Skip all front matter: Jump to Page 1

This report is part of the RAND Corporation research report series. RAND reports present research findings and objective analysis that address the challenges facing the public and private sectors. All RAND reports undergo rigorous peer review to ensure high standards for research quality and objectivity.

RAND NATIONAL DEFENSE RESEARCH INSTITUTE

U.S. Navy Employment Options for UNMANNED SURFACE VEHICLES (USVs)

Scott Savitz, Irv Blickstein, Peter Buryk, Robert W. Button, Paul DeLuca, James Dryden, Jason Mastbaum, Jan Osburg, Phillip Padilla, Amy Potter, Carter C. Price, Lloyd Thrall, Susan K. Woodward, Roland J. Yardley, John M. Yurchak

Prepared for the United States Navy

Approved for public release; distribution unlimited

This research was sponsored by the Assessment Division of the Office of the Chief of Naval Operations (OPNAV N81) and conducted within the Acquisition and Technology Policy Center of the RAND National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Combatant Commands, the Navy, the Marine Corps, the defense agencies, and the defense Intelligence Community.

Library of Congress Control Number: 2013951904

ISBN: 978-0-8330-8143-8

Cover images by DefenseImagery.mil and Antique Maps/Planet Art

Cover design by Tanya Maiboroda

RAND OFFICES

SANTA MONICA, CA • WASHINGTON, DC

PITTSBURGH, PA • NEW ORLEANS, LA • JACKSON, MS • BOSTON, MA

DOHA, QA • CAMBRIDGE, UK • BRUSSELS, BE

www.rand.org

Summary

Over the past two decades, the military roles and contributions of unmanned vehicles have grown dramatically, and this trend appears likely to continue. However, unmanned surface vehicles (USVs)—maritime vehicles uninhabited by personnel that maintain continuous, substantial contact with the surface—have received less attention and investment than unmanned vehicles that operate in the air, on the ground, or under the sea. Given this anomaly, the Office of the Chief of Naval Operations, Assessment Division (OPNAV N81) asked RAND to research the prospective suitability of USVs for U.S. Navy missions and functions.

Scope

The purpose of our research was to ascertain to what extent and in what ways USVs are likely to be suitable for contributing to the fulfillment of U.S. Navy missions and supporting functions. This is a qualitative study that aims to link U.S. Navy needs and considerations with the capabilities that USVs can provide.

In delineating the scope of this report, it is important to emphasize that it is not intended to be an update to or replacement for *The Navy Unmanned Surface Vehicle Master Plan* (2007) or the USV portions of *The Unmanned Systems Integrated Roadmap FY2011–2036* (2011). In fact, one of our key recommendations is that a new USV master plan, roadmap, or both be pursued. Rather, this report is intended to provide insights to those seeking to understand how USVs can be employed

in U.S. Navy operations, to lay a foundation for future roadmaps or master plans, and to offer a starting point for stakeholder community discussion of how best to proceed with USV development.

Analysis of the USV Marketplace

We began our analysis by reviewing current and emerging USV markets: what USVs are available or in development, the missions of those USVs, their capabilities, their attributes, and the countries in which they are being developed.[1] We found 63 USVs in what we deemed to be the current market—i.e., they had been tested and demonstrated. The overwhelming majority of these USVs were relatively small (11 meters or shorter), with correspondingly limited endurance, power output, and payload capacity. Approximately half of these USVs are made in the United States, and nearly all of the rest are manufactured in friendly nations. While several of these USVs are capable of multiple missions, most USV capabilities are directed toward only a handful of mission categories: observation and collection, characterization of the physical environment, mine countermeasures (MCM), security against small boat threats, and testing or training platforms. We also found an additional 22 USVs in a less advanced state of development. These are primarily small, low-endurance, low-payload platforms and are likewise manufactured in the United States or countries with which the United States has close ties.

Development of USV Concepts of Employment

Next, we developed and evaluated the prospective ways in which the U.S. Navy could employ USVs. We analyzed 62 different naval missions and functions (see Table S.1) to understand how USVs could con-

1 During this review of USV markets and throughout the study, our analysis was informed by repeated engagement with subject-matter experts from other organizations. A full list of these organizations appears in the Acknowledgments section and in Chapter One.

