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Perspective
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Opportunities for the Brazilian Navy to Employ Additional Unmanned Systems

The Brazilian Navy (BN) needs to have both the capabilities and capacity to meet a wide range of demands over vast and diverse geographic areas. In addition to acquiring more manned vessels and aircraft, the BN could expand its capabilities and capacity by investing in unmanned systems across multiple domains, building on existing capabilities. The BN already employs unmanned aerial vehicles (UAVs), primarily for intelligence, surveillance, and reconnaissance (ISR). For example, naval infantry forces use the Horus FT-100 UAV for ISR (having previously used the Caracará UAV), and the BN has been exploring the potential use of the Swell Pro 3 UAV for maritime surveillance. However, as unmanned vehicles become more capable, versatile, multidomain, and affordable, the BN could benefit from using unmanned vehicles for a wider array of missions and environments. This Perspective explores some of the ways the BN could use unmanned systems to improve effectiveness and, potentially, reduce risks and costs. This document has two key purposes. The first is to briefly inform Brazilian decisionmakers as they explore potential ways to incorporate additional unmanned

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systems into the BN. This can contribute to discussions not only within the BN but also in the Brazilian Ministry of Defense, among Brazil's political leadership, and with the wider public. The second is to provide insights for non-Brazilians on the navy of one of the world's leading nations, including its diverse missions and geographic responsibilities, and to show how unmanned vehicles can contribute to the BN's effectiveness. This is valuable both because of Brazil's intrinsic importance and because this analysis may serve as a basic template for how navies of other nations could also employ unmanned vehicles. This cursory examination can serve as a starting point for much deeper analysis of how to select, acquire, and integrate such systems in the context of overall force-structure development.

Overview

This Perspective is divided into three parts. The first characterizes some of the mission and geographic demands that the BN faces. The second presents some of the key features of unmanned systems across multiple domains. The third describes some ideas regarding how the BN could use such systems, as a basis for further exploration.

Abbreviations

BN	Brazilian Navy
EMILY	Emergency Integrated Lifesaving Lanyard
ISR	intelligence, surveillance, and reconnaissance
UAV	unmanned aerial vehicle
UGV	unmanned ground vehicle
USV	unmanned surface vehicle
UUV	unmanned undersea vehicle

The BN Faces Diverse Mission and Geographical Demands

The BN has expansive responsibilities, both domestically and around the globe.[1] Many countries have separate services handling naval and coast guard missions, but the BN combines both sets of missions within a single service. Many services in other nations perform some subset of these missions, and some share the BN's challenge of having to perform them in a range of geographic areas, so the issues it faces—and the opportunities to mitigate them using unmanned vehicles—may be relevant to a number of audiences. The following paragraphs describe first the BN's coast guard responsibilities, then its naval ones.

From a coast guard perspective, the BN needs to secure the nation's vast river basins and expansive offshore waters against nonmilitary threats, such as cocaine smuggling, pollution, and illegal fishing, while also assisting Brazilians in distress. Given Brazil's sheer scale, these domestic responsibilities alone make substantial demands on a military force of roughly 60,000 personnel (including 15,000 naval infantry). Brazil is the world's fifth-largest country by area and the sixth-largest by population, with the ninth-largest gross domestic product, comparable to that of Italy and substantially larger than those of South Korea, Russia, Canada, or Australia. Most of Brazil's 210 million people live along its long coastline, which is also a critical maritime highway through which Brazil exports goods roughly equivalent to two-thirds of its gross domestic product. Brazil's maritime exclusive economic zone is the tenth largest in the world, encompassing considerable living and mineral resources extending into the Atlantic Ocean. In recent years, this offshore area has come to be called the "Amazônia Azul" (Blue Amazon), reflecting its importance to the nation's strength, amplified by the discovery of its large oil reserves. The BN needs to achieve maritime domain awareness and effective response capabilities throughout the Blue Amazon to counter a wide variety of threats and risks. These include smuggling, pollution, violations of the exclusive economic zone by foreign fishing vessels, possible attacks by terrorists or nation-states, and obstructions that pose hazards to vessels. As Brazil builds up its offshore oil infrastructure in the Blue Amazon and as vessel traffic in the region increases over time to reflect the nation's economic and demographic growth, the need to protect this area will only grow.

