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Engineering Unmanned Surface Vehicles Into an Integrated Unmanned Solution 49

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Engineering Unmanned Surface Vehicles Into an Integrated Unmanned Solution

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Abstract

The Chairman of the Joint Chiefs of Staff, General Mark Milley, has directly, and without hesitation, said that a much larger 500-ship U.S. Navy will be necessary to contain Chinese expansionist ambitions. Part of the move to pursue a 500-ship fleet rests upon the hope for as many as 140 to 250 unmanned vessels. However, this aspiration collides with Congressional concerns that the U.S. Navy has yet to come up with a convincing concept of operations (CONOPS) for using the small, medium and large unmanned vessels it intends to buy. This article presents such a CONOPS that will not only allay Congressional concerns, but also lead to a more effective integration of unmanned surface vessels into the Navy fleet.

Perspective

In his best-selling book, *War Made New*, military historian Max Boot notes, "My view is that technology sets the parameters of the possible; it creates the potential for a military revolution."[1] He supports his thesis with historical examples to show how technological-driven "Revolutions in Military Affairs" have transformed warfare and altered the course of history.

The U.S. military has embraced a wave of technological change that has constituted a true revolution in the way that war is waged. As the pace of global technological change has accelerated, the United States has been especially adept at inserting new technology to pace the threat. As Bruce Berkowitz points out in *The New Face of War*:

> Wartime experience suggests that the right technology, used intelligently, makes sheer numbers irrelevant. The tipping point was the Gulf War in 1991. When the war was over, the United States and its coalition partners had lost just 240 people. Iraq suffered about 10,000 battle deaths, although no one will ever really be sure. The difference was that the Americans could see at night, drive through the featureless desert without getting lost, and put a single smart bomb on target with a 90 percent probability. [2]

While both books cited are over a decade old, what they say about technology remains on point regarding the ways that the U.S. military has embraced new technologies. Today one of the most rapidly growing areas of innovative technology adoption by the U.S. military involves unmanned systems. In the past several decades, the U.S. military's use of unmanned aerial vehicles (UAVs) has increased from only a handful to more than 10,000, while the use of unmanned ground vehicles (UGVs) has exploded from zero to more than 12,000. The use of unmanned surface vehicles (USVs) and unmanned underwater vehicles (UUVs) is also growing, as USVs and UUVs are proving to be increasingly useful for a wide array of military

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applications. The exploding use of military unmanned systems (UxS) is already creating strategic, operational, and tactical possibilities that did not exist a decade ago.

These systems have been used extensively in the conflicts in Iraq and Afghanistan, and will continue to be equally relevant—if not more so—as the United States' strategic focus shifts toward the Indo-Asia-Pacific region and the high-end warfare this strategy requires. While these unmanned systems are of enormous value today and are *evolving* to deliver better capabilities to the warfighter, it is their promise for the future that causes the most excitement. As the U.S. military buys more and more unmanned systems, it is important to devise concrete plans for the use of these systems and to have naval engineers at the forefront of designing them. These designs will need to focus on open architecture with multi-mission capability.

The U.S. Navy's Commitment to Unmanned Systems

The U.S. Navy has a rich history of UxS development. During the early years of the last century, the Navy and the Army worked together to attempt to develop unmanned aerial torpedoes. However this was a bridge-too-far given the state of technology during those years, and the project was ultimately abandoned. Other attempts to introduce unmanned systems into the Navy and Marine Corps occurred in fits and starts throughout the first half of the last century, but these also met with limited success.

By the turn of the century, the technology to control unmanned systems had finally matured to the point that the U.S. Navy believed it could successfully field unmanned systems in all domains—air, surface, and subsurface—to meet a wide variety of operational needs. As with many disruptive and innovative ideas, the Chief of Naval Operations Strategic Studies Group was tasked to attempt to determine the feasibility of introducing unmanned systems into the Navy inventory.

The U.S. Navy's commitment to—and dependence on—unmanned systems is seen in the Navy's official Force Structure Assessment, as well as in a series of Future Fleet Architecture Studies.[3] Indeed, these reports highlight the fact that the attributes that unmanned systems can bring to the U.S. Navy fleet circa 2030 and beyond have the potential to be truly transformational.

