new underwater technologies, such as:

- new autonomous underwater vehicle capabilities
- underwater AUV docking systems
- vehicle guidance, navigation and control algorithms
- multiple vehicle cooperation
- acoustic communication
- remote sensor pods and data harvesting

This paper is organized as follows: Section II provides a detailed description of the OTTB infrastructure and the related assets that are operated by the OTL; Section III describes the first few sets of tests that were performed using the OTTB; and the conclusions and a brief description of some of the future work on underwater vehicles are presented in Section IV.

The Ocean Technology Test Bed Installation and Design project has been funded by the Canadian Foundation for Innovation (CFI) and the British Columbia Knowledge Development Fund (BCKDF). The research capacity of the OTTB has been extended to include AUV operations through contributions from Western Economic Diversification Canada.

II. FACILITY DESCRIPTION

The OTTB in water infrastructure is comprised of the following components shown in Fig 1: service buoy, recoverable platform and IAS. The in-water system is connected to the world through the main supply cable, which is an electro-optic cable routed along the seabed from the OTTB back through the VENUS observatory node and to the shore station 3 kilometers away at the head of Patricia Bay. From the shore station, the facility has a dedicated 100 Mbps Ethernet link back to UVic, which is connected to national research networks.

A. Service Buoy

The service buoy is a top-side work platform that is anchored to the sea floor by a three point mooring with a radius of 184m. The buoy itself, shown to the left in Fig 2, is a toroidal platform with an exterior diameter of 8 meters and an interior diameter of 4 meters. The surface of the buoy is large enough that that technicians can easily move around while working on a project and is equipped with fences to protect workers from falling during rough seas.

The buoy is equipped with a dock that can take a vessel up to 14 meters long on calm days (sea state 1 or below), which is typical for the protected waters of Saanich Inlet. Equipment can be moved around or offloaded using the crane and winch.

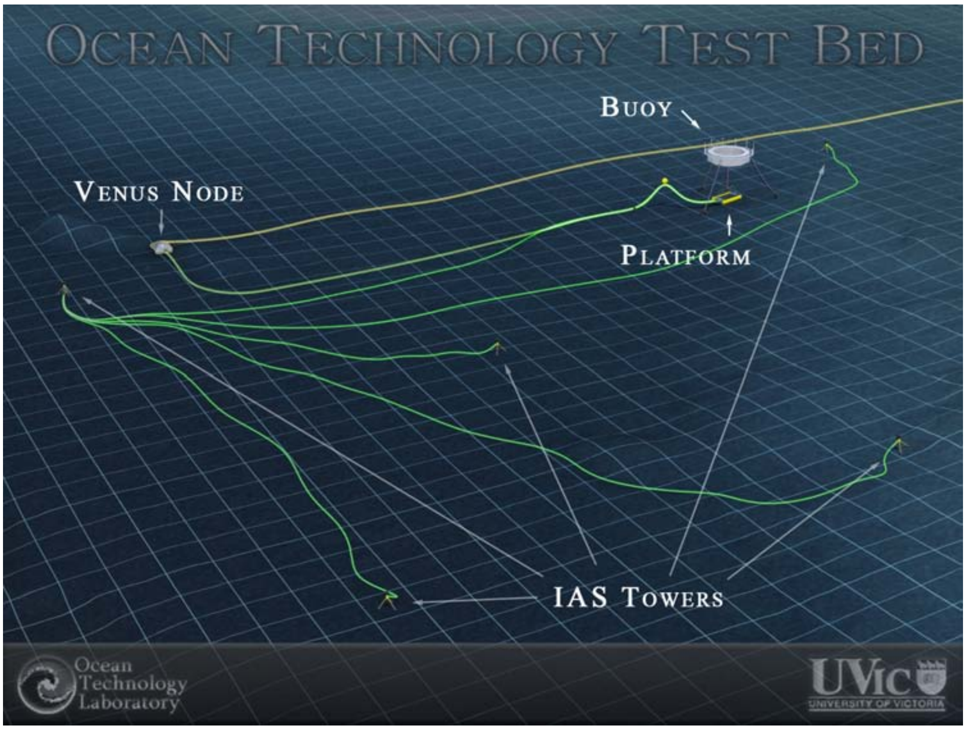

Fig. 1. An overview of the components that make up the Ocean Technology Test Bed

Fig. 2. OTTB Infrastructure: Rendering of the OTTB Service Buoy (left), and the Recoverable Platform (right)