The BN also needs to operate effectively throughout the Amazon basin—the nation's heartland, spanning one-third of its territory—in which river traffic is central to the lives and welfare of millions of Brazilians. Other large river systems also span much of the country and are similarly important in their regions. In many cases, the extremities of river systems either form Brazil's boundaries with other South American nations or cross those boundaries in ways that facilitate both legal and illicit cross-border traffic. Much of the illicit traffic involves cocaine, some of which is consumed within Brazil, with the rest largely moved onward to Africa and Europe. The result is that the BN needs to operate thousands of miles inland to prevent smuggling via inland waterways, to secure Brazil's borders, to mitigate pollution threats, and to rescue Brazilian citizens in the deep interior of the country.

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These domestic responsibilities are complemented by the BN's need to secure Brazil's interests in the Americas and around the globe. As the biggest nation in Latin America by any measure, Brazil has a key role in regional security. To that end, Brazil has been a central contributor to peacekeeping in Haiti since the 1990s, which the BN has supported. Unfortunately, other nations in the region also face issues in terms of governance limitations. The most glaring example at present is Venezuela, which is experiencing political instability, violence, and a rapidly shrinking economy. In the event of a further collapse and/or a full-scale civil war, the BN could play diverse roles: providing humanitarian support, helping restore stability and security, securing Brazil's own territory against spillover of the conflict, and caring for large numbers of refugees entering Brazil. Any such BN operations would likely take place both along Venezuela's Caribbean coastline (where most of its population lives) and along the rivers that span the Brazilian-Venezuelan border. The BN could also become involved in stabilization operations in other nations or in countering rebel groups threatening the legitimate governments of its neighbors.

The BN also secures Brazil's global interests, far beyond the Americas. Brazil has long had a variety of cultural, commercial, political, and other ties with numerous African nations, five of which also share its language. To that end, the BN has trained and exercised with many African nations' coast guards and navies. The BN has also contributed to peacekeeping as far away as Lebanon, the ancestral home of millions of Brazilians. In keeping with Brazil's role as a leading nation of the Southern Hemisphere, the BN helps to support Brazil's involvement in Antarctica and the adjacent oceans, which Brazil's government views as a national priority. Brazil also has close cultural and commercial ties with European, Middle Eastern, North American, and Asian nations, which contribute to corresponding interests in those regions.

To the extent that the BN may engage in conventional state-on-state conflicts, these are overwhelmingly likely to be overseas, stemming from Brazilian interests outside its own region. Brazil's sheer size makes it unlikely that a neighbor would threaten it: It has roughly one-half of the continent's population and one-half of its gross domestic product, each of which is four times that of any other nation. Although these ratios may change over time, given any reasonable amount of defense spending, no other nation or potential coalition could reasonably be expected to pose a major conventional military threat to Brazil's own territory.[2] It also has no outstanding border disputes with its neighbors. The result is that, if the BN anticipates fighting against the armed forces of a nation-state, it will require power-projection capabilities to be able to conduct operations far from its shores, just as it did in the Atlantic, Mediterranean, and Europe during World War II. Moreover, Brazil may be operating as part of a coalition; the fact that Brazil is not part of formal military alliances means that it is unable to predict which nations might be fighting alongside it. Since the BN cannot confidently rely on specific allies for support in niche areas, it must have a high degree of self-reliance. Although, for example, NATO navies can specialize to some degree and leverage their respective strengths, the BN needs to be capable of

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Key Characteristics of Unmanned Systems

Unmanned systems could help address some of the many geographic and mission demands that the BN faces by increasing its ability to perform some missions, complementing manned assets, and reducing costs. In assessing which additional types of unmanned systems might be useful to the BN, beyond those it already has, it is important to specify various characteristics of such systems that shape their suitability for particular missions and environments. The following lists describe some of these characteristics as a foundation for analyzing prospective uses of unmanned vehicles in the final section of the Perspective:

- **Domain.** Commercially available unmanned systems already operate in the air, on the water's surface, under the waterline, and on the ground. Each domain has its relative advantages, depending on the mission and the environment. For example,
  - UAVs are generally faster than those in other domains and can move in three dimensions, enabling them to achieve multiple vantage points. Many of the world's militaries, including navies and coast guards, already use UAVs. Key limitations include their endurance and range, both of which are circumscribed by the energy they need to remain airborne. Moreover, depending on their size, they can be relatively easy for opposing forces to detect and track using radar.[3]
  - Unmanned surface vehicles (USVs) typically have more-limited speeds than comparably sized UAVs but can accommodate larger payloads and can achieve longer endurance in the environment. USVs can deploy sensors both above and below the waterline and even host or support UAVs or unmanned undersea vehicles (UUVs). Key challenges for USVs include avoidance of other surface traffic and seakeeping (being able to survive and operate in various sea states).[4]
  - UUVs can be stealthier than UAVs or USVs and can move in three dimensions but typically move slowly and are cut off from access to the electromagnetic spectrum while they are submerged. Using batteries limits a UUV's endurance and range. To recharge the batteries using fossil fuels, UUVs must periodically surface for extended periods, which detracts from their stealth.[5]
  - Unmanned ground vehicles (UGVs) can operate alongside naval infantry in a variety of roles: They can be remotely controlled to conduct intelligence collection, resupply, and even kinetic attacks. Key challenges include the difficulty of operating in rough terrain and avoiding collisions in complex, dense environments.
- **Degree of autonomy.** Unmanned systems are more accurately described as uninhabited ones: They do not contain a human being who controls their operations. However, the degree to which humans are involved in controlling operations varies greatly. Some systems are remotely controlled, while others can conduct an entire mission almost without human involvement. Most unmanned systems lie

somewhere along this spectrum rather than at its endpoints: External operators are capable of intervening to some degree, but the system also has an autonomous ability to respond dynamically to its environment. The complexities of both the mission and the environment shape the degree to which some combination of sophisticated autonomy and assured communications bandwidth are required.[6]

   - Ability to employ machine learning or artificial intelligence. The software that governs systems with some degree of autonomy may include a machine-learning component. In such cases, the unmanned system, like a human, is continually training in the course of its experience: Its responses to the environment and ways of accomplishing its mission may evolve over time. An autonomous system that uses artificial intelligence (admittedly, a term that various stakeholders define differently) may also make decisions in ways that humans do not fully understand. This makes it more challenging to anticipate a system's responses in a given context or to trust it in sensitive situations.[7]

- **Interactions with other manned and unmanned systems.** Unmanned vehicles may be designed to autonomously coordinate their actions with manned systems, responding to movements or actions without explicit direction. Unmanned vehicles may also autonomously coordinate with one another, enabling the use of swarms, which can collectively achieve distributed effects. For example, groups of autonomous USVs with coordinated behaviors could collaborate to clean up oil spills, avoiding collisions while collectively maximizing their efficiency. Given sonar capabilities, USVs could also be used to search for mines or submarines. Swarms in various domains could be used to launch coordinated multidirectional attacks that a defender would have great difficulty in countering.[8]
- **Range and endurance.** The distances and timelines over which unmanned vehicles can operate in the environment will shape the degree to which they operate as independent platforms, as opposed to short-range additions to the capabilities of other systems.
- **Durability and survivability in different environments.** The BN may use unmanned vehicles in environments ranging from the hot, humid Amazon basin to the freezing shores of Antarctica.[9] Not all systems may be capable of operating effectively in such diverse domains, particularly over protracted periods. In hostile environments, unmanned vehicles can differ greatly in terms of their ability to survive various possible types of attack and continue to operate. In many cases, adding durability and redundancy to enable vehicles to survive attacks that are heavier than small-arms fire may not be cost-effective: It may be better simply to build more vehicles. It may make sense to endow them with software that enables them to resist some electronic attacks or cyberattacks because the marginal costs for doing so are likely to be minimal.