In his FRAGO 01/2019 order, Chief of Naval Operations, Admiral Michael Gilday, emphasized the Navy's plan for a future fleet with substantial numbers of unmanned systems.[4] *Advantage at Sea*, America's new maritime strategy, continues the drumbeat regarding the importance of unmanned systems to the Sea Services.[5] These ideas coalesced in March of last year when the Navy released its *Unmanned Campaign Framework* describing the Service's vision for integrating these platforms into the Fleet.[6]

The U.S. Navy is planning for a substantial investment in unmanned systems—especially unmanned surface systems. For example, the Navy established a Surface Development Squadron, to experiment with unmanned ships.[7] Future development ideas call for a "Ghost Fleet" of autonomous unmanned surface ships that could operate against an enemy force without putting Sailors in harm's way.[8] And it should come as no surprise that Congress is increasingly interested in the Navy's progress on unmanned surface vehicles, as witnessed by an increasing number of Congressional Research Service reports on USVs.[9]

In a slide showing how NAVSEA intended to reach an ambitious future of a fleet populated with scores—even hundreds—of unmanned vehicles, one of three key goals was to, "Integrate USVs with manned host platforms, which control the USVs from a distance."[10] The Navy announced its intention to spend $2.7B into researching and buying ten large unmanned surface ships over the next five years as part of an overall plan to buy 232 unmanned surface, underwater and aerial vehicles of all sizes over the next five years.[11]

In remarks during a U.S. Navy League SeaAirSpace Symposium, the Navy's Deputy Chief of Naval Operations for Warfare Systems, Rear Admiral William Merz, confirmed this commitment unmanned systems when he noted, "Every study directed or initiated from within has told us we have to move out on these [unmanned surface vehicles] capabilities… Our commitment in our last budget to the tune of almost $3 billion in just unmanned surface vessels should be enough to signal to industry we're very serious about this."[12] The U.S. Navy's commitment to unmanned systems is unlikely to wane as increasingly, these platforms continue to prove their utility in performing much of the dull, dirty and dangerous work that the Navy previously assigned to manned platforms."[13]

Unmanned Maritime Systems: The Bridge to the Navy-after-Next

The importance of unmanned systems to increasing the combat power of Navy fleet has been well-documented in the aforementioned Future Fleet Architecture Studies as well as the *Naval Research and Development: A Framework for Accelerating to the Navy and Marine Corps after Next*.[14] The *Naval Research Enterprise Addendum to the Naval Research and Development Framework* drills down to technology areas, and then to specific technologies that will enable the Navy and Marine Corps to field decisive capabilities and dominate the future littorals in a high-end fight. Unmanned surface vehicles and unmanned underwater vehicles are called out as disruptive technologies that can provide leap-ahead capabilities for the Navy.[15]

The Naval Sea Systems Command, as well as the Navy laboratories that provide the technical expertise for the development of many unmanned surface and subsurface unmanned systems, have been accelerating the development of these USVs and UUVs. The Navy has partnered with industry to develop, field and test a family of USVs and UUVs such as the Medium Displacement Unmanned Surface Vehicle (Sea Hunter), the Common Unmanned Surface Vessel (CUSV), the Expeditionary Class MANTAS and Devil Ray next generation Unmanned Surface Vessels, the Large Displacement Unmanned Underwater Vehicle ("LDUUV") and others.

With this look at the commitment to unmanned systems, it is worth spending a bit of time understanding the missions the Navy and Marine Corps have planned for unmanned maritime systems, specifically, unmanned surface vehicles. Operating as they do at the air-water interface on the surface of the oceans, unmanned surface vehicles not only have their own discrete—and growing—list of current and future naval missions, but they also provide the connective tissue between aerial unmanned vehicles and unmanned underwater vehicles as well as their manned counterparts.[16]

Like all unmanned systems, unmanned surface vehicles are critical assets in all scenarios across the spectrum of conflict and become more useful against high-end adversaries. Unmanned surface vehicles enable warfighters to gain access to areas where the risk to manned platforms is unacceptably high due to a plethora of enemy systems designed to deny access: from integrated air defense systems, to surface ships and submarines, to long-range ballistic and cruise missiles, to a wide range of other systems. These unmanned surface vehicles can provide greater range and persistence on station, leading to enhanced situational awareness of an objective area. Indeed, in a high-end fight, unmanned surface vehicles can be viewed as expendable assets once they perform their mission.