B. Recoverable Platform

The recoverable platform, shown on the right in Fig 2, mates with the service buoy and can be lowered to the sea floor using the crane and winch. The platform is equipped with four ballasting drums, once the platform has been winched to the surface the drums are evacuated so that the platform floats and the work crew can safely climb onboard. To lower the platform, the drums are flooded until the platform is no longer buoyant and then the platform is lowered back down to the sea floor with the winch.

The platform is a mounting area for any fixed instruments that users want to connect to the OTTB. Instruments are connected to the OTTB through the Platform Control Module (PCM), shown in Fig 3. The main supply cable, coming from the VENUS node, connects to the OTTB at the PCM. The PCM distributes the 360 volts DC and communication from the main supply cable to eight independent ports. The PCM monitors the current, voltage and ground fault levels of each port at a rate of 1 kHz. This provides engineers with critical data for assessing the status of instruments in the event of a failure. Each port is equipped with deadface switching for all power and communications conductors. The internal components of the PCM were designed using a flexible backplane configuration. The power and communication to each port is managed by a power and network card respectively, with each card plugging into the backplane. The allows the OTL to quickly swap out cards to make repairs or upgrade the system.

The OTTB infrastructure can supply up to 1.5 kilowatts of aggregate power to attached instruments. Nominally, the PCM delivers 48 volts DC and 10/100 copper Ethernet on each of the eight ports, as shown in Fig 4. When a user provides an instrument to be tested, an interface enclosure called a port adapter is configured to convert the OTTB nominal supply to what ever voltage and communications specification the user requires. Several port adapters have been pre-built and are available to

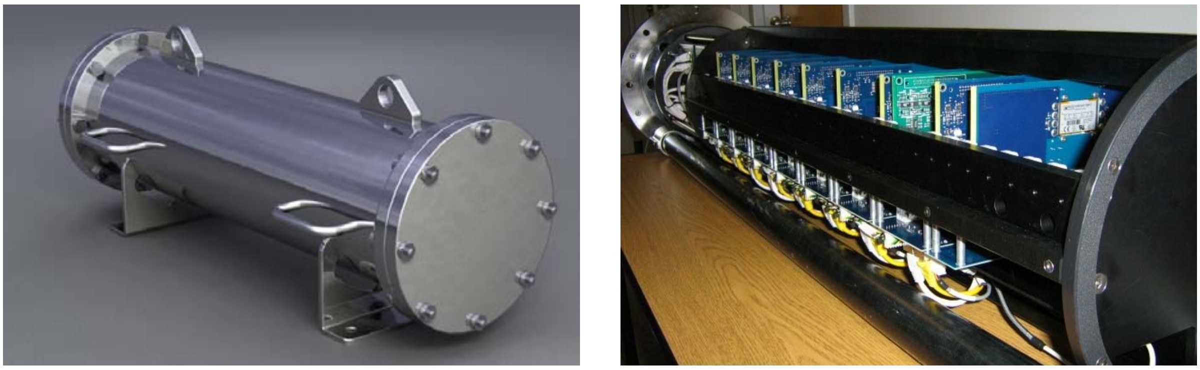

Fig. 3. Platform Control Module: Rendering of the PCM enclosure (left), and the internal layout (right)

