# How Automation and Advanced Control Significantly Increase the Capabilities of Observation-class ROVs

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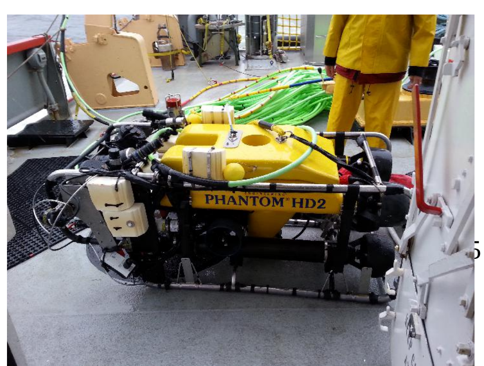
*Abstract* - **Now more than ever, observation-class ROV operators are finding automation and advanced vehicle control provide them the tools needed to allow them to perform their jobs more efficiently and deliver customers greater capabilities. The demand for observation-class ROVs is growing, manufacturers have met the demand, now technology must deliver tools to aid the operation of these complex systems. The effectiveness and intuitiveness of the operator interface is critical to the success of observation-class ROVs because with greater payloads and mission scope, operators have more to manage. Advanced control functions, such as autopilots, dynamic positioning, and sonar or vision-based target-relative control are critical because they provide vehicle stability and ROV performance exceeding traditional operating modes. Automation gives personnel the opportunity to preplan dives and execute jobs proficiently, consistently, and repeatably. The most effective implementations of this technology, like the control system developed by Greensea Systems, will employ a comprehensive solution for pilots that fuses sensor data, vehicle data, navigation, and control into a single, easy-to-use workspace.**

## 1 Introduction. Cramming More Components Onto Observation Class Vehicles.

**Do more with less.** In 1965, Gordon Moore wrote "Cramming More Components Onto Integrated Circuits." The short article introduced the world to the power of integrated electronics and described how they would rapidly allow more and more complex tasks to be achieved in smaller spaces. The content of the article later became



famous as Moore's Law. This concept, proven true over time, has set an industry expectation for doing more with less (less money, less size, less weight, less power, etc.).

Today we find ourselves cramming more components onto observation-class vehicles. Facilitated by advanced manufacturing technologies such as MEMS (Micro-Electro-Mechanical systems) and nanotechnology, the global underwater sensors market is creating smaller and more energy efficient technologies. The smaller the instruments, the more payload we can add to our observation-class vehicles. Today this includes commercial off the shelf DVL systems, probe handlers, pitch and roll sensors, fiber-optic multiplexers, high-definition cameras, and much more.

I ... tion-class vehicle With

**Manufacturing provided vehicle capabilities but did not give the operators the technology to fly them.**

Industry investment in capability-rich components for observation-class vehicles is driving expectations for lower mission costs and higher-quality data, but the components alone cannot meet expectations. Observation-class vehicles are extremely difficult to operate because of their high truster-to-mass ratio and drift. And, unlike work-class vehicles with 3+ operators and extensive staff, the observation-class vehicle is usually manned with one operator – no matter how many components are on the vessel. This has created an information bottleneck; there is a limit to the effectiveness of one operator.

**Automation is essential for utilization of the observation-class vehicle's capabilities.**

To meet industry expectations, observation-class vehicles need automation. Automation and advanced controls provide the solo observation-class pilot with a virtual team, dramatically expanding capabilities as well as providing unparalleled precision. With automation and autopilot controls, the operator can be more aware of their surroundings and add more value to the mission. The combination of the high accuracy of automation and the more situationally-aware operator provides the significant improvement in data the industry is looking for from observation-class vehicles.

This paper describes the importance of automation to advance the utilization of smaller vehicles for increasingly complex tasks.

## 2 The benefits of automation

The subsea industry has been pushing for automation in smaller vehicles because it provides significant benefits – benefits readily understood in the aerial and ground robotics industries where automation is more prevalent. Higher order benefits of precision, risk management, and cost control cut across all industries but there are also many specific and unique benefits associated with automation.

**Repeatable missions.**

Arguably one of the most valuable benefits of automation is repeatable missions. With automation, operators can run the exact same mission again and again and again. With each mission the data collected is directly comparable, making it significantly easier to identify similarities and differences across missions. This is a significant benefit to industries focused on monitoring change over time such as port

and harbor security and science. It is also extremely valuable for organizations required to monitor infrastructure such as oil & gas and governmental agencies.

**Lower risks.**

Military spending on automation/robotics has been steadily increasing as they strive to minimize the risks facing their service people. There is particularly high demand for observation-class ROVs with automation packages to replace human divers in MCM (mine counter measure) activities. With automation, missions can be pre-planned, targets can be tracked, and the ROV can hoover with extreme precision relative to their target while the pilot collects highly accurate data and video. Automation has the clear potential to reduce risk in any offshore situation, especially those involving divers.