Table S.1
Potential Naval Missions and Functions for USV Employment

C^4ISR	Military Deception/ Information Operations/ Electronic Warfare	Surface Warfare	Mine Warfare	Anti-Submarine Warfare (ASW)	Logistics	Ground Attack	Air and Missile Defense (AMD)	Functions	Missions Not Currently Being Performed
Persistent ISR in permissive environments	Disposition/ intentions deception	Armed escort	MCM intelligence preparation of the battlespace (IPB)	Unarmed ASW area sanitization	Unmanned vehicle support	Short/ medium-range ground attack	Sensing and warning—unit level	Search and rescue of conscious victims	Blockship operations/ port detonations
Environmental collection in permissive environments	Communic-ations/ signals deception	Counter fast attack craft (fully autonomous)	Reacquisition minehunting and neutralization	Act as an ASW sensor node	Autonomous ship-to-shore connector	Long-range ground attack (arsenal ship, optionally manned)	Sensing and warning—force level	Complex search and rescue	Deliberately allowing capture
ISR in hostile environments	Radar/ signals deception	Counter fast attack craft (remote control)	Autonomous in-stride minehunting and neutralization	Cued overt ASW tracking	Opposed amphibious landing resupply		Non-kinetic unit defense	Test platform	Impairing adversary sensors

Table S.1—Continued

C^4ISR	Military Deception/ Information Operations/ Electronic Warfare	Surface Warfare	Mine Warfare	Anti-Submarine Warfare (ASW)	Logistics	Ground Attack	Air and Missile Defense (AMD)	Functions	Missions Not Currently Being Performed
USV with tethered unmanned undersea vehicle (UUV) to deploy sensors or networks	Acoustic/ signals deception	Presence patrol	Mechanical mine-sweeping and mine harvesting	Armed wartime ASW area sanitization	Covert/ clandestine special operations forces (SOF) cargo delivery		AMD kinetic force defense (using projectiles or directed energy)	Training support	Provocative, high-risk presence
Environmental collection in hostile environments	Decoy/ counter-measures	Open-water ship-vs.-ship conflict	Influence mine-sweeping	Uncued covert ASW tracking	Unmanned vehicle refueling				Vehicle as surface weapon
Processing, exploitation, and dissemination	Military information support operations	Countering swarms	Minefield proofing	Cued covert ASW tracking	Resupply for manned ships				
Communic-ations relay	Tactical jamming		Minelaying	Cued/ uncued ASW engagement	Military interdiction operations support				

Table S.1—Continued

C^4ISR	Military Deception/ Information Operations/ Electronic Warfare	Surface Warfare	Mine Warfare	Anti-Submarine Warfare (ASW)	Logistics	Ground Attack	Air and Missile Defense (AMD)	Functions	Missions Not Currently Being Performed
Deploy individual sensors	Disguised mission								
Deploy independent sensor network	Info systems (cyber/tech)								
	Computer network attack								
	Diversion								

tribute to their fulfillment. We grouped these missions and functions into ten categories.

For each of the missions and functions listed in Table S.1, we developed concepts of USV employment. We drew on subject-matter expertise to devise ways in which USVs could complement or supplant existing platforms or even perform missions or functions in wholly novel ways. Once we developed one or more concepts of employment for a particular mission or function, we had panels of subject-matter experts analyze and refine them in a series of sessions, modifying and extrapolating from the original concepts.

Assessing Suitability

We assessed the suitability of the USV concepts of employment for these missions and functions based on the criteria summarized in Table S.2. We defined *suitability* as the sum of the net benefits and liabilities associated with using USVs for a particular mission, taking into account the impact on mission effectiveness, risks, costs, capital asset requirements, time lines, the desirability of alternative platforms, USV support requirements, and compatibility with existing programs.

