

SonicWorks Waterside Facilities Security and Inspection

The security of our nation's ports and harbors has become a focus of concern since September 11, 2001. These areas present difficulties not associated with air and ground transportation facilities. Visual surveillance is practically impossible in most places due to the turbidity of the water. Ambient noise from ship motors and other machinery make the effectiveness of traditional sonar systems marginal at best. Even under ideal conditions, traditional systems suffer from an inherent limitation: shallow waters, ship hulls, and underwater structures, all in close proximity, create multi-path reflections of acoustic energy. These reflections, at best, will severely limit the speed at which these systems can scan a given area, and at worst, confuse and overwhelm the system. SonicWorks, Inc. of Portsmouth, Rhode Island, has developed technology to address these and other issues which are barriers to the effective monitoring and surveillance of these areas. Three systems, designed to operate together, or as enhancements to existing equipment, have resulted from SonicWorks' research efforts. The Acoustic Positioning and Navigation System (APNS), the Robotic Control System (RCS), and the "Bee" remote operated robotic underwater vehicles (RORUV) are described here with particular attention to their application to underwater security and inspection or surveillance.

Focus on dock and pier inspection:

The SonicWorks components combine to produce a comprehensive inspection and security system for automated scanning of piers, docks and ship hulls. The inspection process can be performed without holes no matter what the visibility of the water. The system supports both ROV and diver-based inspection. Automated inspection with SonicWorks Bee vehicles is not limited by weather, tides or current. The vehicle's unique abilities allow operating in any conditions, day or night. Automated inspection includes 3D visuals of the inspection area. The scan results can be stored for later comparison and automated anomaly detection. The operator can acquire precision visual and ultrasonic images of the site without endangering a diver. These images can be used to familiarize the dive team and aid in assessment. The system reduces the exposure of divers, limiting diver response to on-site assessment of any anomalies the system locates. The diver tracking component of the system precisely guides the driver to the point of interest while maintaining communications with the surface.

The dock and pier inspection system can be upgraded to full area security. This upgrade provides full time automated intruder detection and 3D sonar imaging of the entire water column. With an advanced classification system the operator can define alarm conditions to minimize false alarms and achieve a high degree of automation. A specialized version of the SonicWorks robotic vehicle, "BeeSting", adds the ability of swimmer/diver intervention to ward off intruders.

Components:

The SonicWorks Acoustic Positioning and Navigation System (APNS)

SonicWorks research focused on development of an acoustic positioning system that could accurately track and fix the position of both active and passive targets. The various types of acoustic positioning systems currently available have several shortcomings. Existing systems are, at best, accurate to the “sub-meter” range. Ultra-short baseline (USBL) systems suffer from a loss of precision proportional to the target’s distance from the transponder. Long Baseline (LBL) systems typically require lengthy setup and calibration procedures. All existing systems are unable to discriminate targets on or near the surface, and cannot reliably identify targets as small as a diver.

In 2003 the SonicWorks Acoustic Positioning and Navigation System was introduced to the market.



Mobile 8 Channel System

The system incorporates cellular technology and advanced signal processing to produce the most accurate acoustic positioning system available today, the underwater equivalent of terrestrial GPS, featuring sub-centimeter accuracy over any size measurement field and the high report rate needed for motion tracking. The APNS is easily deployable in a roughly geometric pattern. The self calibration process takes less than three minutes, and the coordinate system established can be referenced to any existing benchmark, such as GPS. The APNS features update rates as high as 50 times per second, with total cycle times dependent on total range. The system utilizes frequency-hopping within discrete bands in the 100 to 600 kHz range and programmable power control to achieve precision measurement and excellent range. Digital Signal Processing (DSP) is used to achieve a

typical accuracy of $\pm 3\text{mm}$ at 300 kHz over a 100 meter range. Dual calculation ability (time of arrival and time differential) allows tracking of SonicWorks components and independent sources, as well as other manufacture's components. The frequency and power control agility of the APNS allows the system to be used effectively in a wide range of environments.

In 2004 our patent-pending technology for compensation of ship motion was introduced, completing the positional accuracy solution.

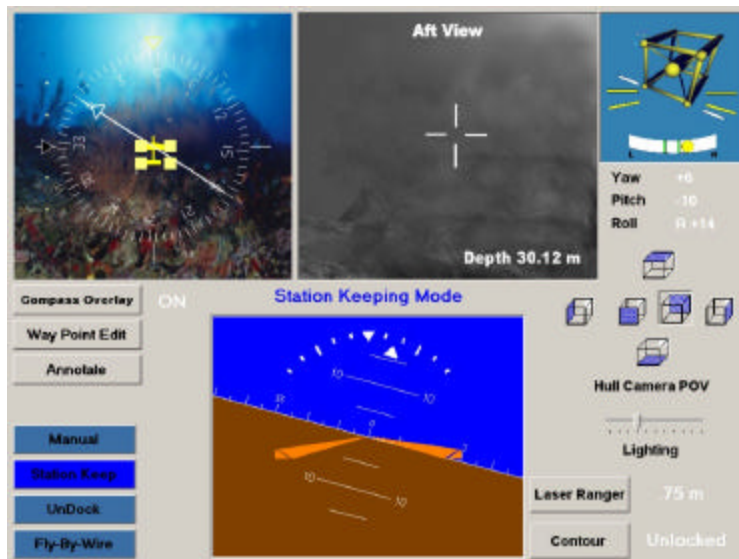
The SonicWorks Robotic Control System (RCS)

SonicWorks Robotic Control System (RCS) is computer control system for ROVs that utilizes the extraordinary precision of the SonicWorks APNS to provide precise flight control ability. The RCS will supplement and enhance the normal operator joystick control for assisted flight control, or provide for fully automated flight control along a predefined path. The level of control enhancement is selectable by the ROV pilot, and can range from simple station keeping to computer-assisted stabilization of manual flight control.

