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Autonomy in Mine Countermeasures – An Overview of Single Sortie-Detect to Engage

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I would like to thank the Chair and the Host for the privilege to speak here today.

The goal of this brief is to increase understanding of how autonomy, when used appropriately, can enhance the ability of weapons to not only serve their intended, legitimate purposes, but also decrease timelines in an extremely time sensitive situation to protect people and assets from, in many cases, deadly, indiscriminate threats.

I will illustrate this point with an example of how the U.S. Navy is incorporating autonomy into countering naval mines.

It is important to understand a little about naval mines and the complexity of mine countermeasures, in particular hunting for and clearing naval mines, before diving into the Single-Sortie Detect To Engage (SSDTE) system.

I will first discuss a little history of US naval Mine Counter-Measures (MCM) and the challenges posed with countering mines in and under the water. I will then step through the SSDTE MCM system to illustrate how autonomy is being used to counter an often-indiscriminate threat, while abiding by the laws of armed conflict, and keeping people safely out of harms way.

From this point forward in this brief and any follow-on discussions, I will use the term “mine” to refer to naval mines.

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The Impact

The Strait of Malacca, pictured, is one of the busiest shipping lanes in the world and ports in the region are racing to capture cargo.

Mooney, Turloch, JOC Events, 14 Dec 2016 https://www.joc.com/international-trade-news/infrastructure-news/asia-infrastructure-news/malacca-strait-port-development-heating_20161214.html

There is a common saying in naval mine warfare… "Any ship can be a mine sweeper… once."

The fundamental goal of a naval minefield is to deny access and maneuver, not necessarily to damage or destroy a specific ship or submarine. Mines, or simply the psychological uncertainty of mines, can create intended effects even without firing. Just the suspicion or belief that mines might be present can stop the flow of sea traffic with impacts to trade and the global economy.

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As an example of the scale of the problem, more than 150,000 mines were laid in the Baltic Sea during both World Wars I and II, with an estimated 60,000 remaining still to be discovered. The fact that these mines still exist creates challenges in shipping lanes and underwater infrastructure.

More recently, beginning in February 2017 mines and water-borne IEDs were planted in the Red Sea, near the ports of Mokha, Midi, and Al-Hudaydah, sinking several vessels and both wounding and killing civilians.

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Arrayed against this global threat, the US Navy, along with our Allies, have put in place the people, platforms, systems, and technologies needed to defeat mine threats. The operational requirements as well as the capacities and capabilities needed for the mine-countermeasures mission continue to be addressed. The US Navy's mine MCM capability developments are focused on significantly decreasing the time it takes to conduct operations and to ensure that risk [posed by mines] remains low.

For the near-term, the legacy, in-service, platform-centric "MCM Triad" of dedicated Surface (SMCM) ships, Airborne (AMCM) helicopters, and Underwater (UMCM) capabilities—primarily Explosive Ordnance Disposal (EOD) divers and marine mammal systems (MMS)—brings proven capabilities to the game. Our strategy is to reduce timelines, reduce risk, and improve operational effectiveness by transitioning from ~~this~~ platform-based, sequential operations to unmanned modular MCM systems employing advanced sensors capable of parallel operations. This future Modular Mine Countermeasures Force will also have sufficient flexibility to deploy from a variety of ship platforms and shore facilities. These next-generation Modular MCM systems will counter quickly the full spectrum of mine threats, assuring maritime access, and maneuver at minimum risk—in short, a new MCM Force of advanced, modular airborne, surface, and subsurface technologies and systems with the ultimate objective being an autonomous single-sortie detect to engage capability.

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Now I will discuss the typical mine types, process of MCM, methods and tools of MCM, and the development of the autonomous SSDTE system.

There are several types of mines that must be countered.

Bottom mines are typically used in shallow water, but have certain applications in deep water and typically have one or more influence sensors to detect a ship overhead. For example, acoustic or magnetic “signature” sensors.

Moored mines can be laid in both deep and shallow water, float at or just beneath the surface, and can either have influence sensors or contact detonate when a ship runs into it.

Rising mines are typically in deep water and can sit at the bottom and raise themselves closer to the surface once their sensors identify a target.

Free floating mines were generally banned several years before WWI (in 1907), but were still used to a limited extent during both world wars. Modern mines are designed to render themselves inert within a few hours should they break free of their mooring. However, after a number of years under or in the water, those deactivation systems could become ineffective creating a dangerous floating mine.