The overall suitability characterization is necessarily qualitative and involves some subjectivity. However, we aimed to minimize the degree of subjectivity involved by using a thorough and traceable methodology. Specifically, we developed a spreadsheet in which we characterized the following regarding USV usage for each of the 62 missions:

- prospective benefits or disadvantages of employing USVs relative to current approaches
  - mission effectiveness
  - mission time lines
  - risk to people and/or capital assets
  - requirement for capital assets
  - degree to which USVs could counter emerging adversary capabilities

Table S.2
Criteria for Evaluating the Suitability of USV Concepts of Employment for Particular Missions or Functions

Degree of Suitability	Criteria
Highly suitable	• Significantly increases effectiveness or addresses capability gaps • Reduces risks, costs, need for capital assets, and/or time lines • More appropriate than alternative unmanned or manned platforms • Acceptable transportation, hosting, and support requirements • Programmatic compatibility
Possibly suitable	• Moderately increases effectiveness • Little/no reduction in risks, costs, need for capital assets, and/or time lines • Alternative unmanned or manned platforms potentially more appropriate • Challenges relating to transportation, hosting, and support • Limited programmatic compatibility
Less suitable	• Very limited benefits (or net negative impact) in terms of effectiveness • Increased risks, costs, requirements for capital assets, and/or time lines • Less appropriate than alternative unmanned or manned platforms • Serious impediments relating to transportation, hosting, and support • Programmatic incompatibility

  - potential to cause an adversary to expend resources to counter USVs
  - reliability considerations
  - redundancy considerations
  - ability to achieve the desired degree of stealth or overtness
  - secondary missions and ancillary benefits
- any specific USV attributes that are relevant to the mission
- the degree to which the mission is conducted in particular environments
  - open waters
  - confined waters
  - hostile waters

  - friendly waters
  - high-traffic conditions
  - low-traffic conditions
  - high sea states
  - low sea states
- technological development of USVs for the mission
  - technology readiness level (TRL)
  - qualitative characterization of technology needs
  - technological development risks
  - ability to leverage technological developments also required for USVs to fulfill other missions
  - ability to leverage technological developments also required for other emerging platforms (notably unmanned systems) to fulfill other missions
- programmatic issues associated with using USVs for the mission
  - tactical integration
  - organizational acceptance
  - training requirements
  - qualitative cost considerations
  - program risk
- autonomy, communications, and preprocessing requirements
  - navigational autonomy requirements
  - assured communications requirements
    - for all purposes
    - specifically for the employment of weapons
  - preprocessing requirements
  - networking with other unmanned vehicles
  - ability to trade off between autonomy and assured communications
- relative desirability of other platforms for the mission and relevant attributes for consideration
  - UAVs
  - UUVs
  - manned platforms
- prospective impact of having an optional manning capability while conducting a mission

- prospective utility of replenishment at sea for the mission
- prospective impact of payload modularity on mission capabilities
- prospective utility of an energy scavenging capability
- classes of USVs that might be desirable for this mission.

The material in this spreadsheet was then used as a basis for qualitatively characterizing both the suitability of USVs for the mission (highly suitable, possibly suitable, or less suitable), as well as the degree of technological maturity associated with USV development for the mission.

Comparison of USVs with Other Platforms

One criterion—the appropriateness of USVs relative to other platforms—deserves special attention. USVs are always in competition with manned and other unmanned platforms for missions. To help determine the degree to which USVs are more or less appropriate for a given mission than other unmanned platforms, we compared the performance attributes of USVs with those of unmanned aerial vehicles (UAVs) and UUVs, as shown in Figure S.1.

As indicated in Figure S.1, USVs have greater potential payload capacity and endurance than comparably sized unmanned systems in other domains. They are able to use higher-density energy sources than UUVs (hydrocarbons instead of batteries), and, unlike UAVs, they do not need to burn fuel merely to maintain their vertical position; if desired, they can move relatively slowly for days or weeks without refueling. A comparison of the relative sizes and payloads of some aircraft and vessels is illustrated in Table S.3.

USVs also have the unique ability to operate sensors and communicate both above and below the waterline. Broadly speaking, missions in which payload weight, endurance, and multi-domain capabilities are important—and risk, cost, or other considerations make unmanned platforms preferable to manned ones—are likely to be more appropriate for USV employment. Likewise, missions in which speed is critical are likely to be more appropriate for UAVs, and missions in which stealth is paramount will favor UUVs. In most cases, there will be trade-offs among several desired attributes.