**Lower costs.**

Automation of observation-class vehicles can also lower financial risk. The current costs for a work-class vehicle to be offshore are substantial. Using automation, observation-class vehicles become a more powerful tool while incurring significantly less costs to operate, requiring smaller ships, smaller crews, and smaller handling systems. Automated ROVs with larger payloads can now become a viable alternative to larger ROV systems.

Cost-savings associated with efficiencies of smaller vehicles is particularly attractive to the oil and gas sector which has been under pressure due to falling oil prices. According to BBC News, "Research from the investment bank Goldman Sachs predicted that they (oil and gas companies) would need to cut capital expenditure by 30% to restore their profitability at current prices."2

**Precise navigation**

Military and other security agencies are also eager to use automated observation-class ROVs because of their precise navigation on small littoral vehicles with respect to objects of interest. This is of increasing importance as we see a worldwide shift of navies towards focusing on littoral region patrols and port security versus deep ocean operations. The nature of port and shoreline security requires small, lightweight, and man-portable UUVs. Automation dramatically improves forward observation, reconnaissance, mine countermeasures, ocean rescue and port security. Precise navigation is also imperative for tunnel inspection, something requiring the combination of small and accurate.

**Decreased operator fatigue; longer mission life**

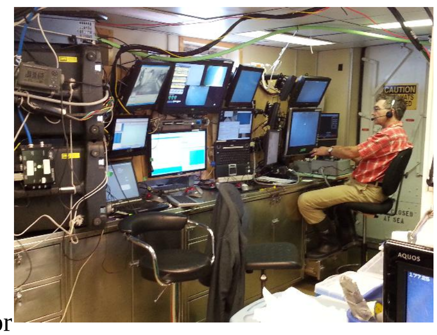
Finally, a benefit that cannot be underestimated is the ability to decrease operator fatigue. Automating vehicle functions decreases the operator stress and allows them to be more aware of their surroundings. New situational awareness by the operator reduces risks associated with the mission and can improve its overall success. Because observation-class operators are usually flying solo for 12 hours, automated systems can provide a virtual team supporting the operator throughout the day.

## 3 An overview of the automated control system

The fully-automated control system is comprised of three feature sets: integrated navigation, autopilots and automation.

**Integrated navigation.**

Integrated navigation fuses the data from multiple sources into one integrated workstation – all the vehicles payloads are on one screen providing significantly higher quality data.  For many operators this means they no longer have to toggle between 4+ monitors and can now rely on one single screen for all their information including sonar or vision navigation and positioning. Adopting a universal navigation and control system for the vehicle is the first step toward automation and maximizing the potential of the ROV.



Integration provides a common place to gather, log, and playback data. There is a dramatic improvement in the data quality mined from every mission because there is more accurate navigation and positioning (including geographically correct visualization) as well as mission planning, logging and reporting. Hypak/Winfrog is no longer necessary when using an integrated navigation solution.  This option is available for almost all vehicles including small inspection class vehicles with limited sensor sets.

NEED PHOTO OF INTEGRATED NAV TO WORK SIDE-BY-SIDE WITH OTHER PHOTO (BEFORE/AFTER)

**Autopilots.**

Autopilots provide operators with a virtual team and enhance stability for more accurate and reliable data. Because inspection class vehicles manned with a single operator now have functionalities previously reserved for work class vehicles manned with 3+ operators, the smaller vehicle's potential efficiency has been limited.  Autopilots relieve that problem by providing a computer-generated team for the sole inspection class vehicle operator. Autopilots help prevent operator fatigue and allow the operator to have higher levels of situational awareness. They also optimize the vehicle by providing station keeping, dynamic and sonar-based positioning, target tracking (including bottom following) and stabilization (video and sonar).  This option is a good choice for vehicles with moderate to high sensor sets.

Autopilot controls provide operators with single-touch vehicle positioning for:

- Auto Altitude
- Auto Depth
- Auto Pitch/Roll
- Auto Heading

- Auto Velocity
- Auto Descent/Ascent

Within autopilots, operators also gain dynamic positioning including heading job and depth/altitude jog.

**Automation.**

Automation helps operators get the most out of their ROV with precise, consistent data that is repeatable across time and operators. The most important aspect of autonomy is the ability to repeat missions (and their resulting data sets) again and again and again. Operators can pre-plan their data and repeat at will. This is highly valuable for riser or pipeline inspections, port and harbor inspections, and mine reconnaissance. Now, you can load up what was done before and run the same mission. The data sets will be identical. This capability is important for vehicles used for repeated inspections of all kinds.

PAGE 13 – a common workspace for multiple missions, vehicles and sensors.