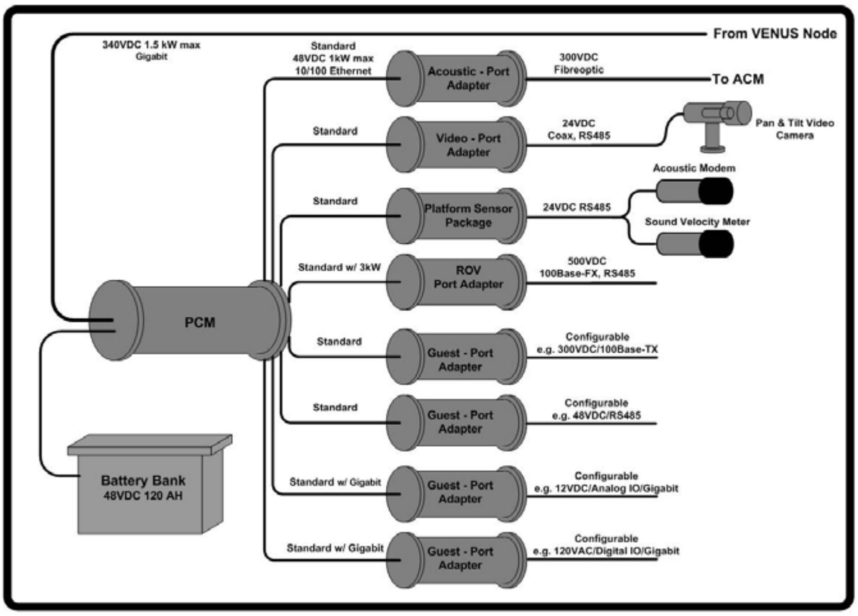

Fig. 4. An overview of the components that make up the Ocean Technology Test Bed

be configured to meet customer requirements. While the OTL only maintains a 100 Mbps Ethernet link from the shore station to the world, the underwater infrastructure and shore station are capable of providing gigabit Ethernet so higher bandwidth applications can be supported.

The platform will be outfitted with a pan-tilt video camera system and with a sensor package that includes:

- **WHOI Micro-Modem** which provides a mode for underwater devices to communicate acoustically with the OTTB infrastructure.
- **Three axis orientation sensor** for measuring the attitude of the platform
- **Sound Velocity Sensor** for measuring the speed of sound in the local area.
- **Precision Pressure Sensor** for precisely measuring the current water pressure or depth.

In the future, a battery bank will be added to the platform which will allow the OTTB to host higher power applications for short term experiments. To support this, there is one port configured as a high power port that can support a device that draws up to 3 kilowatts of power.

C. Integrated Acoustic System

The IAS system is a cabled acoustic network that can be configured to provide acoustic communication, positioning or tracking. The IAS consists of five centrally-managed towers that are cabled together with fiber optic communication, as shown in Fig 5. The IAS uses the IEEE 1588 Precision Time Protocol (PTP) to provide timing at each tower. In the shore station, there is a grandmaster clock which is disciplined using the pulse per second (PPS) output from the GPS base station. The grandmaster clock is used as a PTP master which in turn is used to discipline oscillators in each of the towers. This precision time source enables the IAS to timestamp acoustic signals with microsecond accuracy.

The IAS is highly configurable, each tower is equipped with a hydrophone and projector controlled by an FPGA. The towers can be configured to transmit and receive user-assigned signals between 10kHz and 50 kHz. The received signal is timestamped at the tower and then sent up to the central processing computer in the shore station. This design enables a wide variety of researchers to use the system to test communication, networking, and positioning algorithms.

Initially, the IAS is going to be configured as a precision tracking system for the OTTB test range. Background information on underwater tracking and positioning systems can be found in [3]. In the tracking configuration the towers are configured as passive listeners and the position of the target is computed using the differences in the time that a ping is received at each of the towers. To use the tracking system, a vehicle or other asset will simply be equipped with a pinger and will otherwise be free to operate as usual. The IAS tracking system will be able to track off-the-shelf pingers that are used with other commercial tracking systems as well as custom pingers developed at the OTL. It is anticipated that the IAS will be able to achieve a static accuracy of ± 10 centimeters.