While the Navy is committed to buying large numbers of unmanned maritime vehicles, it has yet to come up with a convincing concept of operations (CONOPS) for how they will be used during conflict against a determined adversary. The U.S. Congress has indicated increasing skepticism that the billions of dollars the Navy intends to invest in these platforms should continue, absent a clear understanding of their intended use. Indeed, a defense publication reported this Congressional concern this way:

> The Navy has yet to produce a concept of operations or even a coherent public strategy to back up the investments they want to make. Further, Congress is wary of appropriating money for platforms that rely on technologies that haven't been fully developed yet.[17]

FIGURE 1. MARTAC Devil Ray T38 with embedded MANTAS T12 USV Ready for Launch

The inability of the Navy to develop a convincing CONOPS for the use of unmanned maritime systems may simply stem from a lack of imagination and/or a complete misunderstanding of the current USV state-of-the-art technology. As the Navy looks to allay Congressional concerns and accelerate the fielding of unmanned maritime systems, the emphasis should be on no longer thinking of each unmanned maritime system as a "one-of," but rather, to package these together as in multiple-sized and function vehicles designed for specific missions. The emphasis must remain on USV ship design that is focused on modularity and open architecture characteristics to accommodate sensors, weapons and payloads for specific missions, where the platform remains constant and the modularity within the platform allows for the "modular shift" to support multiple missions.

The Navy has categorized the range of USV's into "Large" LUSV, "Medium" MUSV and "Small" USV categories. The technical challenge is to make these different sized craft work together as an integrated team of platforms that not only operate together but can be launched and recovered from each other in a larger UxV-UxV operational, mission-focused, environment. Effectively, this integration can be looked at as an Integrated Unmanned Solution where the LUSV is sized to operate as part of a Navy Strike Group. The LUSV will carry the MUSVs onboard and they in turn are configured to carry the small USV, along with UAVs and UUVs.

Putting the Pieces Together: A Concept of Operations for Using Multiple-Sized USVs

The U.S. Navy's lack of a concept of operations for operating the large numbers of unmanned surface and undersea vessels was put this way in an article in *USNI News*:

> The Navy has pitched a range of missions for its unmanned surface and undersea vessels, ranging from gathering intelligence to laying mines to launching missiles—the latter of which Congress strongly opposes at this point in the USV's development—but few concrete concepts of operations have been released, and the finer details of the Pentagon's Battle Force 2045 still haven't been released.[18]

The concept of operations we propose is to marry various size unmanned surface, subsurface and aerial unmanned vehicles to perform missions that the U.S. Navy has—and will continue to have—as the Navy-After-Next evolves. Simply put, the Navy can use the evolving large unmanned surface vehicle as a "truck" to move smaller USVs, UUVs and UAVs into the battle space in the increasingly contested littoral and expeditionary environment.

While there are a plethora of important Navy missions this Integrated Unmanned Solution combination of unmanned platforms can accomplish, this article will focus on two: intelligence surveillance and reconnaissance (ISR) and mine countermeasures (MCM). There are many large, medium, small and ultra-small unmanned systems that can be adopted for these missions. The technical challenge remains that they must be designed to ensure that the "multiple sized" UxVs associated with these missions can be adapted to work together in an "integrated" common mission goal.

Rather than speaking in hypotheticals as to how unmanned vehicles might be employed for these two missions, we will offer concrete examples, using commercial-off-the shelf-unmanned systems that have been employed in Navy and Marine Corps events. In each case, these systems not only demonstrated mission accomplishment, but also the hull, mechanical and electrical (HME) attributes and maturity that Congress is demanding before proceeding ahead with robust acquisition of Navy unmanned systems. Congressional concerns in this area were articulated in a *Defense News* article:

> Unmanned surface vessels are all the rage in the office of the Secretary of Defense, and the U.S. Navy has lined up behind the effort. But Congress remains skeptical until it sees the Navy make progress on the basics.
>
> In the latest sign of Congressional ambivalence on unmanned surface warships, the House Seapower and Projection Forces subcommittee called for restricting funding for procurement of any large, unmanned surface vessels—LUSVs—until the Navy can certify it has worked out an appropriate hull, mechanical and electrical systems.
>
> It's the same kind of subsystem development language that was championed in the Senate Armed Services Committee's mark of the FY21 NDAA, that "requires the Navy to qualify the main engines and generators for certain unmanned surface vessels prior to vessel procurement," according to a summary of the mark.[19]

While there are a wide range of medium unmanned surface vehicles (MUSVs) that can potentially meet the U.S. Navy's needs, there are three unmanned surface vehicles that appear to be furthest along in the development cycle. These MUSVs cover a wide range of sizes, hull types and capabilities. All have proceeded along different development paths. They are:

- The Vigor Sea Hunter, which is the largest of the three, and was designed from its inception to be totally unmanned. Under contract with DARPA, the craft was launched in 2016 and was built at a cost of twenty million dollars.
  - The Sea Hunter is a 132-foot (40 meter)-long ***trimaran*** (a central hull with two outriggers) with twin screws, powered by two diesel engines. A sister ship, the Seahawk, with the same mission, was delivered this past year.
  - The USV weighs 135 tons, which includes 40 tons of fuel. The craft can carry a payload up to an additional 10 tons.
  - Sea Hunter has a cruise speed of 12kts and a burst speed of 27kts.

