Pushing the Limits of Range
Long-range Amphibious Operations

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Abstract: The *Marine Corps Operating Concept* states that a Marine Air-Ground Task Force composited to defeat a near-peer competitor with antiaccess/area denial (A2/AD) capabilities may demand more emphasis on the air combat element. This analysis goes well beyond the current doctrine for amphibious operations by proposing a future military concept termed *long-range amphibious operations*, or operations that rely almost exclusively on an air combat element, and the possible long-range deployment of surface connectors for ship-to-shore movement. Such amphibious operations may hold promise for overcoming A2/AD capabilities while providing new capabilities along the range of military operations and support of American long-term strategic interests. This analysis provides a rare attempt to systematically examine the strengths, weaknesses, technological capabilities, and characteristics of such long-range operations to understand the current promise and perils of long-range amphibious operations, evaluating what acquisitions will best support such amphibious operations, and incentivizing constructive discussion concerning doctrinal innovation in relation to amphibious operations.

Keywords: amphibious operation, amphibious warfare, forcible entry, air combat element, amphibious equipment, air assault, near-peer competitor

This analysis assesses the technological capabilities, limitations, and vulnerabilities of long-range amphibious operations through the year 2028, when the procurement of medium- and ultra-size future vertical take-

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off and landing (VTOL) aircraft begins. *Long-range amphibious operations* are defined as operations that seek to keep amphibious ships 100 nautical miles (nm) or more from the amphibious objective area. This is a distance that allows for multi-layered defense against anitship cruise missles that can include the use of long-range interceptors, such as the Standard Missle 2 and Standard Missle 3, while relying more on medium-range engagements than long-range missions for defense—an idea proposed by the Center for Strategic and Budgetary Assessments (CSBA).[1] Thus, this article explores a future military concept that concentrates on potential forces and their possible capabilities. That said, this article will not go into the utility and feasibility of amphibious operations themselves, assuming such operations are an important tool to have for commanders and policy makers.

After an explanation of the threats in a contested amphibious landing, it will be shown that for long-range amphibious operations using the Sikorsky CH-53K King Stallion, it is feasible to use an air combat element to transport, provide fire support for, and provide air resupply for Marines. This would include the use of batteries of the M777A2 (a 155 mm howitzer towed artillery); a light armored vehicle (LAV) variant, the M142 High Mobility Artillery Rocket System (HIMARS); the Oshkosh Defense Joint Light Tactical Vehicle (JLTV); and the AM General High Mobility Multipurpose Wheeled Vehicle (HMMWV or humvee), which could be used in an air assault from an Expeditionary Strike Group (ESG) or Marine Expeditionary Brigade (MEB) assault amphibious task force up to 110 nm from shore. However, this analysis will show that such operations carry their own limitations because of the loss of M1A1 Abrams main battle tanks, amphibious assault vehicles (AAVs), heavy logistic support, and naval gunfire support (NGFS).

This analysis will then assess long-range amphibious operations by the capabilities that may be deployed through 2028. It will be shown that to optimize future long-range operations, drastically increase their radius of action, and increase the weight of equipment transported by VTOL aircraft, the U.S. Marine Corps will need to acquire Marine attack tiltrotors, utility tiltrotors, and ultra-heavy VTOL aircraft. An assessment of the strategic advantages and disadvantages of this type of warfare will follow. This will culminate in a series of acquisition recommendations for the U.S. Navy and the Marine Corps to enhance long-range amphibious operation capabilities.

The ultimate purpose of this article is to analyze the feasibility and effectiveness of future long-range amphibious operations in the execution of U.S. strategic interests. This military concept will need to be tried and tested by strategists and commanders long before they can be used in simulations and wargames. Ultimately, the goal of the study of this military doctrine will be to one day in-

fluence new doctrine for the benefit of troops that face the challenge of defeating enemy militaries armed with antiaccess/area denial (A2/AD) technologies.