A variety of computer assist modes are available to address several common control weaknesses of conventional manual operation:

1. ***Station Keeping:*** The pilot has found problem and needs to document the inspection point. In a typical situation the pilot cannot release the stick while he types in an inspection annotation; either an assistant makes the notation while the pilot attempts to hold the vehicle in position, or the vehicle is flown up hard on the surface (not a best practice) while the pilot makes a quick notation. With RCS, the touch of a button locks the vehicle in position while the pilot zooms the camera in on the area in question and types the problem description into the APNS annotation system, automatically tagging the position, time, video and any other data recording for later review.
2. ***Undocking Control:*** The pilot may enter station keeping mode to compensate for lateral current, and then fly with enhanced control. The system accepts pilot input in steps in the desired direction, while automated control handles the lateral current. The vehicle control system automatically compensates for the effects of currents (within thruster limits). The pilot can ignore the effects of lateral current while directing flight, improving precision and reducing fatigue.
3. ***Fly-by-Wire Mode:*** In normal manual flight, the pilot is constantly compensating for vehicle dynamics and water currents when applying joystick inputs to achieve the desired course or destination. This process requires the pilot to use the video images, known vehicle handling characteristics, environmental and rough position information. The magnetic characteristics of a ship's steel hull, and the EMI produced by the vehicle thrusters, render normal compass-based piloting ineffective. The uncertainty of position and destination, varying currents, and

poor visibility produce rapid pilot fatigue and increase operator error. In contrast, the SonicWorks APNS and RCS, in Fly-by-Wire Mode, allows the pilot to apply direction control inputs for “point and go” piloting, without regard to vehicle dynamics; no crabbing or complex thrust control to compensate for. Additionally, the APNS with RCS offers the ability to visually follow the flight path in real time in a virtual 3D environment with video overlay, applying simple directional inputs while the system takes care of the variables.



RCS Pilot Interface

Together, the APNS and RCS greatly simplify the process of conducting comprehensive inspections of ship hulls, resulting in faster, more accurate, and more detailed surveys. Labor costs and exposure are minimized through the use of computer-controlled robotic equipment instead of divers, and through reduced costs for support personnel. This means a more efficient, less costly, and more profitable inspection program.

The SonicWorks APNS and RCS are available for retrofit to many existing ROVs for inspection tasks. SonicWorks’ staff has experience in automation of over 15 ROVs for precision inspection of ship hulls, dams, tanks, tunnels and nuclear facilities. Our experience and expertise are available to assist our customers in creating the next generation of ROV inspection vehicles.

SonicWorks Robotic Underwater Vehicles

The SonicWorks “Bee” is the next generation in underwater robotic vehicles. High performance characteristics and high precision positioning and control combine to make the Bee ideal for the most demanding inspection and intervention tasks.

The Bee is unique in its ability to operate at any attitude, conforming to the shape and slope of the surface to be inspected. The vehicle thrust control system actively controls

the attitude and position of the vehicle to precisely fly operator-directed or totally automated course lines. Scanning operations may be preprogrammed and flown for comprehensive inspections with no holes.



The “Bee”

The Bee produces a very high thrust to mass/drag ratio to enable stable vehicle operations in currents of up to six knots. Four articulated thruster assemblies combine to produce up to 300 lbs. of thrust in any direction, resulting in a “Total Degree of Freedom” vehicle. In addition, a unique tether system is designed for low drag and high strength, allowing for unrestricted vehicle movement.

The Bee’s structure is composed of carbon composite materials and engineering plastics, with less than 1 square inch of exposed stainless steel and titanium. The hull and fittings are designed for low maintenance and high reliability in any environment. The Bee has a displacement of 70 lbs. and a 24 lb. payload capacity. The light vehicle weight and maneuverability allow launch and recovery from small vessels in a wider range of weather than possible before.

The outstanding control and thrust capabilities of the Bee give the vehicle unsurpassed ability to apply a variety of tools in powerful ways. The thrust capability can enhance the operation of a gripper by applying up to 300 lbs of force at any angle or even rotationally. The vehicle stability system allows for the precision application of water jetting.

Versions of the “Bee” have been designed to handle specific tasks, with ship hull inspection and dam inspection as the primary mission for “Inspector Bee”.

“Inspector Bee” is designed for applications in ship husbandry and security (inspection for ordnance and contraband). Standard equipment includes a low light color camera, with interfaces other equipment such as additional cameras, lighting, sonar devices, altimeters, NDT devices, cathodic probes, and other instruments. Provision is made for the attachment of a variety of tools including grippers, collection bottles, and water jetting systems.

All versions of the “Bee” rely on the SonicWorks APNS as the primary positioning and navigation system. The vehicle also uses an integrated inertial guidance module for system backup. With the addition of the Robotic Control System, and SonicWorks’ precision laser/optical Hull Contouring system, “Inspector Bee” provides the capability to fully automate a ship hull inspection operation.

The APNS with RCS can be configured to automatically scan a ship’s hull or other underwater structure by following a pre-programmed flight path. The pilot can establish waypoints for the vehicle scans and increment or step the base position to fly the next scan. The APNS with RCS, by precisely monitoring and maintaining the vehicle’s position, ensures that the scanning process fully covers the inspection area, with no holes or gaps. The RCS setup for automated scans can use physically established waypoints, manually entered waypoints, CAD model overlays, or combinations of all three. Curved surfaces may be traversed with the Hull Contouring option, which allows the vehicle to maintain position at a prescribed distance from the hull, normal to the plane of the hull, for precision application of NDT probes or other inspection equipment.