Opportunities for the BN to Use Unmanned Systems

The BN already uses the Horus FT-100 UAV, as noted earlier. This compact UAV (it weighs just 8 kg, or 18 lbs) contributes to ISR in ground environments. The BN is also currently pursuing additional unmanned vehicles that might contribute to its operations. To stimulate thinking about how the BN might develop concepts of operations for these vehicles and select the types it wants, a series of applications is described below. These applications are not meant to be comprehensive, but merely indicative of how the BN might use unmanned vehicles. These potential applications can be grouped under three broad categories:

- maritime domain awareness
- logistics and disaster response
- kinetic use.

The following paragraphs explore each of these categories in different mission and geographic contexts.

Maritime Domain Awareness

Unmanned vehicles are particularly capable at contributing to domain awareness. This section presents some of the many ways in which they could do so throughout the BN's operating environments.

Offshore and Coastal Environments

Unmanned vehicles could be used for maritime domain awareness in both offshore and coastal environments. Having greater maritime domain awareness could help alert the BN to unreported offshore oil spills, such as the one that contaminated beaches in northern Brazil in 2019. Inexpensive aerial observation of spills using UAVs could facilitate containment, cleanup, and attribution throughout the Blue Amazon. UAVs or USVs could also help observe smuggling vessels transiting Brazilian waters, including in locations far offshore, freeing manned assets to respond to observed threats and to conduct other missions. Awareness of vessels in need of assistance, vessel collisions, and other crises could be increased through the use of USVs that endured in the environment for days or weeks, periodically relocating as needed. UAVs based on BN vessels, USVs, or shore stations could provide additional awareness. In searching for a lost vessel or aircraft in the Atlantic, such as following the 2009 crash of Air France flight 447 en route from Rio de Janeiro to Paris, having unmanned platforms to complement available manned ones could accelerate the search.

These unmanned vehicles could also help secure coastal and offshore infrastructure against attack. For example, having distributed USVs and UAVs in the vicinity of offshore oil rigs could provide advance warning of possible attacks by criminals or terrorists, similar to those that frequently occur in West Africa. Likewise, these systems could detect possible threats to coastal cities or their ports from incoming hostile vessels. Remotely controlled USVs or UAVs could even be made to deliberately collide with attackers or to use remotely operated weapon systems against them.

Using unmanned vehicles rather than manned ones in Brazil's coastal and offshore environments has several advantages. An unmanned vehicle can have a much higher payload ratio than a manned one because it does not need to provide for basic human needs. An unmanned

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vessel does not need to contain living quarters, space for food storage and preparation, clean water, and medical supplies; therefore, it can be smaller, cheaper, and lower maintenance than a comparable manned vessel. Likewise, an unmanned aircraft does not need equipment or space to keep a pilot alive, and its range is limited only by its fuel consumption, not by the endurance of the pilot. An unmanned vehicle can also reduce risks to personnel: Smugglers shooting at an unmanned vehicle shadowing them cannot harm anyone, but they do reveal their intent so that manned vehicles can use appropriate protection and force. Unmanned vehicles may also be able to operate in polluted areas, such as the vicinity of chemical spills, avoiding human exposure or the need for humans to heavily impair their performance by wearing copious protective equipment. In short, while personnel will be required to remotely operate these vehicles and observe the information they collect, doing so remotely can reduce both risks to personnel and stresses on them. To the degree that these systems have some autonomy and advanced pattern recognition, it may be possible for a few human beings to operate and observe the feeds from a large number of unmanned vehicles, which would further reduce costs relative to using manned platforms.

In Brazil's vast coastal and offshore environments, both USVs and UAVs would need to be selected for long ranges and the ability to endure in the environment over long periods. Moreover, they could need to have some degree of autonomy, given the potential for losing communications links with faraway manned vessels or bases on land. Such autonomy would include some degree of collision-avoidance capabilities, particularly in more densely trafficked coastal environments. The vehicles would also need to be designed to survive and operate in a variety of sea states.