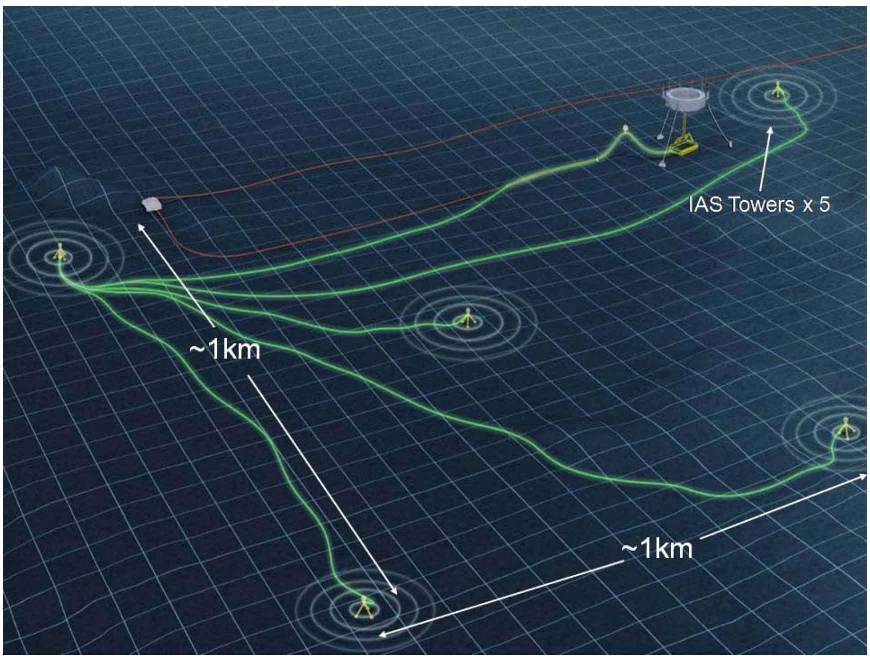

Fig. 5. An overview of the Integrated Acoustic System

D. Shore Station and User Interface

The OTTB shore station provides a communication portal to the underwater infrastructure. The system can be accessed from the outside through a secure Virtual Private Network (VPN). This allows outside users to log onto the network and monitor their equipment. When an OTTB client logs into the VPN their device appears as if it is locally connected to their computer. Each client has their own separate virtual LAN (VLAN) which ensures that data remains secure from other users. This configuration allows clients to use their own software to monitor and control their instrument. This eliminates the need for users to coordinate software with the OTL or develop special drivers for their instruments. Since the system is accessible from anywhere that has an Internet connection, this facility can be used by those who do not have easy access to the ocean as a tool for evaluating new products.

The shore station is also equipped with the following equipment:

- **RTK GPS Base Station** which provides a high quality PPS signal and differential corrections to vessels in the OTTB arena.
- **Grandmaster clock** which provides a stratum 1 Network Time Protocol (NTP) server and an PTP master
- **Long Range Wireless Base Station** which provides a 25 Mbps wireless connection to surface vessels operating in the OTTB arena.

The long-range wireless system allows surface vessels operating within the OTTB arena to connect to the OTTB network at data rates of over 25Mbps. This allows the surface crew to remain in constant communication with the underwater infrastructure during operations. It also allows users from around the world to remotely participate in operations that are occurring in the OTTB test range.

The target tracking information from the IAS and the GPS signals from surface vessels operating in the OTTB arena can be viewed in real-time in a 3D graphical interface based on Google Earth. This interface shows the OTTB arena, all tracked subsea vehicles or targets, and surface vessels. This allows users to visualize tracked targets and their positions relative to fixed objects in the OTTB space. This allows vehicle operators to monitor complex vehicle behavior such as AUV docking, or autonomous operations near fixed installations. In combination with the long range wireless system, this interface allows entire development teams to be remotely participating in operations occurring in the OTTB test range.

E. Vehicles

The OTL also operates two vehicles in the test range: a Bluefin-12 AUV and a Saab SeaEye Falcon ROV. These vehicles, shown in Fig 6, are used for general work around the site, scientific data collection, and engineering research.

1) Saab SeaEye Falcon ROV: The Falcon is a versatile observation class ROV. This vehicle is primarily used on the OTTB for surveying and helping to retrieve equipment. The OTL is also in the process of modifying this vehicle to support a wider range of ROV based research projects. An additional electronics housing is being added to the vehicle, which will provide Ethernet communication with the surface and enable alternate methods of controlling the vehicle. These modifications will make the Falcon a more versatile platform for supporting engineering research.