Knowing the Challenges of a Contested Amphibious Operation

First, it is important to explain the challenges that will be presented in an amphibious operation against contested coastline. An analysis from Rand explains the dangers associated with amphibious operations in contested areas, which explains the advantages and disadvantages inherent in the use of amphibious forces in contested littoral combat zones:

Antiship missiles and tactical aircraft. Potential enemies can detect an Amphibious Task Force (ATF) over-the-horizon (OTH) as well as deploying tactical aircraft and launching a large number of antiship missiles. Although the ships of an ATF have several options for missile defense, including point defense, area missile defense, and defensive counterair, the closer the ships of the ATF come to shore, the less effective these defenses become. This is because it is easier to detect an ATF the closer it is to shore, because the reaction time of an ATF to aircraft and missiles decreases the closer to shore it is, and because the number of weapons an enemy may use increases the closer to shore an ATF comes. These same issues are also true of ships performing naval surface fire support for the ATF.

Submarines operating in both the open ocean and littoral waters. Enemy nuclear submarines can threaten the ships of an ATF as it transits to the battle zone. The ATF may be most vulnerable during this period. As seen in the 1982 Falkland Islands War, Argentine attacks using fixed-wing aircraft armed with Exocet missiles managed to sink one ship of a British ATF. However, the damage was not sufficient to stop the ATF from performing an amphibious operation.[2] Lower-speed diesel submarines cannot threaten as wide an area, but they are very difficult to detect. Diesel submarines are a significant threat to an ATF and ships providing naval surface fire support during an amphibious operation.

Mines laid in approaches, in shallow water, and in the surf zone. As the easiest way to stop an amphibious assault, mines can threaten amphibious shipping, surface connectors carrying the larger and heavier elements of the assault force, and the landing force equipment and personnel as they move ashore. Mines represent a way for less advanced forces to limit the amphibious capabilities of more advanced navies. This is evident in the First Gulf War (1990–91) with the decision not to carry out an amphibious assault by Ma-

rines, and in the failure to prosecute an amphibious assault in the Korean War at Wonsan (1950).[3]

Air defenses, ranging from sophisticated integrated air defense systems to short-range, shoulder-fired weapons and small arms. These are principally a threat to transport and support aircraft, but they may be used against fire support elements.

Opposing forces ashore who directly oppose the movements of the landing force. Even if there is relatively light opposition to movement ashore, adversary land forces can pose significant opposition to the landing force once it arrives.[4]

Technological and Logistical Assumptions and Challenges Pertaining to Near-Term, Long-range Amphibious Operations

For the near future of the next five years, the following factors limit the range, weapons, and capabilities of long-range amphibious operations and the effectiveness of American strategic interests. A carrier strike group (CSG) or multiple CSGs will likely be required for a long-range amphibious operations due to the need to control the airspace over contested coastline being invaded, to suppress coastal antiair defenses, and to provide considerable close air support to the ground maneuver element. There are also limitations related to the range of the aircraft used. The combat radius of a Bell Boeing MV-22B Osprey is 428 nm when transporting 24 Marines and a ramp-mounted weapon system.[5] However, the loiter time of an Osprey is only 20 minutes when traveling 428 nm.[6] This means the aircraft will have little time before needing to head back to an ATF to refuel. Further limitations of the Osprey include its ability to transport external loads 428 nm or to transport internal loads 428 nm unless they are 6,000 pounds or lighter.[7] Six thousand pounds is not even enough to transport the M1161 Growler internally transportable vehicle (ITV).[8] If transporting an ITV, the combat radius of the Osprey falls to as few as 220 nm.[9]