Brazilian River Systems

Long-endurance USVs operating along Brazil's rivers could observe possible smuggling operations, particularly near the country's borders or where multiple rivers converge. These USVs could linger in the waterspace for weeks, spending most of their time at anchor but also periodically relocating to observe different parts of their environments and, perhaps, even shadowing suspected smuggling vessels. These vehicles could collect video and audio information and data on the communications of suspected smugglers, then stream this back to fixed stations along the river for humans to assess. Based on intelligence from the USVs and other sources, UAVs could be launched periodically, either from shore or from a USV itself. This would provide overhead views to enable wide-area observation and the ability to shift locations rapidly or to track a fast-moving vessel. Using USVs and UAVs in conjunction would leverage both the endurance of USVs and the greater speeds and altitudes of UAVs. Both USVs and UAVs could periodically return to the fixed stations for refueling and maintenance. To keep costs low, these platforms would not be designed to withstand sustained attacks. However, any attacks against them would unequivocally demonstrate hostile intent, cueing manned assets to pursue the attackers.

Having unmanned vehicles (perhaps including the existing Horus FT-100 system the naval infantry already uses) provide maritime domain awareness in Brazilian rivers could have various benefits beyond countering smuggling. In the event of vessel collisions, extreme flooding, or other rescue scenarios, having distributed unmanned vehicles would provide a network of predeployed sensors to aid in response. Likewise, having continuous information flows about spills of oil or other chemicals could help the BN and other responders contain the spill and clean it up. In both 2015 and 2019, Brazil experienced the collapse of dams that contained polluted mine tailings, causing surges of contaminated mud to overrun people and buildings. Achieving domain awareness was critical to locating and aiding survivors, recovering bodies, and figuring out how best to limit downstream pollution that harmed communities and ecosystems. In future situations like these, having USVs or UAVs based along nearby rivers could help provide time-critical information to responders. Similarly, if state collapse in Venezuela leads to large numbers of refugees migrating along the Uraricoera River into Brazil, distributed unmanned vehicles with video sensors could help achieve awareness of where the migrants are, their physical condition, and their most immediate needs for survival.

One of the key challenges in this concept of operations would be ensuring reliable communications between the unmanned vehicles and their operators. This is not too difficult for UAVs, since their altitude facilitates unobstructed electronic communications (although the rainforest environment absorbs electromagnetic energy). USVs, which have more of a challenge in this regard, could employ small balloons or rotary UAVs tethered via long, retractable cables, which would give them the effective altitude they would need to facilitate communications with towers at the fixed stations. Alternatively, they could relay information via long-endurance UAVs that would be based at the fixed stations and continually relaunched. Operating high-altitude aerostats at the fixed stations could also work, although these might be expensive and would need to be retracted in bad weather. Finally, as privately owned satellite communications become increasingly inexpensive, those might be an option as well.

It is likely that inland waterways would require different USVs from those in coastal and offshore environments. Tall vegetation and other obstructions can impede vision and communication for USVs, so they may need to have tethered balloons (or even tethered UAVs) that can compensate. The high density of traffic and occasional shallow areas along winding rivers make collisions or groundings of USVs more likely than in offshore areas, so smaller-draft vessels that are more adept at collision avoidance will be needed in this environment.

Beyond Brazil

Unmanned vehicles could also provide maritime domain awareness beyond Brazil's own waters. When conducting peacekeeping or humanitarian assistance, information-collecting USVs and UAVs could help clarify key information regarding potential risks of violent confrontations or where victims in need of help are. For example, after a hurricane or tsunami, USVs and UAVs could help detect individuals trapped on temporary islands requiring rescue. Remotely controlled UGVs and short-range UAVs could also help increase the awareness of naval infantry ashore, providing awareness of what is happening in dense, obstructed urban environments. For example, the BN contributed to disaster response following the Haitian earthquake of 2010, although without the benefit of unmanned vehicles; were Haiti to be hit by another natural disaster, followed by disorder and violence, information streams from unmanned vehicles could help the BN save lives and restore stability in the complex environment of Port-au-Prince.

Another environment where unmanned vehicles could help the BN is the Antarctic, where Brazil has a permanent base and regularly sends naval vessels. Knowing ice conditions and localized meteorology can help ships improve their performance in this harsh environment. Ship-launched UAVs that fly ahead to observe ice and weather conditions can be useful in the Antarctic. In addition, short-range UGVs with sensors that can assess ice thickness could roam ahead of icebreakers, ascertaining the most advantageous pathways for icebreaking. Both types of vehicles would need to be tailored to handle extreme conditions, in which systems designed for more moderate climates might become brittle or otherwise fail.