FIGURE 2. Vigor MDUSV Sea Hunter

- Range for the Sea Hunter is its strongest plus. The craft was designed to be underway unmanned for 70 days. As such, at cruise speed, with the significant fuel that it can carry, the craft will have a range of 10,000nm.

- The Textron ***monohull*** Common Unmanned Surface Vessel (CUSV), now referred to as the MCM-USV, features a modular, open architecture design. The MCM-USV is compatible with both LCS configurations.
  - The MCM-USV has a length of 39 feet, a beam of 11 feet and a draft of 26 inches.
  - Propulsion is twin screw diesel.
  - MCM-USV weighs 17,000lbs and can carry a payload of up to 3,500lbs.
  - The MCM-USV has a cruise speed of 12kts with burst capability up to 35kts with an endurance range at cruise speed is 1200nm.
- The Maritime Tactical Systems Inc. (MARTAC), ***catamaran*** hulls, unmanned surface vehicles (USV) include the MANTAS T12 and the Devil Ray T24, T38 and T48 craft. All four feature a modular and open architecture design. The composite carbon fiber hull was designed to greatly minimize the hydrodynamic drag by moving the laminar-to-turbulent flow breakpoint further aft.
  - The T24, T38 and T48 USVs are 24-foot, 38-foot and 48-foot long, respectively, with beams of 10 feet, 11 feet and 12 feet and drafts of 14 inches, 18 inches and 28 inches.
  - Each is propelled by either inboard or outboard twin-screw diesels.
  - The T24 weighs 7,300lbs with payload carrying capability of 1,800lbs.
  - The T38 weighs 9,800lbs with a payload carrying capability of 4,500lbs.
  - The T48 weighs 13,000lbs with a payload carrying capability of 10,000lbs.
  - The T24 has a cruise speed of 15-30kts. T38 and T48 both have cruise speeds from 25-40kts.
  - Burst speed capability is up to 60kts for the T24 and up to 80kts for the T38 and T48.
  - At cruise speed of 25kts, the T24 has an endurance range of 800-1200nm. The T38 has an endurance range of 1,500 to 2,000nm and the T48 endurance range is 2,000 to 2,500nm.
  - The T24, T38 and the T48 are all equipped with an autonomous launch, tow and recovery system from an indented section aft near the waterline, thereby providing a “rail type” winched launch and recovery of installed UUV, ROV, USV or towed craft.

FIGURE 3. Textron MCM-USV

FIGURE 4. MARTAC T38

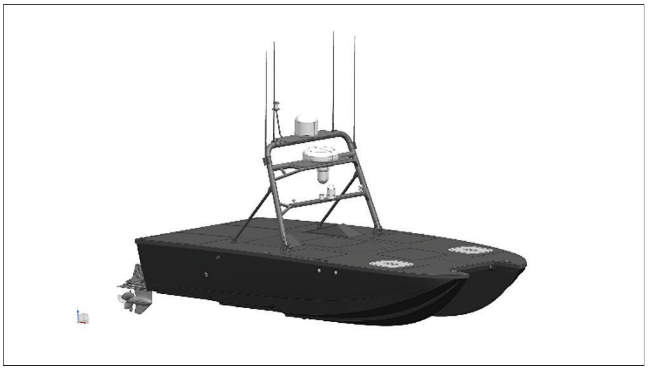

FIGURE 5. MARTAC T24 Final Design Graphic

All three of these MUSVs are viable candidates to be part of an Integrated Unmanned Solution CONOPS. This paper will use the MANTAS and Devil Ray craft for a number of reasons. First, they come in different sizes with the same HME attributes. Second, the Sea Hunter is simply too large to fit into the LUSVs the Navy is considering. Third, the MCM-USV is the MUSV of choice for the Littoral Combat Ship (LCS) Mine-Countermeasures Mission Package and all MCM-USVs scheduled to be procured are committed to this program. Finally, the MANTAS and Devil Ray are COTS MUSVs that the Navy has wrung out in exercises, experiments and demonstrations over the past several years. Three T12 and two T38 USVs are currently in service with CTF-59 (Unmanned Surface Vessels and Artificial Intelligence) in Bahrain. They likely can be married together to show Congress and others that the Navy does, indeed, have an effective way to use these platforms operationally.