Mines can be laid by numerous means, from aircraft, naval vessels, submarines, to even converted merchant vessels, as shown in the pictures above.
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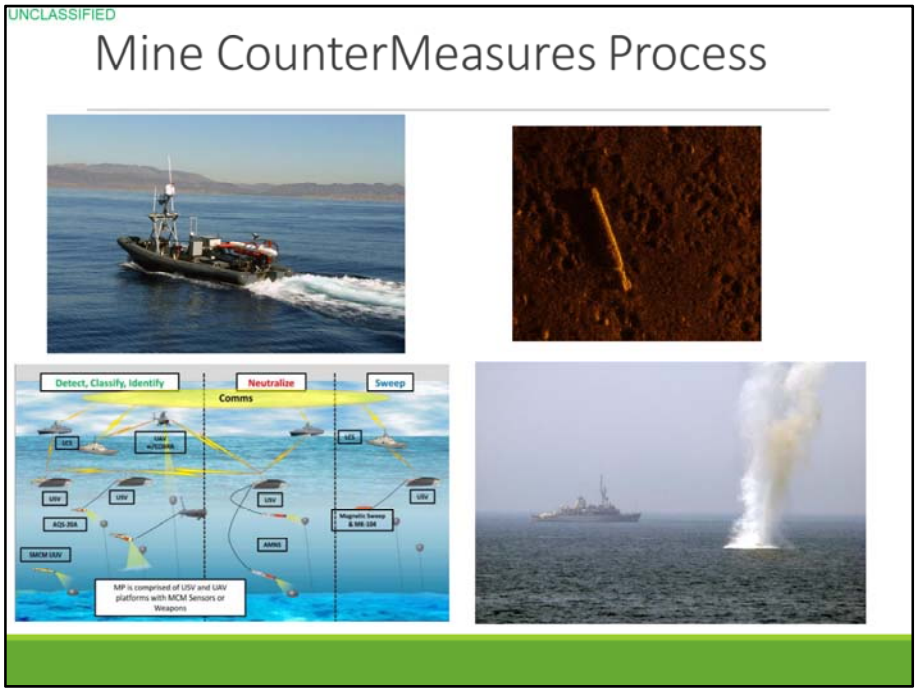

The entire MCM process comprises **five steps: (1) detection; (2) classification; (3) localization; (4) identification; and (5) neutralization**. Sonars are the primary means to detect and classify mine-like contacts. Once an object is detected and classified as a mine-like object, additional sensors are used to localize and identify the item as either a mine or a Non-Mine/Mine-Like Object (e.g., a discarded water heater or refrigerator). This identification step can be carried out by sonar, human divers, video cameras on unmanned undersea and surface vehicles (UUVs and USVs), remotely operated vehicles (ROVs), and/or laser systems.

Once a mine threat is believed to exist, the first phase in MCM is minehunting. This phase combines the detection and classification steps and provides a relatively high degree of certainty that an area of concern contains mines, is mine-free, or the risk of a mine strike has been minimized. Depending on the systems used, minehunting can contain several additional sub-steps. An area is first scanned with a sensor system. Once that step has been completed, data is returned to the host and post mission processing and analysis is conducted prior to moving on to the identification step. The processing and analysis phase can take an equivalent amount time as the scanning phase, or more. In some cases, the data will be sufficient to identify the object as a mine, but will often require another pass with additional sensors.
Depending on the localization accuracy of the mine-like object provided by the detect and classify minehunting system, the characteristics of the bottom (e.g., smooth or rough, silty or sandy), sediment type, clutter, and the depth of the water, among other factors, the process of reacquisition, identification, and finally neutralization of each mine-like contact can become

extremely challenging and can take several hours.

The identification step is performed on contacts classified as mine-like. Contacts that are identified as a mine must be rendered safe before the Navy mine countermeasures Commander, or the Coast Guard District Commander or Captain of the Port in a domestic mine/water-borne IED crisis, can declare a route or area cleared.
Once the object is identified as a mine, a neutralizer will be deployed to render the mine inert. Typically, neutralization of a mine is completed by ROVs, human divers, marine mammals, or "connected" Unmanned Undersea Vehicles (UUVs), which is a UUV that is connected to the surface and uses communications to show an image of the mine before the neutralizer is activated.

Depending on the mine threats discovered, or thought to exist, the final step may include influence sweeping of the area. Influence sweeping is an attempt to trigger primarily bottom mines that were not detected in the minehunting steps.

I stepped through all of this to demonstrate the complexity of MCM. No one will ever say MCM is easy and if they do, they have not done it before.