2) Bluefin-12 AUV: The Bluefin12 AUV, called MANO, is 3.75 meters long and 0.3 meters in diameter. It is a flooded vehicle and uses an articulated tail thruster for propulsion and control. MANO was built for the OTL by Bluefin Robotics in Boston MA. The purpose of this vehicle is to provide support to scientists wanting to collect data in Saanich Inlet and to act as a test bed for testing and demonstrating new AUV technologies. This particular vehicle has been designed with a fully independent payload system. This allows us to easily modify the payload to add or remove instruments for testing.

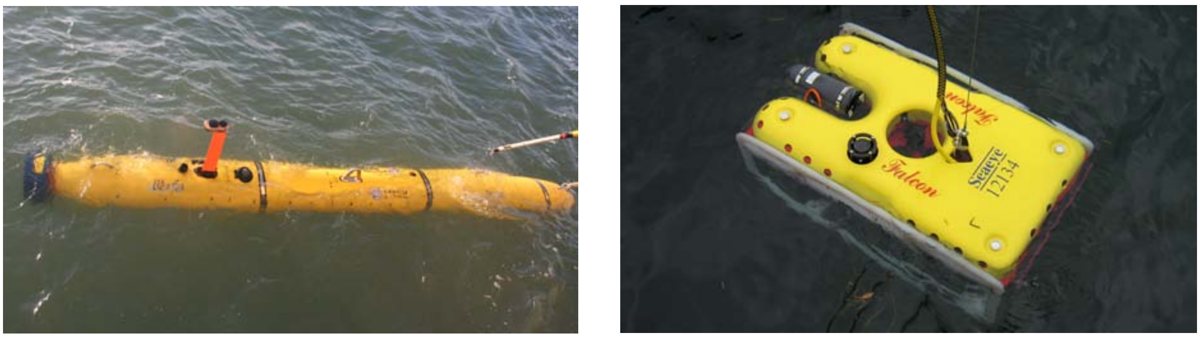

Fig. 6. Vehicles operated by the Ocean Technology Lab: Bluefin-12 Autonomous Underwater Vehicle (left), and Saab SeaEye Falcon Remotely Operated underwater Vehicle (right)

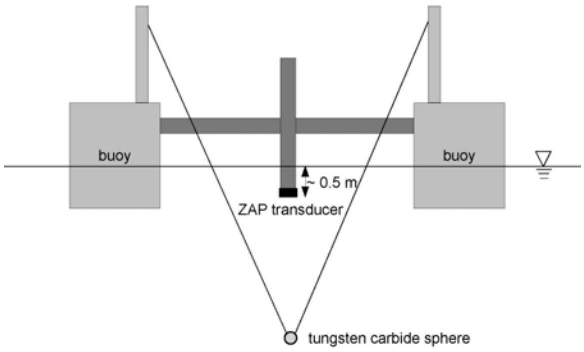

Fig. 7. OTTB Users: Calibration of the Echo Sounder used as a Zooplankton Acoustic Profiler (ZAP) (left), and HD Camera Testing (right)

III. The First OTTB Users

After two years of work, the OTTB finally became operational in a limited capacity in the fall of 2009, and new components are coming on line all the time. The OTTB is expected to be fully functional by the end of 2010. In the mean time, the OTTB has already begun hosting clients and providing service in a limited capacity. The following section describes the first three experiments that have utilized the OTTB facility.

A. Calibration of a 200-kHz Echo Sounder

Researchers affiliated with the VENUS cabled observatory used the OTTB to calibrate a 200-kHz echo sounder (Acoustic Water Column Profiler; ASL Environmental Sciences). The scientists have deployed the instrument on the VENUS node in Saanich Inlet and have been using it to look at variability in zooplankton abundance and their behavior. One of their problems with prior deployments is their limited capacity to calibrate the instrument. A detailed calibration requires a steady platform, deep water and unobstructed water around the instrument to minimize reflections and erroneous readings. This is difficult to achieve when calibrating the instrument off a pier or in a tank. Therefore, even though the researchers had noticed some interesting behavior, it was difficult to quantify without the calibration values.

The OTTB provided an excellent opportunity to calibrate the instrument in the open ocean. The team used the OTTB service buoy as a platform for the calibration. A horizontal brace was erected across the hole in the center of the buoy, and the echo sounder was suspended from the brace at approximately 0.5 meters depth. Then tungsten carbide calibration spheres were suspended below the echo sounder and data were collected at each depth. On the OTTB site the team was able to get calibration data for distances ranging from 17-37 m. The result of the study by these researchers is available in [4].