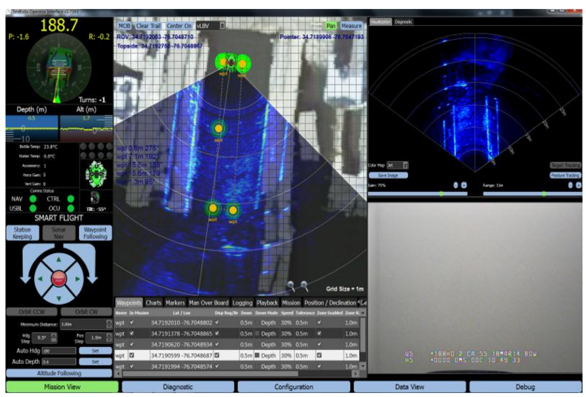
*Sonar*

Visualization

*Heading & Attitude*

*Depth /*
*Altitude data*

*Autopilot controls*
*Single-touch vehicle*
*positioning*




*Imported targets from survey data*

**Performance data.**

Although subsea automation is not as prevalent as aerial or land automation, there are several hundred automated subsea vehicles operating today, many of which are observation vehicles. Following is typical performance data for an observation-class vehicle.

| Typical Performance Data* | |
|---|---|
| Stabilization | 0.5deg RMS roll, pitch error |
| Heading control | 0.25deg RMS error |
| Vertical control | 0.1m RMS error |
| Positioning | 0.1 RMS error |

| | |
|---|---|
| Velocity | 0.25m/s RMS error |

**Dependent upon sensors and actuators.*

## 4 Conclusion

Working on it...

## 5 Acknowledgements

Greensea would like to thank our industry partners and the early adopters of this technology: Tritech, Kongsberg Mesotech, SeaBotix, and Teledyne Benthos.

The development and adaptation of this feature-based navigation system for micro mechanically scanning sonars, such as the Tritech Micron Sonar, is based upon work supported by the Defense Advanced Research Projects Agency (DARPA) under Contract No. D14PC00137. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Defense Advanced Research Projects Agency (DARPA); or its Contracting Agent, the U.S. Department of the Interior, Interior Business Center, Acquisition Services Directorate, Division III.

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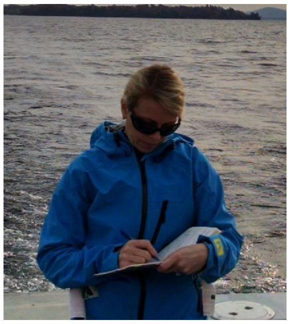
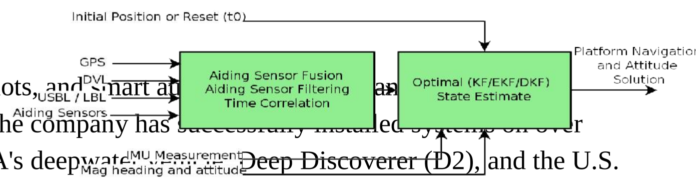
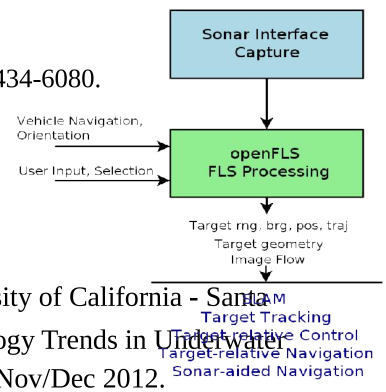


Marybeth Gilliam is the CMO and Director of Sales of Greensea Systems, Inc. Marybeth worked in advertising, marketing, product development, and market research for over 20 years in both New York and San Francisco before joining Greensea. She has a degree from The University of Vermont.

## 7 Greensea Systems, Inc.




Greensea develops integrated navigation, intuitive autopilots, and smart at[illegible] an[illegible] Vehicles. Since opening in Richmond, Vermont in 2006, the company has [illegible] over 400 vehicles, including high-profile ROVs such as NOAA's deep[illegible] Deep Discoverer (D2), and the U.S. Navy's CURV 21. Greensea now offers a commercially available workspace based on the powerful openSEA core technology that can optimize any size vehicle.




To learn more, visit greenseainc.com, find us on Facebook, or give us a call at 802-434-6080.

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While the power of integrated electronics drives manufacturing advancements in SWaP (size, weight and power) creating increasing capabilities in smaller packages,

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Needs a virtual team.

