USV At-Sea Refueling

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PROBLEM STATEMENT

The Navy's Littoral Combat Ship (LCS) is the centerpiece for using unmanned maritime vehicles (UVs) for conducting mine warfare (MIW), anti-submarine warfare (ASW), and surface warfare (SUW). Unmanned Surface Vehicles (USVs) will be a common component to the packages being developed to carry out these warfare missions. Fuel capacity is a critical variable in the design trade-offs involving both the LCS and the mission packages, sensors, and communication equipment. The military effectiveness of the USVs and the host platform can be maximized by the implementation of a fueling system that can fuel the USV:

1. Before the mission begins while on-board the host platform.
2. After the USV is launched over the side of the host platform.
3. When the USV returns to the host platform without bringing the USV aboard.

A sailor would manually connect and disconnect the fuel hose in Fueling scenario #1. Similarly, the fuel connection in Fueling scenario #2 would be made by a sailor while the USV is aboard the host platform and the disconnection would be triggered remotely while the USV is in the water. Fueling scenario #2 extends the endurance of USVs without exceeding the weight capacity ratings of the Launch and Recovery system. Fueling scenario #3 requires connecting and disconnecting the fuel hose either remotely or autonomously.

Solutions should incorporate the entire system and process, including mother ship equipment, USV equipment, control algorithms, and. emergency disengagement. USV fuel tanks can be assumed to be half-full at initial launch. Both diesel and JP-5 fuels will be used by USVs. The solution must not include temporary manning of the USV. It must not add significantly to the weight of the LCS or USV. The solution must provide a reliable connection and fuel transfer in at least Sea State 3 with a goal of Sea State 4. The technique must prevent fuel spillage at any point during the operation. It must prevent fuel contamination in the expected dirty, high-water conditions. It must accommodate the configurations of mission systems on board a USV. There are three key parts:

1. A light weight fuel handling system for LCS. This must be compact and light weight in order to minimize the changes to the ship. This may include composite materials and other means to provide significant weight reduction to current fuel handling systems in the references.
2. The USV control algorithms needed to maneuver the USV in proximity to the ship in sea state 3 or less in order to safely fuel the USV. This also includes approach/station keeping algorithms and the monitoring and control functions aboard the LCS.
3. Safety. The system should be designed with fail-safe mechanisms to prevent fuel spillage, contamination of the fuel, and ignition of the fuel.

WHO CAN BENEFIT?

The Littoral Combat Ship will benefit from our system as it reduces the frequency of handling USVs thus increasing the mission availability of the LCS. Other surface combatants (DDG51, DDG-1000, LPD-17, etc) who may operate USVs or manned small craft can also implement the USV fueling system with minimal impact. In fact, any Navy, Coast Guard, NOAA, or commercial ship operator who uses small boats on a regular basis can benefit from the reduced manning requirement and low risk of fuel spill our system provides. The system is scalable from a simple manned refueling of a manned boat all the way to a completely autonomous refueling of a USV hundreds of miles from the nearest person.

BASELINE TECHNOLOGY

Current approaches are simple, based around the same technology used at gas stations since the introduction of the automobile. However, they require constant attention from a sailor to operate and monitor for spillage. With the development of USVs, there is no longer a need to have personnel aboard the craft. In some cases, it is very difficult to put a sailor onboard to refuel. Therefore, it is very desirable to be able to refuel without manning an otherwise unmanned craft.

The goal for the fuel transfer system is zero fuel loss to the environment. In addition to the costs associated with cleaning up a fuel spill, federal law provides for fines up to $25,000 per spill. The consequence of a fuel spill igniting would pose significant danger to both the USV and to the platform transferring the fuel. Therefore, safe execution of fuel transfer requires zero fuel loss and elimination of ignition sources.

