KVH

White Paper

Solving Navigation Challenges of Subsea Vehicles Through Sensor-fusion to Support Advanced Vehicle Control

Greensea Systems adopts KVH Industries' 1750 IMU to create accurate, affordable inertial navigation solutions for subsea remotely operated and autonomous vehicles

KVH FOG FIBER OPTIC GYRO

APPLICATIONS STUDY
Sensor-fused Advanced Control and Navigation Systems

The 1750 IMU is an ultra-compact, extremely precise inertial sensor system ideal for autonomous applications where size, weight, and power consumption must be minimized.

Situation

Driven by a desire for cost-savings and improved efficiency, engineers working with autonomous underwater and remotely operated vehicles (ROVs) are incorporating greater amounts of sophisticated technology, along with the capacity to support a multitude of advanced payloads and sensor packages including high-definition cameras, Doppler Velocity Logs, intervention tools, and much more. The result is Observation/Inspection class AUVs and ROVs capable of accomplishing complex missions that previously required the use of large and much more costly Work-class platforms.

Challenge

One of the biggest challenges facing underwater vehicles of any size is reliable navigation and control. Obtaining navigation data from the Global Navigation Satellite System (GNSS) is not an option for underwater vehicles, because seawater is opaque to electromagnetic signals, so other methods, such as north-seeking systems and dead reckoning, are now being employed. While naval submarines and some very large Work-class ROVs rely on expensive, large, heavy, and power-hungry north-seeking navigation systems, this is not an option for the smaller Observation/Inspection-class autonomous underwater vehicles and ROVs.

> "The KVH 1750 IMU has hands down the best performance of any IMU at its price point. The 1750 is compact and has superior gyros, which is great for small, observation class vehicles."
>
> **Ben Kinnaman**
> President and CEO of Greensea Systems, Inc.

Currently many smaller vehicles employ a dead-reckoning navigation system using a Doppler Velocity Log and surface GPS for a heading reference. This system estimates the position of the vehicle based on its previous position (or fix) and its course and speed over a known interval of time. Dead reckoning is subject to significant errors since both speed and direction must be accurately known at all times for position to be determined accurately. Subsea applications also introduce other hurdles not realized on land or in air environments. These include current-induced "crabbing" and heave, which can be addressed with the integration of an inertial sensor.

Solution

Greensea Systems developed a cost-effective inertial control system (INS) using the KVH high-performance fiber optic gyro-based 1750 inertial measurement unit (IMU) as its core processor. The Greensea INSpect GS4 INS is designed for inspection class ROVs, offering a solution to challenging navigation problems and enabling advanced vehicle control. Greensea's navigation system is based on KVH's 1750 IMU and Greensea's proprietary algorithms and software for processing large amounts of data including inertial data, position, attitude, pitch, roll, heave, speed and heading.

The versatile KVH 1750 IMU used in Greensea's navigation and control system can be configured to accept data from multiple aiding sensors including:

- Ultra Short Base Line (USBL)
- Doppler Velocity Log (DVL)
- Long Baseline Survey (LBL)
- GPS
- Odometers
- Altimeters
- Alternative orientation sensors

The flexible Chiton ROV can pass through curved structures, and then become rigid to move through the water by using hydraulics to control a series of ligaments.

Greensea's pioneering navigation and control solutions shorten the distance between what the operator is thinking and what the ROV is actually doing. The fully integrated inertial navigation solution with integrated depth and heading-aiding sensors accepts data from any available navigation-aiding sensor including USBL, LBL, DVL, and GPS to aid in the final navigation solution. Using the optimized navigation solution and Greensea's intelligent vehicle control system, the ROV can now perform advanced tasks for the operator.

The high performance KVH 1750 IMU in Greensea's INSpect GS4 provides an accurate vehicle position necessary for advanced automation capabilities such as station keeping, dynamic positioning, target tracking and full mission execution. Operators gain situational awareness because instead of focusing on flying the vehicle, they can take a step back and get a big picture view of what the data is telling them.

Greensea customer, Geoff Cook, Operations Manager for SeaView Systems, Inc. notes, "Not only does Greensea's control system enhance the efficiency of the project, it enhances the efficiency of the ROV by reducing the wear of the thrusters. Integrating the control system will reduce project costs and vehicle maintenance."

Using Greensea's OPENSEA™ software engine, the INSpect GS4 fuses data from available navigation-aiding sensors with the high input rate KVH 1750 IMU to produce an accurate and stable "state of the system" estimate. The INSpect GS4 supports up to eight aiding sensors, and is configurable through the Greensea user interface application. The entire navigation and control solution is built on a flexible and scalable software/hardware architecture to enable Greensea to add capability to the system through the addition of plugin software modules. These modules add automation, autopilots, and mission planning to the basic inertial navigation solution.

