STATEMENT OF DAVIS S. SANFORD

NAVAL UNMANNED & FUTURE TECHNOLOGIES

ROLLS-ROYCE MARINE NORTH AMERICA, INC.

BEFORE THE

UNITED STATES SENATE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

SEPTEMBER 13, 2018

Chairman Thune, Ranking Member Nelson and Members of the Committee, thank you for allowing me to come before you today to discuss innovative technologies in commercial and naval unmanned and autonomous surface vessels; and to offer a perspective on the current opportunities and obstacles that industry anticipates as these next generation ships and systems move closer to becoming a widespread reality.

Rolls-Royce is one of the world's leading industrial technology companies pioneering cutting-edge technologies that deliver the cleanest, safest and most competitive solutions to our planet's vital power needs across land, sea, and air.

With operations in the United States for over 100 years, Rolls-Royce has more than 6,300 employees across 27 states; producing state-of-the-art engines and propulsion systems. In addition to powering some of the world's foremost civilian aircraft, we provide U.S. engineered power systems and equipment for a number of Department of Defense aviation platforms, including the C-130 transport; the V-22 Osprey tilt rotor; the unmanned Global Hawk and Triton; and the short take off and vertical landing (STOVL) variant of the F-35 Lightning II.

In addition to powering 70 international maritime forces, and on over 30,000 commercial vessels, Rolls-Royce is a proud provider of power products to the United State Navy and Coast Guard. Our hardware can be found on the Nation's most capable ships, including the *Nimitz* and *Ford* class aircraft carriers; *Arleigh Burke* and *Zumwalt* Class destroyers; both variants of the Navy's Littoral Combat Ships; and the Coast Guard's National Security, Offshore Patrol, and Fast Response cutters. In fact, more than ninety percent of the Navy's battle force ships are driven by propellers crafted in the Rolls-Royce propeller foundry in Pascagoula, Mississippi.

Rolls-Royce is at the forefront of innovation and experience in the maritime sector. Today, the Rolls-Royce Ship Intelligence group already delivers multifaceted enhancements in vessel performance, operation and safety, and it will continue to play a role in redefining the industry as we move toward a more remote and autonomous world. Rolls-Royce believes remote and autonomous ships will be safer, more efficient and cheaper to build and operate. Our unrivalled expertise and equipment knowledge will help transform today's vessels for tomorrow's needs.

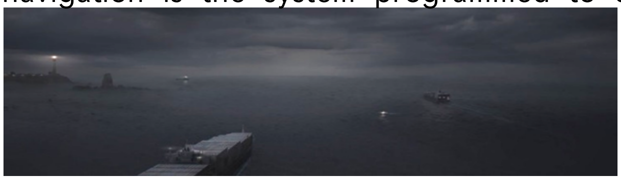
Current Developing Technologies

Worldwide, there are over 100 companies working on small unmanned surface vessels, ranging in size from a few feet up to 50 feet in length. Each ship has demonstrated differing abilities to operate without human input in applications ranging from recreation and commercial, to defense and security operations. Looking to the emerging unmanned surface market, these vessels are in the medium to large size, typically over 90 feet in length. These vessels are considerably more complicated, and, when manned, have licensed mariners operating the bridge, and a separate set of licensed marine engineers operating critical ship systems, including engines, electrical plant, cargo handling, and ballasting operations.

When discussing the technologies under development, it is useful to think of them in two categories that relate to how a manned vessel operates: bridge autonomy and ship system autonomy.

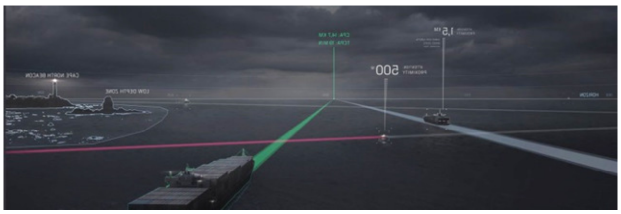
Bridge Autonomy

Bridge autonomy technologies will reduce or replace activities typically performed by a vessel's deck officers. These activities include; mission planning, autonomous navigation, situational awareness, and communications. Mission planning defines where the vessel is going and how it will get there. Autonomous navigation is the system programmed to execute the mission plan, including adherence to the International Regulations for Preventing Collisions at Sea (COLREGS), cognizance of navigational aids, and obstacle avoidance.