Furthermore, in an amphibious operation that attempts to take full advantage of the combat radius of an Osprey, troops will need to create landing zones to gain access to logistical supplies flown in by the aircraft. The Osprey also has a combat radius of only 50 nm if carrying a 10,000-pound external load.[10] Other aircraft have similar issues related to range and load-bearing capacity. The combat radius of the Boeing F/A-18E/F Super Hornet is only 390 nm when armed with two AIM-9X Sidewinder missiles and 4,000 pounds of bombs for interdiction missions.[11] In addition, this aircraft is the current backbone of U.S. Navy carrier air wings.[12] There are additional issues related to range. Long-range

amphibious operations operating more than 100 nm away from an ATF will demand a heavy reliance on aircraft for fire support. While the Lockheed Martin F-35B/C Lightning II aircraft have a greater combat radius than the Super Hornet fixed-wing aircraft, the Lightning IIs are not the backbone of U.S. Navy carrier battle groups.[13] In addition, the number of F-35Bs on amphibious assault ships will be limited to maximize the number of transport aircraft.

The new CH-53K King Stallion can transport equipment or vehicles that weigh 27,000 pounds farther than 110 nm in high-altitude or hot environment conditions.[14] This allows King Stallions to transport one HIMARS, one LAV variant, one JLTV, two humvees, one M777A2 howitzer towed artillery with room for projectiles, or two 10,000-pound cargo pallets.[15] Although its combat radius of 110 nm is extraordinary, it is one of the biggest restrictions for long-range amphibious operations. Fire support from VTOL aircraft are limited to 119 nm, which is the combat radius of the Bell UH-1Y Venom utility helicopter. While the Bell AH-1Z Viper attack helicopter has a wider combat radius of 131 nm, for both the Venom and Viper aircraft to work in tandem, the range is more limited.[16]

To begin an assessment of these facts, we must first fix an outer range of an amphibious assault using Ospreys. Four hundred and twenty-eight nautical miles is simply too far for an amphibious landing force composed entirely of infantry to seize territory. The combat radius of Super Hornet aircraft prevents this because the landing force will be entirely reliant on fixed-wing aircraft for fire support and for deep strikes against enemy reinforcements that threaten the amphibious objective area. Due to the need for significant close-air support, 390 nm (448 statute miles) is the maximum range of an amphibious assault with lightly armed forces.[17] Even then, deep strikes against enemy reinforcements will not be possible.

Thus, the longest-range amphibious assault of lightly armed forces will likely be less than 390 nm from an ATF. Even then, significant numbers of strike aircraft will be needed, because less than one-third of all aircraft would be in the amphibious objective area to provide fire support, based on the general rule that an aircraft needs one-third of its fuel to conduct operations when it travels its maximum combat radius.[18] If the Marines desire ITVs, the range of the amphibious operation will be reduced to as little as 220 nm. In addition, the Marines will be reliant on Osprey carrying internal cargo of 6,000–8,300 pounds, which will result in a need for landing zones for air resupply. Medevac (medical evacuation) will also be an issue since it may take more than an hour to fly wounded soldiers back to a hospital aboard a ship, given the Osprey has a maximum cruise speed of 270 knots.[19] It will also be difficult to quickly mass aircraft at such long ranges, because many aircraft will be in transit to the amphibious objective area, in transit to the ATF, or refueling and rearming.

Realistically, we are discussing more of a raider or reconnaissance force than an actual amphibious assault to seize territory, especially when fighting for contested coastline. Another use for such operations are extreme long-range capabilities for amphibious withdrawals, such as during a noncombatant evacuation and for humanitarian aid. That said, such long-range operations also present valuable capabilities in conflicts against lightly armed foes where infantry and ITVs may be sufficient for an operation's objectives. For example, the seizure of Afghanistan's Kandahar Airfield by Naval Task Force 58 using lightly armed forces 350 statute miles from an ATF.[20] In addition, a lightly armed force of only infantry and ITVs, working at extreme ranges, may be sufficient for preassault raids, feints, other forms of military deception, pre-assault raids, and for accomplishing some of the objectives of a broader amphibious assault. In addition, by deploying aircraft from hundreds of nautical miles from shore, the ATF gains the ability to conduct amphibious operations from blue-water ocean outside of a state's exclusive economic zone. This will increase the likelihood that an ATF remains undetected, which increases the surprise and initiative of an ATF's amphibious operations. This freedom of maneuver may give an ATF the option to operate close to allied military bases and expeditionary advanced bases. This provides the opportunity for an ATF to stay within reach of friendly, land-based antiship weapons and aircraft. Two hundred nautical miles also allows for a better defense against antiship cruise missles, because it allows for more long-range engagements using long-range interceptors. This allows for current missle defense tactics to be used, as opposed to proposed tactics.