In conflict situations, unmanned vehicles could provide vital, time-critical information, as has been demonstrated with UAVs for the past two decades. For example, such vehicles could monitor a speedboat taking an unusual course, ascertaining whether it is likely to pose a threat to BN ships (e.g., like the boat that detonated next to the USS *Cole* in 2000). In a conflict, USVs and UGVs could also provide information about threats in their respective domains. UUVs could be used to clandestinely observe an adversary's ports or vessels, freeing submarines for other missions. The advantages of using unmanned vehicles for these operations include risk reduction and savings in cost and personnel. The fact that an unmanned vehicle does not require the space and systems associated with human habitation can also enable such vehicles to have smaller signatures than manned platforms, making them harder to detect and to target.

Logistics and Disaster Response

A mantra about unmanned vehicles is that they are particularly useful in performing tasks that are "dull, dirty, or dangerous." By performing these tasks, such vehicles not only reduce risks and tedium but also free manned assets to focus on other missions. Unmanned vehicles could also perform some logistical functions and aspects of disaster response that fall into these categories, as this section describes.

Unmanned vehicles could handle routine logistical deliveries of fuel, spare parts, medical supplies, and other materiel in a variety of situations, and eliminating the need to sustain personnel within a vehicle can increase its payload. For example, unmanned vehicles could be used to resupply ships at sea or remote outposts along Brazil's rivers, many of which have limited road access. A large rotary-wing UAV, such as the U.S. Navy's Fire Scout MQ-8B, can deliver up to 320 kg of materiel. USVs could deliver much larger quantities of supplies or equipment, albeit at lower speeds. Personnel could be involved in loading and unloading the vehicle at both ends; only the monotonous transit would not require human presence. Human operators may still be required to remotely pilot the vehicles, particularly in areas of dense traffic and near the endpoints of the journey, although autonomous waypoint navigation may obviate the need for close supervision.

Such logistical support can be particularly valuable in disaster response, where copious quantities of materiel need to be deployed rapidly to an area. As noted earlier, unmanned vehicles can also provide key awareness in responding to disasters and can also be used to take direct action to mitigate the effects of that disaster. For example, OceanAlpha has developed USVs that can fight fires on ships or coastlines, complementing the firefighting capacity of manned assets (OceanAlpha Group Ltd., undated). USVs can also aid in rescue; the Emergency Integrated Lifesaving Lanyard (EMILY) USV is a motorized, buoyant vehicle that can be directed to race out to people in distress, providing them with a large flotation device and life jackets while they await extrication (Hydronalix, undated). In addition, USVs could aid in cleaning up polluted environments. Pairs of such vehicles can use booms to help contain oil or other chemicals, and USVs can even collect oil using skimmers or absorbent materials. For example, Sea Machines Robotics has already installed autonomous controls on oil-skimming vehicles (Sea Machines Robotics, 2019). Reducing the need for humans to be involved in this dirty, tedious work would be beneficial, particularly if the spill involved chemicals that are more hazardous than crude oil, as in the previously mentioned mining dam collapses. A USV performing this function while moving relatively little could work for days or more without having to return to port. By contrast, a manned vessel would either need to return to port on a daily basis or sacrifice considerable space to accommodate the crew's needs for food, cooking, fresh water, living quarters, and bathroom facilities.

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Unmanned vehicles can also be used numerous ways in combat.

Kinetic Use

Unmanned vehicles could also be used for a variety of kinetic actions. For example, USVs could be used to help protect sensitive port facilities and key vessels from seaward attack; Protector USVs, for example, can be equipped with nonlethal water cannons and guns (Rafael Advanced Defense Systems, Ltd., undated). Once an intruding vessel's intent had been sufficiently established, a USV could either collide with it to prevent rapid movement toward its target or could attack it directly. Given the potential presence of noncombatants in port environments, such actions would likely need to be remotely controlled, rather than autonomous. UAVs could also be used in similar fashion, perhaps crashing into an intruding vessel's engine or shooting that engine from behind to impede further movement.