Needs to harness the power of the components to provide better utility – better data to

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## 4 Improving communications between ROVs and operators

Technical significance aside, Greensea's products offer clear value to the offshore industries by providing a means to operate remote systems with more efficiency, effectiveness, precision, and intuition than ever realized. While these are products are based on disruptive technologies with no current market analog, adoption of these products will be widespread and quick based on the value they offer. As powerful operator interfaces, automation, and precise positioning are now commonplace in other industries ranging from consumer goods to aviation, so too will they be in subsea industries such as ROV and AUV operations. Greensea's technologies and products are poised to set the standard and brand of automation, navigation, and operator interfaces subsea. The Phase I Greensea technology, Endal, is currently in the SeaBotix vLBV ROV and being integrated into several work class ROVs (see illustrations 24, 25, 26).

will enable the pilotwill will need to become easier to pilotdramatically improve the communications and intervaceautomate

As industry invests in capability-rich components for observation-class vehicles, their expectation is dramatically improved performance, or put another way, excellent quality data. The output

describes the rapidly increasing capabilities of observation-class ROVs – vehicles experiencing significant growth because current shift towards

really good data. vehicle's capabilities improve, the industry expectation is to see an equal improvement in data. Including inspection class ROVs want to do more with less. The industry has answered that demand… operators are findiing applications for smaller vehicles manufactures are answseing

More capabiltiy int these small packages than we have ever found before

The resutl is obs class that have tone os payload and being used in complicated situations. Short pat ht o why we are hre.

human bottleneck

computing

minaturization , of  seen the important advancement of  Today we find While this has contributed to some extremely feature-rich small vehicles,

However, while sensor technology and manufacturing have accom

This concepts presented in Moore's article  participates in the rise of the observation-class vehicle.

are not so different.   We are “cramming” more and more increasingly smaller components onto the vehicle requiring an integration.

This paper describes the rapidly increasing capabilities of observation-class ROVs – vehicles experiencing significant growth because current shift towards The world is accustom to doing more in increasingly smaller spaces.  Observation-class ROVs

*“The object was to miniaturize electronics equipment to include increasingly complex electronic functions in limited space with minimum weight. “*

Observation-class vehicles are experiencing the “cramming of components” part but only recently are they benefiting from integration.

Today we could just as easily call Observation-class vehicles are a by-product of the same.  Manufacturing has

Observation-class vehicles have become increasingly popular because they are less expensive to operate.  Critical payload components  critical payload components – in real cost as well as to operate.   due in large part to both the miniaturization of critical payload components and pressure from operators due to the high costs of the support vessels required to handle large vehicles.

Industry has been pushing for better capabilities in smaller vehicles. Some of the increasing demands have been driven by changes in operational behavior such as the worldwide shift of navies towards focusing on littoral region patrols and port security versus deep ocean operations. The nature of port and shoreline security requires mall lightweight, and man-portable ROVs.

The commercial offshore industry continues to invest heavily in observation-class ROVs because they are less costly to operate. They require smaller ships, smaller crews, and smaller handling systems. As these smaller ROVs increase the sophistication and variety of their payloads, they are becoming a viable alternative to larger ROV systems.

Cost-savings associated with efficiencies of smaller vehicles is particularly attractive to the oil and gas sector which has been under pressure due to falling oil prices. According to BBC News, “Research from the investment bank Goldman Sachs predicted that they (oil and gas companies) would need to cut capital expenditure by 30% to restore their profitability at current prices.” [2]

## Operator Bandwidth

The number and complexity of inspection class ROV components are advancing faster than their human interfaces.

Inspection class ROVs can now be equipped with multiple high-definition cameras, profiling sonars, multibeam sonars, EM systems, cable tracking systems, intervention packages, and science skids. The expansion of payloads has been immense. Many of these payloads require precise navigation and control to provide high-quality data. This has created significant challenges for operators as they attempt to pilot the vehicle and operate payloads.

The potential of our machines has become limited by what one person can do alone. While larger work class vehicles with large payloads have 3+ people operating the vehicle, the inspection class ROVs are usually flown by just one operator. The lone operator trying to navigate across multiple disconnected screens is stretched to fly the vehicle, leaving very little opportunity to provide situational awareness for the mission.

oday we find ourselves cramming more components onto observation-class vehicles. This is driven by an industry asking us to do more with less and facilitated by advanced manufacturing technologies such as MEMS (Mic ntegrated navigation fuses the data from multiple sources into one integrated workstation. For many operators this means they no longer have to toggle between 4+ monitors and can now rely on one single screen for all their information including sonar or vision navigation and positioning. A vast benefit in itself, this process of combining all data sources is important for obtaining a fully-automated system. Integration provides a common place to gather, log, and playback data. There is a dramatic improvement in the data quality mined from every mission because there is more accurate navigation and positioning (including geographically correct visualization) as well as mission planning, logging and reporting. Hypak/Winfrog is no longer necessary when using an integrated navigation solution. This option is available for almost all vehicles including small inspection class vehicles with limited sensor sets.

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