Reduced Visibility Environment

Situational awareness tools include radar, LiDAR (light detection and ranging), video, thermal imaging, and Automatic Identification System (AIS), allowing the vessel to identify and avoid other vessels and obstacles.

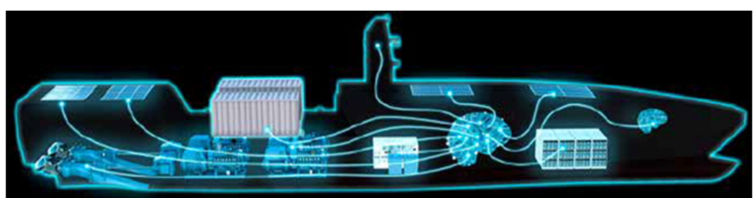


Intelligent Awareness

The situational awareness data feeds into the autonomous navigation system, enabling it to safely execute the mission. Despite the vastness of the open ocean, the sea is a constantly moving body, with vessels operating at different speeds and traveling in all directions. This greatly increases the complexity built into an unmanned vessel so that it may operate autonomously.

Autonomous Ship Communications includes transmissions with other vessels, both manned and unmanned, via VHF, and communications to shore facilities through VHF, cellular networks, and/or satellite communications. It is critical for cyber security be built into all autonomy systems at the beginning to ensure that the vessels cannot be hacked or taken over by third parties.

Ship System Autonomy



Ship System Autonomy Network

Ship system autonomous technology applications reduce or replace activities typically completed by the vessel's marine engineers. The primary system performing this function is an autonomous machinery control system, designed to execute the decisions that a typical on board marine engineer would make based on standard bridge operations. These include but are not limited to, speed and direction, maintenance of ship system requirements, equipment availability, and system troubleshooting, among many others. The machinery control system uses energy management, equipment health monitoring, propulsion control, and integrated platform management systems and other enabling technologies to monitor, control and direct the on board ship systems (ie power generation, propulsion, electrical distribution, ballast, lighting, lubrication, fuel, cooling, steering, and water).

Energy management technology monitors and compares the current operational profile of a vessel and assesses how it might more efficiently operate. An example of this would be an adjustment of vessel speed to enable the propulsion plant to run at peak performance. Similar to equipment deployed in the Rolls-Royce powered civil aviation fleet, equipment health monitoring surveys the ship's systems to ensure that they are operating properly, and to identify potential issues that may forecast a system shutdown. A propulsion system equipment health monitoring system could identify a fault in an engine lubricating oil system, shutting the unit down to prevent an engine failure. Additionally, if an engine shut down could potentially result in the vessel's grounding, or result in a similarly dangerous situation, the autonomous machinery controller, through communication with the autonomous navigation system, could independently make the decision to operate the engine until the risk has passed.

The continued development and operation of ships with electric propulsion systems will lead to improved reliability, reduced maintenance, and improved energy efficiency throughout the ship. These technologies complement those being developed for the autonomous operation of unmanned surface vessels.

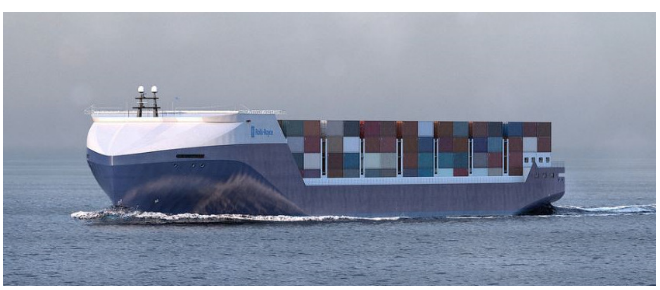
Shore Side Operations

Currently under development, shore side remote operating centers may have the capability of performing many of the operations and system maintenance functions for certain cargo ships and other vessels. These centers will be manned by professional mariners and engineers, on-hand to support unmanned fleet operations.