Beyond 131 nm, there will be no attack aircraft escort for the Ospreys. This likely prevents forcible entry operations against a defended coastline. Furthermore, a lightly armed force of only infantry and ITVs may be overwhelmed by enemy armored forces, as was a problem in World War II for airborne infantry. For example, during Operation Market Garden at the Battle of Arnhem in the Netherlands, in which lightly armed British soldiers failed to hold their objective against German armored units, which overwhelmed them.[21]

In the near future, a more realistic range of an actual amphibious assault over a long range to seize contested coastline would be 110 nm. This would provide Marines an air assault combining LAVs, towed artillery, HIMARS, JLTVs, "up armored" humvees, and both utility and attack VTOL aircraft, while being well within the combat radius of carrier-based, fixed-wing aircraft and allowing for Ospreys to loiter longer. This is significantly more firepower compared to a reliance on only carrier-based, fixed-wing aircraft and lightly armed forces.

As for the land warfare capabilities of such a landing force, light armored reconnaissance units armed with LAV variants possess mobility, firepower, and security, which are "best employed not as a substitute for infantry and armor in

the attack or defense, but to perform reconnaissance and security missions that allow armor and/or infantry to close with the enemy decisively."[22]

Thus, LAVs are no substitute for heavier armored vehicles, such as main battle tanks. This means that Marines will achieve decisive victory over an opponent in long-range amphibious operations through infantry deployed from VTOL aircraft in an air assault. The landing force will be able to deploy powerful artillery assets to aid Marines on foot in long-range amphibious operations. HIMARS, M777A2 towed artillery batteries, and various types of mortars will give significant fire support to Marines beyond that provided by VTOL and fixed-wing aircraft. In addition, LAVs and humvees offer Marines ambulances, electronic warfare capabilities, a vehicle that can carry logistical supplies and other equipment, or significant mobile firepower to infantry units. However, there will not be enough humvees or JLTVs to provide rapid transportation for Marine units on foot. To give mobility to Marine fireteams will require Growler ITVs, since they can fly on Ospreys, because they are, typically, far more numerous than King Stallions in an air combat element. Even then, these unarmored vehicles are so heavy that the Osprey will only be capable of transporting one ITV and a Marine fireteam using it, which is one-sixth of the Marines carried if all troops are foot mobile. Regardless, this means that Marines will lack the protected, mobile firepower they now possess in amphibious operations that use AAVs.

A chief problem for Marines will be defeating enemy armored vehicles, which near-peer competitors possess by the hundreds if not thousands. Against such enemy forces, Marines will have to rely on man-portable antitank weapons and fire support from artillery, VTOL aircraft, and fixed-wing aircraft. Another major concern is that Marines will be dependent on towed as opposed to self-propelled artillery. Radar can detect artillery and trace it back to its source, which allows for counterbattery fires.[23]

This means that the Corps' current efforts to modernize artillery and develop active countermeasures to rockets, artillery, mortars, guided missiles, and ballistic missiles may have an enormous impact on future long-range amphibious operations and our long-term strategic efforts. For example, the procurement of lightweight, self-propelled artillery that is King Stallion transportable will offer extraordinary capabilities to long-range amphibious operations. Despite these drawbacks, such long-range amphibious operations may be a useful tool against enemies with significant coastal defenses but a low number of main battle tanks or other heavy-armored vehicles in the amphibious objective area. In summation, the quality and capabilities of Marines on foot and the lightweight forces and aircraft supporting them determine the effectiveness of long-range amphibious operations.