Figure S.1
USV Attributes Compared with Other Similarly Sized Unmanned Vehicles

● Clear advantage for USV ◖ Near parity ○ Clear disadvantage for USV

	USV Comparison with UAV		USV Comparison with UUV	
Attribute	Relative Advantage	Comment	Relative Advantage	Comment
Endurance	●	Advantage most pronounced when USVs can operate at low speed	●	Hydrocarbon fuels with unlimited oxidizers versus batteries and/or fuel cells
Power				
Propulsion	◖		●	UUVs are more volume-limited for propulsion systems; heat dissipation can be an issue
Mission packages	◖		◖	USVs have more power; UUV packages have lower power requirements
Speed	○		●	UUVs are speed-limited to a few knots
Range	○		●	
Payload capacity	●	UAV space, weight, and power for payloads are limited	●	Low energy density reduces UUV internal volume for payloads
Sensors				
Above the surface	○		●	
Subsurface	●		○	UUVs have more types of sensors and can position them better
Communications	◖	UAVs have better vantage points, but USVs have cross-domain capabilities	●	
Stealth	◖	Both USVs and UAVs have potential to be stealthy	○	
Autonomy requirements	○	UAVs have fewer traffic-avoidance problems and no seakeeping issues	◖	UUVs have limited seakeeping issues and fewer traffic-avoidance problems, although they need to avoid undersea hazards; USV autonomy demands are mitigated by better reachback capability

RAND *RR384-S.1*

Table S.3
Comparison of Vessel and Aircraft Sizes and Payload Capacities

Platform	Domain	Dimensions (m)	Payload Capacity (kg)	Payload Divided by Length x (beam or wingspan) (kg/m²)
7-meter rigid-hull inflatable boat (RHIB)	Surface	7 (length) 3 (beam)	700	100
Predator UAV	Air	8 (length) 11 (wingspan)	500	63
11-meter RHIB	Surface	11 (length) 3 (beam)	1,500	136
X-47B	Air	12 (length) 19 (wingspan)	14,000	61
Hercules C-130J-30	Air	35 (length) 40 (wingspan)	20,000	14
Landing Craft Air Cushion (LCAC)	Surface	26 (length) 14 (beam)	68,000	187
Landing Craft Utility (LCU)	Surface	41 (length) 9 (beam)	113,000	306
C-17	Air	53 (length) 52 (wingspan)	137,000	50

NOTE: Aircraft are shown in brown, while vessels are shown in black.

Results of Suitability Analysis

Table S.4 divides the 62 missions and functions we evaluated into three levels of suitability for USV employment (highly suitable, possibly suitable, and less suitable) and three levels of USV technological development (in or near market, emerging, and incipient). Of the 62 missions and functions, we deemed 27 to be highly suitable for USV employment.

As the left-hand cell of the top row shows, USV applications that are already in or near the combined civilian/military market are almost all highly suitable for U.S. Navy missions and functions. For example, USVs for the search and rescue of conscious victims have already

Table S.4
Naval Missions and Functions by Level of Suitability for USV Employment and Level of USV Technological Maturity

	In or Near Market (≥ TRL 8)	Emerging (TRL 4–7)	Incipient (≤ TRL 3)
Highly suitable	C^4ISR: • Persistent ISR in permissive environments • Environmental collection in permissive environments Mine warfare: • Influence minesweeping • Mechanical mine-sweeping and mine harvesting Functions: • Test platform • Training support • Search and rescue (SAR) of conscious victims	Mine warfare: • MCM IPB • Reacquisition minehunting and neutralization Surface warfare: • Armed escort Military deception/information operations/ electronic warfare: • Disposition/intentions deception • Comms/signals deception • Radar/signals deception • Acoustic/signals deception • Decoy/countermeasures • Military information support operations ASW: • Unarmed ASW area sanitization Functions: • Unmanned vehicle support • Processing, exploitation, and dissemination	C^4ISR: • ISR in hostile environments • Environmental collection in hostile environments Mine warfare: • Autonomous in-stride minehunting and neutralization • Minelaying Surface warfare • Counter–fast attack craft (fully autonomous) Functions: • Autonomous ship-to-shore connector • Complex SAR Missions not currently performed: • Impairing adversary sensors
Possibly suitable	Surface warfare: • Counter–fast attack craft (remote control)	C^4ISR: • Communications relay among manned assets • Deploy individual sensors • Deploy independent sensor network Surface warfare: • Presence patrol	Ground attack: • Short/medium-range ground attack • Long-range ground attack (arsenal ship, optionally manned) AMD: • AMD kinetic force defense