The KVH commercial off-the-shelf 1750 IMU is designed to deliver advanced performance and flexibility for demanding applications such as Greensea's navigation system for AUVs and ROVs, in which size, weight and power consumption must be minimized. The unit combines very low noise accelerometers with the precision of KVH's DSP-1750 fiber optic gyros (FOGs) – the world's smallest high-performance FOG. Utilizing proprietary algorithms, the 1750 IMU provides the INSpect GS4 with extreme accuracy and stability, and the ability to program the data output rates up to 1000 Hz.

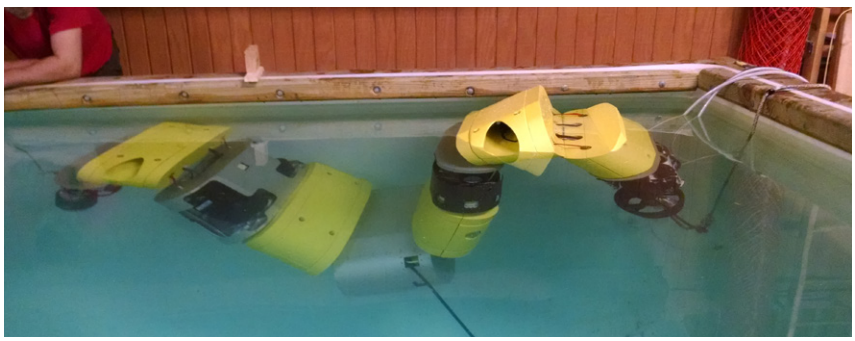
Greensea Systems Control Engineer, Colin Riggs, supervises a sea test of a SeaBotix ROV inspection class vehicle with the Greensea INSpect GS4 featuring the KVH 1750 IMU.

"Integration into our INS couldn't be simpler or more precise. The mechanical integration was easy, too. KVH's engineers were prompt and responsive in all communications. They've got a team of true pros."

Ben Kinnaman
President and CEO,
Greensea Systems, Inc.

The 1750 IMU also provides Greensea engineers the capability to tailor the communications of the inertial solution to create the desired message output from both the gyros and the integrated accelerometers. Greensea's navigation and control system also requires large amounts of data to be processed quickly and accurately. The 1750 IMU offers flexible RS-422 asynchronous communications with adjustable baud and data rates. This enables Greensea engineers to minimize the communications latency. As a result, this solution delivers accurate information to the navigation system faster, increasing position accuracy.

Greensea's Navigation System with Integrated 1750 IMU	
Miniature Integrated INS with 1200 kHz DVL, FOG-based IMU, and 0.01% Depth Sensor	
Positioning Accuracy	0.3% of distance traveled, RMS
Resolution	0.05m
Length, Diameter	26cm, 13.5cm
Weight (in water)	2.2 kg
Power	<10W, 24VDC
KVH 1750 IMU by the Numbers	
Bias instability	(max, 25°C) ≤0.1°/hr, 1σ
Angle Random Walk (ARW)	≤0.012°/√hr
Bandwidth	(-3dB) ≥440 Hz
Baud Rate Selectable	9.6 Kbps to 921.6 Kbps
Weight	(max) 0.7 kg (1.45 lbs)



The Chiton by SeaView Systems is a flexible ROV designed to inspect a section of the Rondout Aqueduct that feeds water to New York City.

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About Greensea Systems

Founded in 2006, Greensea develops technology to improve the relationship between man and machine, and to make the work they do together more effective, more efficient, and more powerful. Greensea develops advanced inertial navigation and automation systems for unmanned underwater vehicles (UUV). Using the openSEA software library and modular openSEA Suite architecture, Greensea provides software packages for AUVs, ROVs and stand-alone sensors to the commercial, military and scientific underwater communities. Greensea Systems, Inc., 10 East Main Street, PO Box 959, Richmond, Vermont 05477. Web: greenseainc.com. Phone: 802.434.6080.

About KVH Industries

KVH Industries is a premier manufacturer of high-performance sensors and integrated inertial systems for defense and commercial guidance and stabilization applications, having sold more than 19,000 TACNAV® systems and 87,000 fiber optic gyros. The company is also a leading provider of in-motion satellite TV and communications systems, having designed, manufactured, and sold more than 175,000 mobile satellite antennas for applications on vessels, vehicles, and aircraft. KVH is based in Middletown, RI, with research, development, and manufacturing operations in Middletown, RI, and Tinley Park, IL. The company's global presence includes offices in Belgium, Brazil, Cyprus, Denmark, Hong Kong, Japan, the Netherlands, Norway, Singapore, and the United Kingdom.

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