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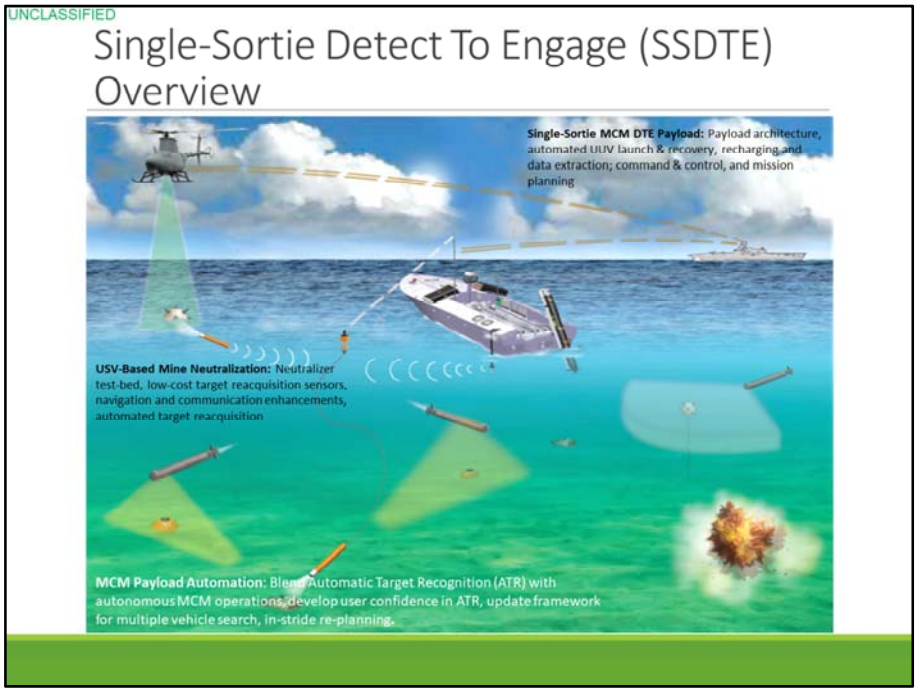

In order to address these long timelines and complexities, we have been working on a system of systems that utilizes autonomy to reduce or eliminate some of the most time consuming steps. The MCM Single Sortie Detect to Engage system consists of 2-4 highly flexible and adaptable systems that work together autonomously in order to shorten the mine hunting/clearing timelines. We also have the ability to operate several systems simultaneously, further reducing the time to clear a suspected minefield.

I will discuss one configuration of this system of systems approach. Additionally, I would like to note that since the system is in its early days, we will allow the system only to autonomously classify and identify mines that are in the water volume, typically meaning they are tethered to anchors and floating in the water column. As technology improves and trust is built in the system, it will be possible to expand the system to conduct missions against other types of mine threats and water-borne IEDs.

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For the configuration being discussed today, the primary component is an Unmanned Surface Vessel (USV) that carries minehunting UUVs and neutralizing systems. The USV is used for its fast transit speed, lower susceptibility to subsurface mine threats, and ability to act as a communications relay for the undersea systems to the host ship. This USV will first transit to the suspected minefield and launch the UUV minehunting system(s). While the UUV(s) are conducting their mission, the USV will continuously monitor the surface for traffic that might be entering the exclusion zone. Should a vessel enter the potential threat area, data will be sent to the host ship to relay warnings to the vessel.

The system uses automated algorithms enabling the in-situ planning, scheduling, and deconfliction of UUV missions. These algorithms also generate MCM plans to directly minimize risk and optimize performance based on the environment. The UUV(s) will begin to search the suspected minefield using the generated route, which is also based on the anticipated threat type(s), and is designed to ensure complete coverage of the assigned area. Once the UUV detects and classifies an object as a mine-like object, it will turn on its identification system and proceed to identify the object. If the UUV is unable to identify the object autonomously, it will send the data through the USV to an analyst on the host ship for a decision. Each time this happens, the data is stored in a library which continues to improve the automatic identification system. Once the UUV has completed its mission or is running low on power, it will return to the USV for recharging and full data download.