TECHNOLOGY DESCRIPTION

USV Fueling System

Feature	*Advantages*	*Benefits*
Dry break coupling	Prevents fuel leakage upon disconnect	Minimizes risk of environmental impact
60 GPM transfer rate	Rapid refueling in <15 mins	Minimal impact to mission
COTS based components	Proven, reliable hardware	Minimum risk
Crawl, walk, run product development cycle	Enables system to be fielded in stages	Early implementation in the fleet
Refueling after launch without sailor aboard USV	Reduces manning requirement	Increases safety
Remote connection of refueling hose	Allows longer USV missions	Increased mission availability

CURRENT STATE OF DEVELOPMENT

Overview:

A dry-break fueling connector, based on a commercially available design from Snap-tite, was developed to meet both the manned and unmanned USV fueling CONOPS.   As with the previous phase the design puts the less complex “male” fueling probe end on the USV because, in theory, there will be more USVs than fueling stations and doing so should reduce overall USV costs and complexity.

The “female” fueling connector end has been designed to perform either the manned or unmanned mission by making the primary components between the two variants common. For example, the manned version of the connector adds a handle and protective bumper whereas the unmanned version has a feature for making terminal alignment between the male probe and female connector end.   The commonality between the two variants is especially useful during this SBIR phase so that development costs are controlled. The connector is robust, light weight, and user-friendly.

Manned Connection:

Figure 1, View of “manned” fueling nozzle.

The manned fueling nozzle, shown in Figure 1, was designed around a COTS dry-break, push-to-connect-style connector. The biggest change from the stock part is that the locking collar is replaced with a custom unit that integrates the unlocking/locking function with the pneumatic remote disconnect feature.   An air plenum is formed between the locking collar and the connector body that allows actuation of the locking collar without the need for additional cylinders or air bladders but still allows the nozzle to be disconnected manually by pulling on the handle. The design reduces the number of components and reduces the overall size and weight of the connector. The diameter of the fuel nozzle itself is less than four inches but incorporates two handles large enough to grip with a gloved hand. The removable handle is aluminum with a MIL-SPEC polyurethane over-mold that facilitates grip as well as mitigates shock if the nozzle is dropped. The over-mold material, CONATHANE EN-1556, was selected to provide good resistance to abrasion, weather, fuels, and solvents. In addition it is dyed purple to match JP-5 fuel systems. A bumper ring on the front end of the nozzle, made from similar polyurethane, provides further shock protection.

Major components are anodized 6061 aluminum alloy with subcomponents (springs, balls, etc) made from stainless steel. Figure 2 shows the coupling engaged to the USV probe and ready to transfer fuel (left) and disconnected ready to get underway (right).

Another feature incorporated into the new design is visual feedback that a fuel connection is secure and fuel transfer may begin. As shown in Figure 2, a green indicator strip becomes visible only after the locking collar springs forward and locks the fuel nozzle to the fuel probe.   This feedback is in addition to the tactile feedback one gets when the two pieces physically mate but provides an added level of awareness.