However, one key consideration will hamper efforts to deploy forces so far

from amphibious ships—the varied speeds of aircraft. Osprey will embark and disembark troops and internal cargo far faster than helicopters, given their varied cruising speeds. Thus, to have armed escorts, Ospreys will have to fly slower than originally designed, which will be less fuel efficient and may be unsafe due to stalling speeds. These differing cruising speeds also may present problems of coordination for command and control.

That said, even at 110 nm, the ATF may be within a nation's exclusive economic zone, which may risk detection from a wide variety of civilian and military vessels. This could end in a naval battle using antiship cruise missiles, antiship ballistic missiles, and hypersonic missiles. Upon detection of an ATF, an alerted enemy may redeploy forces, including surface-to-air missiles, to combat an amphibious landing. To highlight how dangerous a rapid response by a defender is to a detected landing force, the Dieppe raid in France during World War II is an excellent example. Even without precision-guided weapons and modern vehicles, it took German defenders only 15 minutes to mass their forces between a first wave of Allied infantry and a second wave of Allied tanks. Even additional infantry landing, flanking the Germans in tandem with the second wave of tanks, was not enough to dislodge the German defenders. The rapid response by German forces and terrain that benefited the defenders were the death knell of the operation, which ended in 60 percent losses.[24]

In contrast, even if detected, the ATF in a long-range amphibious operation will have increased response time to, and layers of defense against, missile attacks and a reduced likelihood of mine attacks. They will also have the range to pick and choose where to land forces across a long coastline, even while under attack. This will allow commanders to mass landing forces where the enemy is weakest, even against an enemy alerted to the presence of the ATF. The shear amount of coastline that is threatened by an ATF with such reach will also enhance deception operations. Defenders responding to deception operations may mass their forces in the wrong locations and, due to the size of the area of operations, lack the ability to rapidly redeploy their forces to other locations, creating weak points that a commander can exploit.

Heavy Armor and Long-Range Amphibious Operations

A problem with long-range amphibious operations, in general, is that the amphibious operation depends primarily on infantry, since the operation will lack heavier equipment such as M1A1 Abrams main battle tanks, AAVs, and heavy logistic support. Simply put, there remains no technological options for transporting main battle tanks by VTOL aircraft, even within the next 15 years.

Thus, if it is determined that an amphibious operation requires main battle tanks, that infantry transport on armored personnel carriers such as AAVs, or that there is a need for heavy logistic support, then transport by surface is the

only option. To do this, part of the ATF equipped with well decks will need to either do one of two things. First, they can come closer to shore than 100 nm, with the goal of carrying out an over-the-horizon amphibious operation using surface connectors. However, if the ATF is detected, then such an operation will be very risky to the amphibious ships and for all landing craft involved, especially given the slow speed of landing craft, utilities (LCUs) at 8–11 knots and the very slow speed of AAVs at 6 knots.[25] These are speeds that will demand that amphibious ships come very close to shore, possibly 24 nm or less to deploy landing craft. At 24 nm to shore, antiship cruise missiles and hypersonic missiles will allow very little time to react. For hypersonic missiles, troops will have at most 24 seconds to react. Landing vehicles also will face great risk from precision-guided weapons, given their slow speed and hours-long transit time. Mines and obstacles also could present severe problems for slow landing vehicles. Second, they could deploy ship-to-shore connectors and landing craft, air-cushions (LCACs) approximately 100 nautical miles from shore to transport a limited number of AAVs, main battle tanks, and heavy logistic support to shore. This distance is due to the range of hovercrafts, which for the earlier LCAC is 250 statute miles with a 60-ton payload.[26] Another issue is that only ship-to-shore connectors are normally designed to carry an Abrams tank between the two hovercrafts.[27] There is also the problem that a limited number of tanks and AAVs may be insufficient to push onto the objective. Although, if the amphibious force was composited with all its surface connectors being ship-to-shore connector hovercraft, then it is possible to transport a substantial number of Abrams main battle tanks to shore in one lift. However, hovercraft will spend around three hours traveling to shore, which will leave them open to attacks by precision-guided weapons if they lose the element of surprise. Last, mines will still hold some threat even for hovercrafts, which are less susceptible to them.[28]