Table S.4—Continued

	In or Near Market (≥ TRL 8)	Emerging (TRL 4–7)	Incipient (≤ TRL 3)
Possibly suitable (cont.)		Missions not currently performed: • Provocative, high-risk presence • Vehicle as surface weapon AMD: • Sensing and warning (unit level) • Sensing and warning (force level) • Non-kinetic unit defense Military deception/information operations/ electronic warfare: • Tactical jamming • Disguised mission • Info systems (cyber/tech) • Computer network attack • Diversion Functions: • Opposed amphibious landing resupply	Functions: • Covert/clandestine SOF cargo delivery Missions not currently performed: • Blockship operations • Deliberately allowing capture
Less suitable		ASW: • Act as an ASW sensor node • Cued overt ASW tracking Functions: • Maritime interdiction operations support	ASW: • Armed wartime ASW area sanitization • Uncued ASW tracking • Cued covert ASW tracking • Cued/uncued ASW engagement Surface warfare: • Surface warfare (open water, ship vs. ship) Functions: • Resupply for manned ships

been used to save lives in civilian contexts,[2] and other nations' navies already employ USVs for influence minesweeping.[3] The U.S. Navy could acquire USVs to fulfill the concepts of employment listed in this cell within the next several years.

The concepts of employment listed in the center and right-hand cells of the top row are also highly suitable for naval missions, but they depend on technological capabilities that are at an earlier stage of technological advancement. The U.S. Navy could consider investing in research and development (R&D) to bring these technologies to fruition.

The U.S. Navy could also consider investing in USV technologies to support naval missions for which these technologies are "possibly suitable" (middle row). Employing USVs for these purposes may provide fewer benefits, greater liabilities, or both compared with the missions and functions listed in the top row; however, there may be net benefits that justify such investment. U.S. Navy investment in USVs for those missions for which they are "less suitable" (bottom row) is not recommended due to a combination of low or negative effects and considerable liabilities.

Overall, we found that USVs could improve the effectiveness with which a number of missions are performed. This improvement stems, in part, from the USVs' potential for long endurance, which is advantageous for persistent ISR; MCM; and other missions.

As expected, USV concepts of employment reduced tactical and operational risks relative to current practices. In dangerous environments, such as minefields, it is far better to use unmanned platforms than manned ones. Moreover, a reduction in operational risk could allow a more aggressive posture that would force an adversary to change tactics or increase resource expenditures.

---

[2] One prominent rescue USV is the Emergency Integrated Lifesaving Lanyard (EMILY).

[3] Influence minesweeping entails having a towed body emit acoustic, magnetic, and other signatures that resemble those of a ship. This causes influence mines to detonate without inflicting harm on an actual ship.

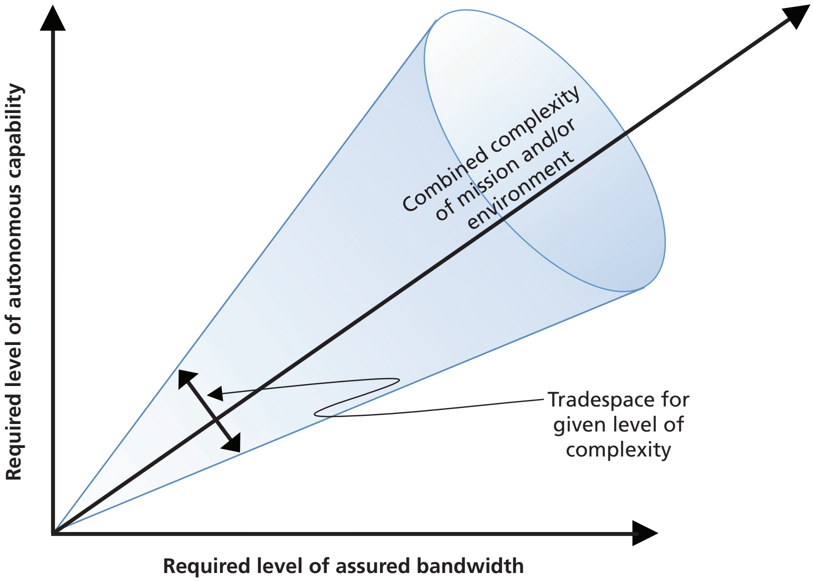
Opportunities with Respect to USVs

In the course of our analysis, we found three mission-transcendent opportunities with respect to USVs. First, USVs could uniquely enable cross-domain integration, increasing the capabilities of other unmanned vehicles or networks. USVs can leverage their relatively large payloads, large reserves of power, and long endurance to provide services for other unmanned platforms—e.g., physically transporting them, preprocessing data for them, and providing electric power via a tether. Second, USVs could be highly effective in overcoming challenging anti-access/area-denial (A2/AD) environments, particularly in military deception, information operations, electronic warfare, and cyberwarfare missions. USVs can help to counter A2/AD challenges by reducing risks to personnel and capital assets; dispersing capabilities into small, hard-to-target nodes; and expanding tactical choices by creating new concepts of employment. Third, we found that increased investment in USV research, development, and acquisition could facilitate technology transfers to other unmanned and manned R&D programs.