Roll-Royce Remote Operating Center Concept

As envisioned, mariners could monitor vessel operations from a supervisory position and take over remote operation of the vessel when near port, or if other circumstances require. It is also conceivable that harbor pilots will be able to take command of arriving vessels sailing into port, thus removing the risk associated with a pilot transferring to a ship at sea, and potentially improving the efficiency of bringing a ship into port. System monitoring, data analysis, and failure diagnosis of equipment operating on vessels at sea, performed by maritime professionals, may also be performed at these facilities.

Impact of Emerging Technologies



Rolls-Royce Autonomous Container Ship Concept

These technologies are expected to positively improve safety and increase efficiencies benefiting the marine industry. In terms of safety, it is notable that more than 70 percent[1] of all marine accidents are the result of human error or interference. By reducing or eliminating the number of people operating a vessel, it's expected there will be

[1] European Maritime Safety Agency Annual Report 2015

fewer accidents. However, autonomous ship systems are not failsafe and autonomous systems will not reduce the accident rate to zero as the acceptance and use of autonomous ships may also result in new types of accidents.

Cost savings will be another driver for the commercial industry to invest in autonomous vessels. Through improved vessel efficiency, reliability, and availability, it is estimated that transportation costs could decrease by 20 percent. Cost savings can be found through lower power usage and demand, fewer operating and hotel load systems, elimination of the deck house, and a consequent reduction in the number of systems requiring maintenance at sea.

Despite these advances, there are and will continue to be shipping activities that require a full crew, maintaining humans in the loop, particularly for shipborne activities that might be considered higher risk or labor intensive. Examples would include passenger vessels, oilfield service and crew boats, and ships carrying hazardous materials. In some of these applications, however, automating systems like navigation may still be possible.

In evaluating the impact of emerging technology, the improved quality of life for the mariner is a very important factor to consider. Instead of spending several months at sea and away from home, mariners will have the option to pursue a career allowing them to work shore side, returning home after a scheduled work shift. As autonomous ship systems make the inevitable transition from commercial to military applications, specialty vessels may be fielded and autonomously missionized or remotely operated for dangerous or repetitive operations. Examples include ISR operations in hostile waters, border security, search and rescue, and drug smuggling detection and interdiction.

Risks to Maritime Industry

The acceptance and adoption of commercial autonomous ships and ship intelligence systems carries both risks and opportunities for the maritime industry. The greatest risk may be that of a cyber-attack, whereby a foreign or independent actor takes control of an unmanned vessel for ransom, theft, or terrorist purposes. In addition to hardening shore side and shipboard control systems, vessels must also be designed to thwart or prevent ship boardings at sea.

There is also a potential impact to the number of licensed US mariners that may be at sea at any one time. With an increased use of automation and autonomous technologies for shipping and ship operations, licensed and trained mariners may spend less time at sea as opportunities are created for them to move off the vessel and into remote operating centers or other ship support activities. To fill the need for mariners in the autonomous ship space, maritime academies must adapt their curricula to meet demand for a new class of sailor.

Applications

Rolls-Royce is a technology leader in the field of autonomous shipping and ship intelligence systems, and is actively testing and refining its systems and capabilities. Rolls-Royce is collaborating with Svitzer, a global towage operator, in

Remote Control Svitzer Hermod Bridge— Rolls-Royce / Svitzer Remote Operating Center, Copenhagen

demonstrating the world's first remotely operated commercial vessel, the 91 foot *Svitzer Hermod* tugboat. The tug, located in Copenhagen Harbor, demonstrates the ability of a land based captain to remotely control a working boat and executing representative tugboat operations from a remote operating center at the company's headquarters.

Rolls-Royce has also engineered and installed automatic water crossing systems into vessels operated by Fjord1, a Norwegian passenger ferry company. These ferries, first delivered in 2017, provide autonomous, point to point, ferry service for passenger and vehicular traffic, and rely on a totally electric propulsion system. For these and other commercial vessels, Rolls-Royce developed and implemented complementary energy management and equipment health management systems.