Packaging An Integrated Unmanned Solution

Part of evolving and operational concept for employing unmanned surface vehicles involves placing them in the environment where they can perform their missions of intelligence surveillance and reconnaissance and mine countermeasures. This is not a trivial task, especially since the United States must be prepared to deal with peer and near-peer adversaries with robust anti-access and area denial (A2/AD) capabilities.

If the U.S. Navy wants to keep its multi-billion-dollar capital ships out of harm's way, it will need to surge unmanned maritime vehicles into the contested battlespace while its manned ships stay out of range of adversary A2/AD systems, sensors and weapons. Small and medium USVs, UAVs and UUVs need a "truck" to deliver them to an area near the battlespace. This is where we propose to leverage the Navy's planned investment in the large, unmanned surface vehicles. This is how a Congressional Research Service report describes this vessel:

> The Navy envisions LUSVs as being 200 feet to 300 feet in length and having full load displacements of 1,000 tons to 2,000 tons. The Navy wants LUSVs to be low-cost, high-endurance, reconfigurable ships based on commercial ship designs, with ample capacity for carrying various modular payloads—particularly anti-surface warfare (ASuW) and strike payloads, meaning principally anti-ship and land-attack missiles. Although referred to as UVs, LUSVs might be more accurately described as optionally or lightly manned ships, because they might sometimes have a few onboard crew members, particularly in the nearer term as the Navy works out LUSV enabling technologies and operational concepts.[20]

Depending on the size that is ultimately procured, the LUSV can carry a number of T38 Devil Ray unmanned surface vehicles and deliver them, largely covertly, to a point near the intended area of operations. The T38 can then be sent independently to perform the ISR mission, or alternatively, can launch one or more T12 MANTAS to perform the ISR mission. Building on work conducted by the Navy laboratory community, the T38 or T12 will have the ability to launch unmanned aerial vehicles to conduct overhead ISR.[21]

For the MCM mission, the LUSV can deliver several T38s outfitted with side-scan and/or multi-beam sonars installed onboard the craft with the added ability to stream/tow a UUV with sonar. These vessels can then undertake the "dull, dirty and dangerous" work previously conducted by Sailors who had to operate in the minefield. Given the large mine inventory of peer and near-peer adversaries, this methodology may well be the *only* way to clear mines safely.

Integrated Unmanned Solution CONOPS—Sampling the "Unmanned-Unmanned" Scenario

Most people can think of a multitude of potential Unmanned-Unmanned missions that could be performed by multiple USV, UAV and UUV platforms working together, autonomously, in an integrated support environment. The mission considerations can span surface, anti-surface, anti-air, mine, anti-submarine, amphibious and expeditionary warfare areas. The scenario presented below is evolutionary in nature in that it builds on existing unmanned surface vehicle work and is well within the ability of a team of naval engineers and designers to adapt a family of USVs to meet the requirements of these scenarios. Given the recent strides in USV development, including (1) craft already in design, (2) craft in fabrication and (3) fully operational craft, USVs designed to meet the scenario requirements presented below can be realized within the next few years.

Setting the Stage:

This scenario is built around an Expeditionary Strike Group that is underway in the Western Pacific. This Strike Group includes three LUSVs under supervisory control from a large amphibious ship. Supervisory control of these three LUSVs during normal underway operations is provided from a single control station on a single ship. The supervisory control station includes seating for a single operator who controls multiple USVs in addition to an adjoining sensor/payload operator for monitoring and controlling the mission sensors/payloads onboard each of the craft. A single supervisory operator station will be required for each LUSV. The LUSV will then be further configured with onboard multiple smaller USVs, UUVs and UAVs.

Each of the three LUSVs are carrying three or more, T38 Devil Ray craft configured with small USVs, UAVs, and UUVs for specific missions. Technical characteristics and configurations of the T38s for this specific sample mission are:

- *T38-ISR* outfitted with
  - Radar, EO/IR gyro-stabilized cameras and EW sensors.
  - Multi-beam echo-sounder/sonar lowered through the moon pool located just forward of the craft center of gravity (CG). The moon pool door opens on command and the sonar is lowered when on station for the ISR evolution.
    - Moon pool doors remain closed during high-speed transit.
  - Two MANTAS T12 - each configured with thermal camera, passive EW Sensors and single-beam or side-scan sonar. The configuration of T12 craft onboard the T38 is in-line, one forward of the other.
    - Autonomous launch and recovery design of the T12 from the T38 uses a set of twin rails on the aft lower deck of the T38. When commanded by the supervisory controller, the T38 performs an angular ballast-down-aft evolution to place the stern into the water and when commanded, allows the first T12 craft to slide into the water. Recovery uses the same rails and a hook at the bow of the T12 to catch the recovery crossbeam which is attached to the rails.
    - The MANTAS T12 is powered up autonomously when it is released. It is then monitored and controlled from a strike group supervisory controller. Communications relay may be required via the T38 to the LUSV to the command ship, depending on distance from the strike group.
  - Two to four UAVs (depending on UAV type/size). Preference will be given to UAV gyrocopters due to the fact that while fixed wing UAVs can be launched from these vessels, they will not be recoverable on this size platform.
    - UAVs are mounted in the bow area rigidly attached to a launch/recovery point for the gyrocopters. They will be protected from wind and spray via shields and/or cover.
    - Launch and recovery is started on command from the supervisory controller and monitored by the controller via the T38 onboard camera.
      - Cover is removed autonomously.
      - The gyrocopter is started. Confirmed start is sent to the supervisory controller and to onboard command/control. Mounts are released autonomously, and gyrocopter launches itself.
      - The gyrocopter is under supervisory control via comms relay to the strike group via the T38.
- *T38-MCM* outfitted with:
  - Radar, EO/IR gyro-stabilized cameras
  - High resolution multi-beam echo-sounder/sonar lowered through the moon pool. Moon pool door opens on command and sonar is lowered when on station for mine-detection evolution.
  - Aft mounted single twin rails on the lower deck of the T38 which allows for an angular ballast-down-aft evolution to place the stern into the water and, when commanded, allows the T38 to stream and then recover a towed Sea Scout (or equivalent) mine-hunting UUV with high-res side-scan sonar mounted on the rails.
  - Streaming, including launch and recovery, is initialized by the supervisory controller. The mine-hunting evolution is closely monitored in real time by an explosive ordnance operator onboard the strike group control ship. The operator will be seated at the same console as the USV craft supervisory controller to ensure that the preset autonomous track inserted by the controller is followed by the craft and to make decisions, as required, regarding any mine-like objects that are detected by either the sonar or the streamed UUV/ROV.

FIGURE 6. T38 with Tow Onboard

Launching and Recovering of the T24/T38/T48 from the LUSV

Should An Integrated Unmanned Solution UxV-UxV approach as introduced in this article be considered for use by the Navy, the final length and beam of the LUSV will determine how many smaller MUSVs, Expeditionary USVs and small USVs it can carry and where they should be placed on the deck. The configurations for each of the USV variants, as designed for the LUSV, will establish the best, and most efficient, autonomous launch and recovery approach. Considerations will be as follows:

- Modified A-frame aft.
- Modified traditional 7m/11m cradle and over-the-side davit on multiple stations port and starboard.
- Ballast system within LUSV to ballast down to USV deck level for a direct drive-on/drive-off solution.

In considering the above options, it is apparent that the third option with the ballast down system may be the most effective for allowing the LUSV to autonomously carry, launch and recover USVs such as the Devil Ray T24, T38 or T48. The NAVY/MSC Expeditionary Sea Bases already are capable of carrying the LCAC hovercraft effectively because of the LCAC flat lower hull and hover skirts. As such, the T24, T38 and T48 catamaran hulls would be ideal for autonomous launch and recovery from a flooded deck.

FIGURE 7. Devil Ray Supervisory Control Station

Operational Scenario for An Integrated Unmanned Solution Mission:

The Expeditionary Strike Group in the Western Pacific is on routine patrol about five hundred nautical miles from the nearest landfall. An incident occurs in their operating area and the strike group is requested to (1) obtain reconnaissance of a near-shore littoral area, associated bays and river accesses and (2) determine if the entrance to a specific bay has been mined to prevent ingress. The littoral coastline covers two hundred nautical miles. This area must be reconnoitered within twenty-four hours without the use of air assets.

Command staff decides to dispatch the three LUSVs for the mission. Two LUSVs are each configured with quantity of four T38-ISR craft and the third LUSV is configured with quantity of four T38-MCM vessels.

The single supervisory control station for the three LUSVs remains manned in the mother-ship for the initial transit to the MUSV launch/departure point, at which time, two others will be manned to provide further supervisory control.

The three LUSV depart the strike group steaming together, in a preset autonomous pattern for two hundred and fifty nautical miles to a waypoint that is central to the two hundred nautical mile ISR scan area, two hundred and fifty nautical miles from the shore. At this waypoint, the LUSV will stop and dispatch the smaller T38 craft and then wait at this location for their return. Steaming at a cruise speed of twenty-five knots, the waypoint is reached in about ten hours.