We found that advances in autonomy and assured communications are path-critical for USVs to conduct complex missions and/or operate in complex environments. Autonomy, assured communications, and mission or environmental complexity form a tradespace. As environments or missions grow more complex, increasingly advanced autonomy and/or assured communications are required. In essence, USVs are subject to a "control triangle" comparable to the well-known naval architects' "iron triangle" of speed, payload, and endurance. Figure S.2 illustrates the three elements of the control triangle in a three-dimensional graph.

While some aspects of autonomy R&D can leverage advances made for UAVs and UUVs, USV autonomy requirements for seakeeping on the surface and maritime traffic avoidance require USV-specific R&D that is unlikely to emerge from other programs. Advances in these capabilities will be critical to the continued development of USVs for virtually all Navy missions and functions. Finally, we note that advances in these areas, particularly the ability to adhere to regulations to prevent collisions at sea, could benefit future manned platforms.

Figure S.2
The Control Triangle



SOURCE: RAND analysis.
NOTE: The above diagram should be viewed as three-dimensional, with the middle arrow projecting off the page.
RAND *RR384-S.2*

Such advances, for example, could reduce watchstanding requirements on manned platforms with limited crews, such as the Littoral Combat Ship (LCS). Autonomous USV operations also present operational and policy-related challenges, since autonomous USVs would need to be integrated into the Navy's command and control (C2) structures.

Approaches and Considerations for USV Development

There are several approaches that could be undertaken in concert to improve the suitability of USVs for naval missions and functions:

- developing standard platforms with modular payloads, which could lower costs through economies of scale (one model for a parent vehicle), as well as improve the flexibility of the relatively small number of USVs that could be hosted on a ship
- enabling optional manning for maintenance support and situational awareness in transit or other benign environments, as well as for missions in which personnel are desirable
- leveraging the long potential endurance of USVs by
  - designing for reliability
  - developing optionally manned refueling, data-transfer, and maintenance vessels to support them
  - enabling "energy scavenging" (collecting energy from the environment) when power requirements are low.

There are also a number of programmatic challenges that need to be taken into consideration as USV programs evolve:

- USVs will exacerbate manpower and manning challenges. A widely accepted lesson learned from UAV and UUV operations is that unmanned systems are not really "unmanned"—they are, more accurately, "uninhabited." In many instances, the number of personnel required to operate and support a single unmanned system exceeds that for a manned platform with a similar concept of employment.
- USVs are likely to augment, not replace, other U.S. Navy manned programs, at least initially; thus, investments in USVs are likely to increase, rather than decrease, U.S. Navy costs for some time. USVs cannot wholly replace any existing capabilities; this is due in part to the multi-mission role of most Navy programs. For example, even if a USV can perform a particular mission as well as or better than a larger manned warship, that does not mean the USV can perform *all* of the manned warship's missions, and it certainly cannot perform them at the same time. Moreover, USVs that cannot self-deploy over long distances will need to be hosted by larger warships. While they can potentially enable fewer large warships to fulfill a given mission than would oth-

erwise be required, they are unlikely to supplant large, manned warships altogether. We also expect USVs to impose additional requirements on the supply chain, logistics, and maintenance infrastructures.

- The U.S. Navy will need to establish what warfare and/or platform communities will "own and operate" USVs once introduced and how those professional communities will be acquired and sustained.
- USVs will pose community sponsorship and management challenges. These relate to the Navy's planning, programming, budgeting, and execution and acquisition decision support systems and the challenges of starting and sustaining a USV program of record. These challenges include deciding which organizations will be responsible for shaping a USV's operational and programmatic requirements, which organization will sponsor the program's resources, and how the development or acquisition program will be organized.