In the not too distant future, the commercial industry is expected to adopt unmanned surface vessels for container ships, bulk carriers, and tugs. In the naval and defense market, unmanned surface vessels are already being studied for broader defensive and offensive operations, special operations, and fleet auxiliary ships. There are a number of companies developing technologies and systems for the next generation of commercial shipping. In fact the Norwegian company Yara is building the world's first autonomous and fully electric container vessel. It is expected to begin autonomous operations in 2020.

In the United States, DARPA and the U.S. Navy are leading the effort to develop and deploy unmanned surface, and subsurface, vessels for a variety of defensive operations, including anti-submarine, mine countermeasure, force protection and survey operations., The U.S. Navy through its ACTUV, Overlord, and other autonomous vessel programs is researching the limitations and capabilities of medium and large unmanned surface vessels, and how they will be utilized in future naval operations.

Barriers to Development

As companies move forward with the development of unmanned surface vessels, and shipping companies consider integrating autonomous ships and ship systems into their fleets, it's important to note that there are maritime regulations, or the lack thereof, that may hinder further development, and consequent adoption, of these technologies. For example, the U.S. COLREGS do not allow for the unmanned operation of a vessel. The Navy, however, has more flexibility in the deployment of autonomous boats or other vessels. The International Maritime Organization (IMO) has similar regulations prohibiting unmanned ship operations. Looking to the future, however, IMO is examining the issues surrounding autonomous vessel operations and is reviewing the universe of maritime regulations and how they might be adapted or amended to satisfy current limitations within ship operations and the International Convention for the Safety of Life at Sea (SOLAS) requirements.

With the exception of the Navy's national defense autonomous vessels work, much of the medium and large unmanned surface vessel development and testing is taking place outside of the U.S. Export control and other perceived restrictions on foreign technologies being imported into the U.S. have inhibited the transfer of autonomous ship technologies to the United States. Quite frankly, companies are concerned that technology brought into the U.S. will be unduly regulated and restricted from selling that commercial technology abroad. Obviously there is a need to control certain autonomous ship technologies that have military and national security applications. However, concern remains that commercial and defense autonomous ship technology will be looped into a generic category making export difficult hence dis-incentivising companies from investing in the U.S. As companies begin investing in autonomous ships and related technologies, including larger unmanned surface vessels, the insurance industry must also plan for and create products that will provide insurance for these vessels, during both development stages and eventual operation. Lloyd's Register is monitoring the performance of the Rolls-Royce and the Svitzer remotely operated tug to understand and evaluate this emerging technology. Within the U.S., insurance companies and regulators will soon need to take an active role in designing and implementing policies and regulation for next generation of passenger and cargo vessels.

As unmanned surface vessels move offshore, the availability of communication and data transfer bandwidths will be a major limiting factor for remote, shore side, autonomous ship operation centers, and their ability to monitor and visualize what is taking place on the ship. While satellite communications have improved greatly over the last decade, the bandwidth needed to exchange real-time information as is currently done with the Svitzer tug, could quickly escalate to a point countering any efficiency gains.

Closing Thoughts

It is critical for the United States and the domestic shipping industry to begin developing a roadmap to logically address both the opportunities for and the barriers to the development of medium and large unmanned and autonomous surface vessels.

Similar to unmanned aerial systems test ranges, to the extent possible, certain areas of our national waters might be delineated for unmanned and autonomous vessels testing. Isolated from recreational boating and cargo sea lanes, industry, with government support, could define a controlled area for testing with predetermined rules, regulations, and monitoring. This would simplify the process for notification and approval by regulatory bodies, including the Coast Guard and other state and local marine law enforcement agencies.

To support the development of unmanned and autonomous ship technologies in the U.S., the Federal Government and industry must collaborate on the development of new and modified export rules relative to unmanned surface vessel technologies. Doing so will enable easier flow of technology between trusted parties, and encourage further technological innovation and collaboration by the United States and its allies.

Once again, we thank the Committee for allowing us to brief its Members on the promise of unmanned autonomous commercial and naval vessels.