Additionally, the goal of including a large number of armored vehicles immediately changes the strategic tenor of the amphibious operation. The security of the amphibious ships coming closer to shore will be less than for the rest of the ATF, which can stay farther from the coastline that they attack. There may be a lack of security for slow amphibious landing vehicles against modern defenses, especially in an antiaccess environment. Slow landing vehicles, such as LCUs and AAVs, would risk being tracked and attacked before ever making it to shore, especially if they must deploy many nautical miles from shore for increased security for their fleet. A fleet of amphibious ships and their escort coming relatively close to contested shoreline for a surface deployment of armored vehicles defeats the primary purposes of long-range amphibious operations. It sacrifices maneuver space from the sea, it makes the ships carrying out the amphibious operation far more vulnerable, it hampers the ability of the landing forces to concentrate strength where the enemy is weakest, it may drastically

reduce the statute miles of coastline threatened by an ATF in a 24-hour period, a fleet of ships coming closer to shore have a far greater risk of detection, and it potentially reduces the surprise and initiative of the amphibious operation. Finally, the amphibious ships traveling closer to shore, most likely *San Antonio*-class ships and *LPD Flight II*-class ships, are expensive, important vessels that cannot be easily risked. The loss of even a few of them could be a major blow to the U.S. Navy and its amphibious operations for years.

However, there are benefits to placing several amphibious ships closer to shore. It would allow the air combat element to more swiftly refuel, rearm, and embark troops and cargo. This would increase the tempo of the operation, thus allowing for more troops, weapons, and logistical supplies to be transported during one period of nautical twilight. This could also positively impact the initiative of the amphibious operation and reduce the number of VTOL aircraft necessary to provide the same level of both air resupply and aerial fire support. Positioning amphibious ships closer to shore would also allow the possibility of using Osprey for heavy external lift. Yet, there remains considerable risk the closer to shore amphibious ships must come.

Naval Gunfire Support and Long-Range Amphibious Operations

A major problem for long-range amphibious operations, in general, is that until aircraft deliver and deploy M777A2 towed artillery and HIMARS, the landing force will not have any fire support except for VTOL aircraft, man-portable mortars, and close-air support provided by fixed-wing aircraft. It will notably be missing naval gunfire support (NGFS), unless ships with naval guns are sent very close to contested shoreline, which makes them extremely vulnerable to antiship cruise missiles, antiship ballistic missiles, hypersonic missiles, mines, and possibly even small arms.

Ships must come close to the shore due to the range of their artillery. The 5-inch/54 caliber (Mk45) lightweight gun, which large surface combatants are armed with, only has a maximum range of 13 nm.[29] This means that for an Mk45 gun to fire inland several statute miles, the ship using the weapon must come within a few nautical miles of shore, possibly within range of small arms. Thus, the risk to large surface combatants providing NGFS is high. Large surface combatants also excel at multiple missions, and they are expensive ships whose loss would be felt for years. This begs the question: Why risk a destroyer or cruiser on NGFS? That said, finding a way to provide NGFS farther from shore has been a hurdle for the U.S. Navy.