USVs could also be used for mine countermeasures; a number of nations have developed unmanned systems to clear minefields while minimizing the need for human beings to enter them. For example, such systems as the U.S. Fleet–class USV can tow minehunting equipment to detect mines or minesweeping equipment to prematurely detonate them.

Unmanned vehicles could be used in numerous ways in combat. For example, such vehicles could conduct electronic attacks against the communications and navigation signals that adversary platforms need. Some could be armed with weapons, as other militaries have long done, although this requires a high degree of confidence in assured communications or advanced autonomy to prevent fratricide and collateral damage. UUVs would have the additional advantage of being able to stealthily enter a hostile environment and launch weapons from within it. The types of weapons that could be used in a warfare environment depend on a detailed evaluation of the scenarios in which the BN intends to use them.

Closing Remarks

This Perspective has very briefly explored how the BN could use additional unmanned systems to help meet its diverse geographic and mission demands. These insights have relevance not only for the BN, with its diverse mission set and globe-spanning responsibilities, but also potentially for the services of other nations that share some subset of its challenges. The document began by delineating some of these demands, then described some of the key characteristics associated with unmanned systems, such as their domain, degree of autonomy, and survivability in various environments. Finally, it presented some potential missions and contexts in which the BN could use unmanned vehicles more extensively than it does at present. This overview can lay the groundwork for more detailed analysis of what types of unmanned systems best fit the BN's needs, and how to integrate them into the BN's overall future force structure.

Notes

[1] This section is based partly on the BN's website (Marinha do Brasil, undated), an overview of Brazil's geopolitical challenges over time (Carmona, 2019), and a book developed by and for the BN (Ribeiro, 2017). Additional historical background came from Scheina, 1987.

[2] One of Brazil's immediate neighbors does have a substantial power-projection capability: Brazil shares a border with France, because French Guiana is an integral part of that nation, despite being located in South America. However, the two countries' last residual territorial dispute (over lobster-harvesting rights) was settled peacefully in the early 1960s, after displays of force from both sides. Despite recent heated rhetoric over environmental issues, there is no reason to believe that Brazil and France would come into military conflict with one another.

[3] Various RAND publications describe some of the issues involved in military use of UAVs. These include Alkire et al., 2010; Gilmore, Chaykowsky, and Thomas, 2019; Peters et al., 2011; Drew et al., 2005; and Lingel et al., 2012. Alaska Center for Unmanned Aerial System Integration, undated, and U.S. Army UAS Center of Excellence, 2010, also provide useful insights regarding applications and context.

[4] These and other issues are explored at length in such RAND publications as Savitz et al., 2013, as well as in O'Rourke, 2021.

[5] These and other topics are addressed in Button et al., 2009, Savitz et al., 2013, and French, 2010.

[6] Other RAND publications, such as Martin et al., 2019, and Gonzales and Harting, 2014, further describe issues relating to autonomy, focusing on USVs and UUVs.

[7] Issues relating to artificial intelligence, machine learning, and related topics are discussed in such RAND publications as Morgan and Cohen, 2020; Morgan et al., 2020; Tarraf et al., 2019; Cohen et al., 2020; Zhang et al., 2020; and Hamilton, 2020.

[8] Some RAND research on this subject includes Edwards, 2005; Arquilla and Ronfeldt, 2000; and Arquilla and Ronfeldt, 2001.

[9] Tingstad et al., 2018, captures some of RAND's research on the challenges of operating in polar environments.

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About This Perspective

The Brazilian Navy (BN) needs to conduct a wide range of missions over vast geographic areas. This Perspective explores some of the ways the BN could use unmanned vehicles to improve effectiveness and, potentially, reduce risks and costs. The document can inform Brazilian decisionmakers as they explore ways to incorporate additional unmanned vehicles into the BN. In addition, This Perspective provides insights for defense stakeholders and the wider public on the navy of one of the world's leading nations and on how unmanned vehicles can contribute to its effectiveness. This is valuable both because of Brazil's intrinsic importance and because this analysis can serve as a basic template for how other navies could also employ unmanned vehicles.

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Scott Savitz is a senior engineer at the RAND Corporation. Much of his research focuses on how to improve the effectiveness and resilience of operational forces, as well as the impact of reallocating resources among those forces.

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