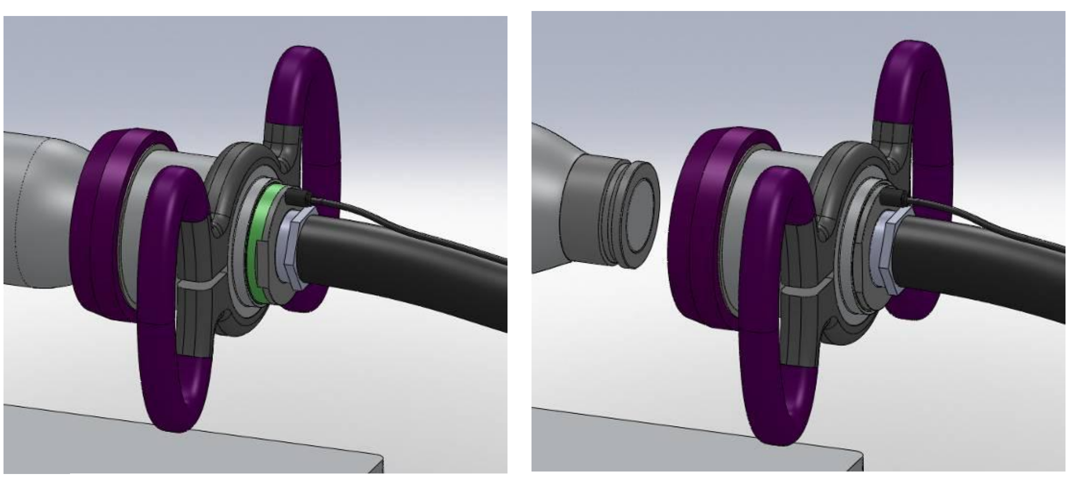

Figure 2, Fueling nozzle connected, ready for fueling (left) and disconnected (right)

A full scale prototype including USV bow mockup is under construction (Figure 3). Development of the unmanned refueling connection prototype is also in progress, slated for testing in December 2010. This system will enable remote connection of the fuel hose, and can used to refuel USVs from a variety of manned and unmanned host platforms without ever putting a sailor aboard the USV.

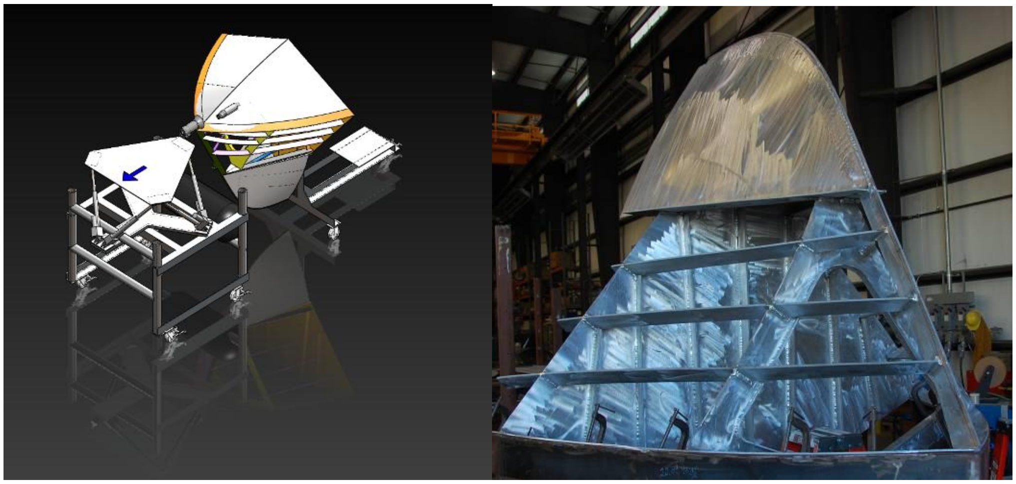

Figure 3, Unmanned connection concept (left) and bow mock up under construction (right)

REFERENCES

TPOC, 850-235-5142
PMS 406, APM Unmanned Surface Vehicles, 202-781-2590

WHEN THE TECHNOLOGY WILL BE READY FOR USE

Current TRL: 4

Future development work on the manned, initial refueling task is simply to validate readiness for shipboard integration. ICD requirements as well as EMI, shock and vibration testing will need to be agreed upon with all stakeholders. The unmanned refueling task is still under prototype development with laboratory testing planned for December 2010. At the conclusion of this testing, a TRL of 5 will be achieved.

ABOUT THE COMPANY

Maritime Applied Physics Corporation is a 72-person employee-owned engineering and prototyping firm based in Baltimore, Maryland (Figure 4). Since 1986, MAPC has specialized in the design, fabrication and testing of high tech prototypes with an objective of transitioning to production. The company offers general mechanical, electrical, aerospace and naval engineering services with a concentration on prototype development of advanced energy systems, robotic vehicles and vehicle engineering. We are currently under contract for design, testing and/or production of several shipboard systems for LCS-2, DDG-1000, and SSN-774 with yearly revenues over $15M.

Figure 4, MAPC's waterfront facility in Baltimore, MD