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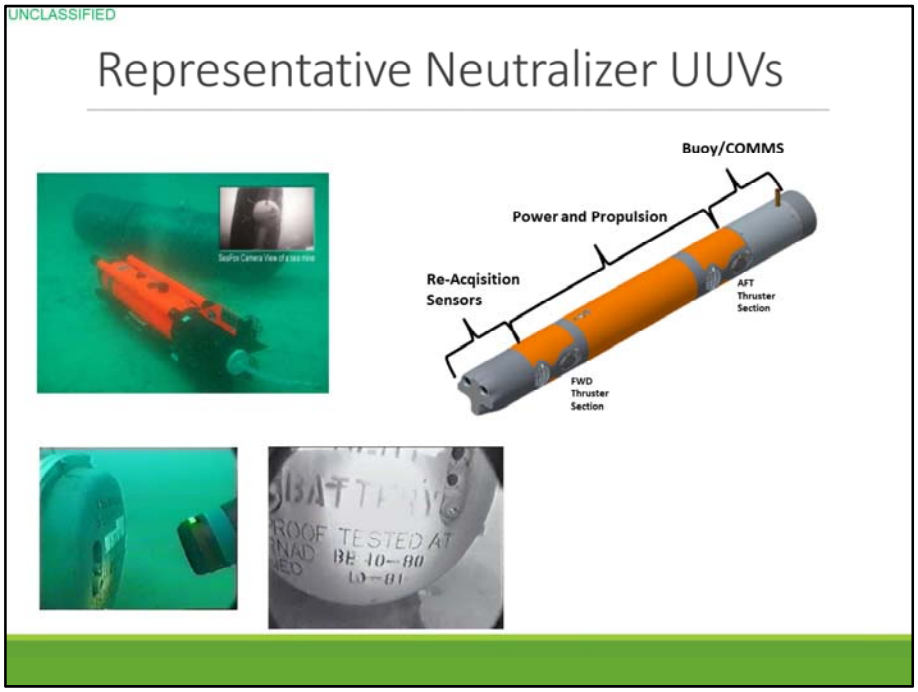

If the UUV identifies an object as a mine, it signals the USV to launch a neutralizer UUV. The system provides the location, depth and other relevant data to the neutralizer. Once the neutralizer is in the water, it deploys a communication buoy. The neutralizer will then autonomously proceed to the mine location and interrogate it again to ensure concurrence. At this point, once it confirms that all external systems (UUVs, USVs, and any other craft) are outside of the mine's threat radius, the neutralizer is able to autonomously render the mine inert. However, at this time, we still maintain a human in the loop to review the image of the mine and approve the final neutralization step.

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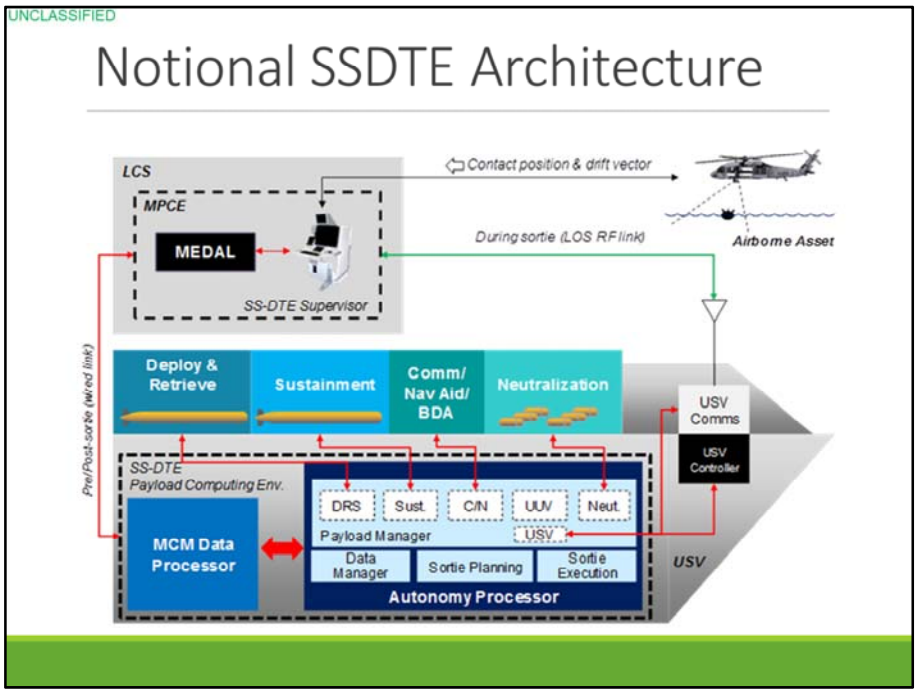

This system has tremendous flexibility, allowing us to be in the loop with every step in the process. Or if desired or necessary, we can allow the systems to conduct limited to full scope missions, autonomously. This would be fairly low risk endeavor as the waters will be closed to commercial traffic due to a potential mining event. Allowing the system to operate autonomously could decrease the timeline even more to clear a minefield/passageway; thereby, reducing the impact and threat to maritime traffic and trade.

In developing this system, we have taken a very deliberate crawl, walk, run approach. The system was designed to fully comply with US Department of Defense guidance, including, DoD Directive 3000.09 . Additionally, this system will allow the MCM Commander to abort the mission, should the need arise, even when the system is in autonomous mode.

I hope this presentation has helped increase understanding of how a highly complicated threat can be mitigated more expeditiously, safely, and efficiently by using autonomy. While I will not be providing any additional technical information on the systems, I do welcome your questions and discussion.

Thank you.