B. High Definition Camera System

High definition video is one of the many exciting new tools available to scientists for studying marine life. Before cable ocean observatories, the bandwidth required to support this type of instrument simply wasn't available. A low light camera with an extended optical zoom range was developed for the Underwater Window project for the purpose of studying microscopic creatures and witnessing phenomena that had never before been captured [5]. This camera platform is able to optically zoom into to a spot on the seafloor approximately one inch across and produce a full HD video of the activities in that square inch. This camera is currently part of the Oceans 2.0 project [6]. The Oceans 2.0 functionality is available at http://dmas.uvic.ca/home.

Prior to deploying the camera on either the VENUS or NEPTUNE observatories the camera was deployed on the OTTB to undergo testing. The power and communication to the camera system was provided through the OTTB test facility. The camera was lowered to the seafloor below the OTTB buoy. Unbeknownst to the project staff, the cable to the pan tilt and lights had been damaged and was slowly taking on water. Within a few days of being deployed the cable caused a ground fault and the camera had to be shutdown. On the OTTB it was possible to go out the day after the failure, retrieve the camera, assess the damage and redeploy the equipment. Ultimately, a portion of the damaged cable was salvaged and reused as an interim cable while a replacement cable was ordered. The entire repair was completed with minimal down time for the camera. If this camera had been deployed on an observatory without this intermediate testing step then the camera would have still failed but the researchers would likely have had to wait for 6 months to a year to retrieve and repair it.

C. Evaluation of a Subsea Asset Location Tool

Searching for lost equipment underwater is time consuming and often results in failure. The SonarBell is a new tool to aid in recovering lost assets. It looks much like a bowling ball and utilizes the different materials in its shell and core to create a constructive interference and deliver a return signal significantly above that a hard reflecting sphere might otherwise deliver.

The SonarBell was evaluated on the OTTB using the Falcon. In this test an imaging sonar was fixed to the OTTB Service buoy and the data from the sonar was relayed to a laptop on the buoy. The SonarBell was attached to the Falcon ROV and operators moved the ROV around in the OTTB arena to evaluate the relative ease of resolving the ROV with and without the SonarBell attached. The evaluation was successful providing valuable information about the utility of this device.

IV. Conclusions and Future Work

The OTTB design and installation project has resulted in an innovative laboratory, Fig 8, that will provide important research opportunities to scientists and engineers and is a necessary research platform from which the role of ROVs, AUVs, and integrated acoustics, in ocean science, can be further explored. The OTTB has already proven it's utility and flexibility by providing a very wide array of services to the first three users. Looking forward, it is anticipated that the collaborative environment made available through the OTTB workspace will provide new opportunities for teamwork between engineers, scientists, and administrators resulting in a more comprehensive understanding of the difficulties and opportunities on a given project. Once the OTTB installation is complete, the OTL will begin utilizing the facility for vehicle research.

A. Bottom Tethered ROV

One area of interest for researchers is the idea of a having an ROV permanently tethered to a fixed subsea installation. This is of interest to industry as well as academics planning for the next big thing on cabled ocean observatories. The OTTB has been designed such that the OTL's Falcon ROV can be plugged into the PCM in a bottom tethered configuration. This will enable researchers at the OTL to do in field testing on many of the items that will be necessary to make ROV's a permanent part of a subsea installation including: material selection, mitigation of bio-fouling, new control systems, and new pilot interfaces.

B. Real-time Path Planning for Autonomous Underwater Vehicles

Starting in September of 2010, the MANO AUV will be part of a new project to develop advanced scientific data collection capabilities. The OTL is working on this project in conjunction with the VENUS observatory. For this research, advanced vehicle behaviors such as obstacle avoidance and real-time path planning will be developed for this vehicle.

Acknowledgment

The OTL would like to thank everyone at UVic who helped make this test facility possible. In particular, Mike England and Joaquin Trapero in the Office of Research Services for their unending support in managing this project and helping to develop new proposals.

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Fig. 8. The Ocean Technology Test Bed in Saanich Inlet