At the launch/dispatch waypoint, the two additional supervisory control stations are manned (now one per LUSV) and command is given by the supervisory controllers as follows:

- Two T38-ISR craft to be launched from each of the two LUSVs carrying the ISR craft. The autonomous mission previously downloaded specifies a waypoint location along the coast for each of the four craft. These waypoints are fifty nautical miles apart from each other, indicating that each of the four T38 craft will have an ISR mission of fifty nautical miles to cover.
- Two T38-MCM craft to be launched from the third LUSV. The autonomous mission previously downloaded has them transit independently along different routes to two independent waypoints just offshore of the suspected mine presence area where they will commence mine-like object detection operations.
- In this manner, each of the six craft will be transiting, independently and autonomously, to their next waypoint which will be the mission execution start point.
- Transit from the LUSV launch point, depending on route, will be about two hundred and fifty to three hundred nautical miles to their near-shore waypoints. Transit will be at seventy to eighty knots to their mission start waypoint near the coast. Transit time is between four and five hours.
- The plan is for each of the T38-ISR craft to complete their ISR scan in four to five hours each and for the two T38-MCM craft to jointly scan the bottom and the water column for the presence of mine-like objects in four to five hours at a scan speed of six to eight knots.

T38-ISR Mission: Four craft fifty nautical miles apart proceeding in the same general direction to cover all sections of the ISR mission:

- ISR mission of each T38-ISR craft is at twelve to fifteen knots cruise speed.
- Supervisory payload controller/monitors all data (radar, camera, sonar) from the T38s under their supervisory control in real-time. Depending on communications paths used, this data may be sent directly to the strike group from the T38, or may be relayed from the T38 to the LUSV, and then on to the strike group controllers.
- During the ISR scan, the payload controller sees a shallow water bay and river access area that he/she wants additional data on. The controller commands "stop" to the respective T38-ISR craft when it is adjacent to the shallow water area that needs scanning. The controller commands autonomous launch of one of the two MANTAS T12 craft on that T38 which has already been preloaded with its autonomous mission. The T38 remains on station in loiter while the T12 performs its shallow water ISR scan. When complete, the

FIGURE 8. Devil Ray T38 launching MANTAS T12

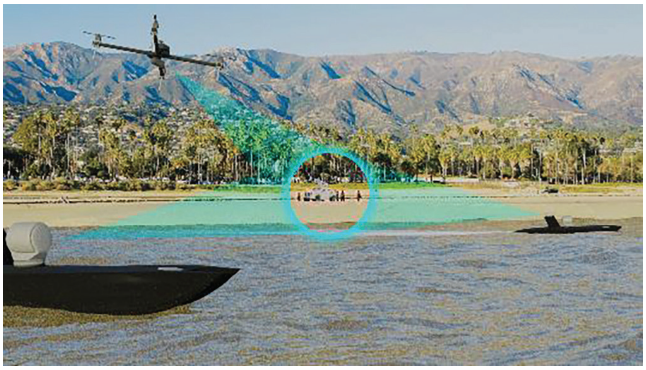

FIGURE 9. T12s launching UAV Gyrocopters

T12 returns to the T38 where it is autonomously recovered. The T38 is then commanded to continue its mission and the supervisory controller adjusts ISR speed for the rest of mission to accommodate time lost with the T12 scan.

- During the ISR scan, a second payload controller of a different T38-ISR craft sees an area inshore that is suspect and wants to obtain more information on that area. When passing the suspect area, the controller commands "stop" to the T38 and further commands autonomous launch of two of gyrocopters that have already been preprogrammed for their mission. The UAVs are unlatched and launched autonomously and the T38 loiters on station awaiting their return. The UAVs send real-time video of the suspect area back to the payload controller on the ship via relay to the T38, then to the LUSV, and on to the ship. When the UAV mission is complete, the craft return to the T38 and, under laser guidance, are autonomously recovered and latched down on the craft.
- Upon completion of each of the four separate, and independent, fifty nautical mile T38 ISR missions at their respective "mission complete waypoints," the craft are released by the controller to return to their LUSVs for recovery onboard.

T38-MCM Mission: Two craft arrive at waypoints near the underwater scan area:

- The craft supervisory controller and the EOD operator work together to ensure that the area is adequately scanned. The craft controller sends a command to deploy the onboard sonar.
- Both craft open moon pool doors and deploy their respective high resolution multi-beam sonars.
- Upon further command from the supervisory controller, each craft deploys its SeaScout UUV tow for side-scan survey of the area
- Each craft has been programmed for the autonomous "lawn mowing" mine detection mission where the overall scan area has been split equally between the two craft.
- The EOD operator sees scan results of both onboard sonar and SeaScout tow-sonar in real time and has the ability to work with the supervisory craft controller to interrupt the autonomous scan to take a second or third pass at any detected mine-like object for further classification or identification.
- Upon completion of the underwater mine detection scanning, the SeaScout UUV tow is autonomously recovered, the onboard sonar is retrieved within the moon pool and the moon pool cover is closed.
- Both T38-MCM craft are released, by command, to return to their LUSV for recovery onboard.

Upon recovery of the six T38 on their respective LUSVs, the LUSVs are commanded to return to the strike group at twenty-five knots cruise speed. The estimated time to return is ten hours.

The timeline for entire mission is as follows:

- LUSV detach strike group to T38 Launch point and launch six T38:—10-12 hours
- T38 transit from launch point to mission ISR/MCM start waypoints:—4-5 hours
- ISR Mission and MCM Mission time from start to complete:—4-5 hours
- T38 transit from Mission completion point back to T38 for recover:—4-5 hours
- LUSV recover T38s and return to strike group formation—10-12 hours

Effectively, even with the Expeditionary Strike Group five hundred nautical miles from shore, the strike group commander will have the results of the ISR and MCM scan of the shoreline littoral area within twenty to twenty-two hours after the departure of the LUSVs from the strike group. The LUSVs arrived back on station in the strike group in less than forty hours, ready for the next mission.

FIGURE 10. SCO Project Overlord LUSV

An effective mission that demonstrated the capability of a true UxV-UxV Integrated Unmanned Solution approach that involved the following different class and size of UxVs:

- Three LUSV
- Six Devil Ray T38 Expeditionary USVs (4 ISR and 2 MCM)
- One MANTAS T12 USV
- Two gyrocopter UAVs
- Two SeaScout towed UUVs

Each of the above UxVs, as depicted in the scenario, are already either:

1. Operational and in use
   a. MANTAS T12
   b. Devil Ray T38
   c. Gyrocopter UAV
   d. SeaScout towed UUV
   e. Four Strategic Capabilities Office (SCO) Project Overlord experimental large, unmanned surface vehicles were just recently turned over to the Navy in San Diego, California.
2. Under consideration for final design and fabrication
   a. LUSV—New design in work

Into the Future With An Integrated Unmanned Solution

As industry partners continue to bring increasingly capable and sophisticated unmanned surface vehicles to Navy and Marine Corps exercises, experiments, and demonstrations, it is likely that operators will help refine the missions these USVs can conduct, as well as demand that these systems be made available to Navy and Marine Corps operators as soon as possible. That is good as far as it goes, however, at the end of the day, the Sea Services will need to demonstrate how these platforms can be used *operationally*.

The CONOPS presented in this article is ambitious in two ways. First, it presents an entirely new way of thinking about how to effectively employ the large numbers of UxVs the U.S. Navy intends to procure. It is also ambitious in that marrying multiple size UxVs together will be a wicked hard problem requiring the naval engineering community to bring innovative thinking to finding a way to make this work—including evolving Key Performance Parameters for these UxVs.[22] Naval engineers have a long history of rising to the challenge, and this is one that they should be keen to take on. NEJ

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GEORGE GALDORISI is Director of Strategic Assessments and Technical Futures, at the Naval Information Warfare Center Pacific, where he helps direct the Center's efforts in strategic planning and decision support. Captain Galdorisi is recognized for his extensive experience with unmanned systems of all types, as well as with artificial intelligence and machine learning.

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Mr. Rowley has served as the Chief Technology Officer (CTO) with Maritime Tactical Systems, Inc. (MARTAC) in Melbourne, FL for the past six years. MARTAC has designed and produced the MANTAS and DEVIL RAY Tactical Autonomous Unmanned Surface Vessels (USV) ranging in incremental lengths from 8ft to 50ft.

Mr. Rowley has degrees of BSEE from University of Oklahoma as well as an MSME and Degree of Ocean Engineer from MIT.

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[22] Key Performance Parameters (KPP) are key system capabilities that must be met in order for a system to meet its operational goals. The Capability Development Document (CDD) and Capability Production Document (CPD) identify the KPPs that contribute to the desired operational capability in a threshold and objective format. Each KPP is supported by operational analysis that takes into account technology maturity, fiscal constraints, and schedule, before determining threshold and objective values. The threshold value of a KPP is the minimum acceptable value considered for cost, schedule, and technology. Performance below the threshold value is not operationally effective or suitable. A KPP also has an objective value that is the desired operational goal considering cost, schedule, and technology.