First, the *Zumwalt*-class destroyer, which were designed for land attack, will stop construction after three ships.[30] One reason for the cancellation of these vessels is a lack of ammunition for the advanced gun system (AGS).[31] The reason

for the ammunition shortage for the AGS is because the cost per round for their unique ammunition has climbed to $800,000 to $1 million per projectile.[32] This is due to the production of so few rounds, because only six AGSs exist. The U.S. Navy very sensibly opted not to purchase more ammunition for the AGS.[33] Yet, the AGS was originally designed to have the ability to fire artillery rounds up to 83 nm instead of 13 nm, a valuable NGFS capability for an over-the-horizon, or long-range, amphibious operation.[34] This means that a weapon meant to provide over-ther-horizon NGFS is now useless. Thus, 155mm naval artillery will not soon supplant 5-inch guns in amphibious operations.

Second, the electromagnetic railgun (EMRG) is years away from implementation on naval ships.[35] In addition, only the *Zumwalt*-class ships currently provide the power generation capability to use the weapon.[36] It is hoped battery packs may allow the weapon to function on naval vessels other than the *Zumwalt* class, but, nevertheless, there remains no easy solution to the problem of putting such weapons on the *Arleigh Burke*-class of guided missile destroyers.[37] Thus, it is unlikely that the EMRG will revolutionize NGFS until the deployment of the proposed future surface combatant destroyers.

Finally, this currently leaves only one technological solution to the dilemma of NGFS within the next 10–15 years: the use of either Excalibur N5 projectiles or hypervelocity projectiles (HVPs) for Mk45 guns. The longer-range HVPs will be able to fire up to 40 nm at a cost of $25,000–$50,000 per projectile.[38] However, this still requires that a fleet composed of several large surface combatants capable of missile defense will be relatively close to shore to provide NGFS. Such ships would exclusively use HVPs to stay 20–30 nm from shore.

This solution has significant problems. First, a fleet of large surface combatants coming relatively close to contested shoreline to provide NGFS partially defeats the primary purposes of long-range amphibious operations. It makes the ships far more vulnerable, and a fleet of ships closer to shore have a far greater risk of detection, which potentially reduces the surprise and initiative of the amphibious operation. Mines also become a much larger issue closer to shore, and even at 30 nm from shore, the time to react to a hypersonic missile launched from the coast would be around 30 seconds or less. There also will be far less time to react to antiship cruise missiles and hypersonic missiles. Thus, the security of the fleet providing NGFS will be substantially less than for the rest of the ATF. Large surface combatants are expensive, strategically important vessels that cannot be easily risked and serve as multimission vessels, whose other strengths are mitigated in the role of NGFS for an amphibious operation. Last, HVP ammunition is expensive. If 5-inch guns must use them exclusively, this means that the NGFS will add considerable expense to amphibious operations. Assuming the fleet providing NGFS fires a conservative estimate of 1,800 projectiles, which is the equivalent of 18 towed artillery teams firing 100 pro-

jectiles each, then the cost of the projectiles alone would be between $45 and $90 million. All of this means that there are simply no easy ways of bringing NGFS to bear for troops deploying from 100 nm or more from shore unless considerable risk is taken.

The current course by the U.S. Navy leaves in doubt what the near future of NGFS will be in an evolving threat environment demanding amphibious operations far from shore. The limitations of NGFS also may threaten the ability of Marines to land from long range with adequate fire support. In addition, the current future of NGFS seems to be the deployment of a considerable number of future surface combatant destroyers armed with electromagnetic rail guns. However, this is a long-term plan for NGFS over the course of decades and may make NGFS less than adequate in near-future threat environments. Thus, what is needed is a long-range interim naval gun that can be installed on current large surface combatants, whose lifetime will stretch on for decades. A new naval gun could increase the range of NGFS, and thus provide increased security for any fleet of large surface combatants that must venture close to shore.

Technological and Logistical Assumptions and Challenges for Future Long-Range Amphibious Operations

The remainder of this analysis will deviate from near-future capabilities and examine what the future of long-range amphibious operations could be through 2028. Starting in 2028, it may be possible for long-range amphibious assaults to more than double their radius of action once procurement of medium- and ultra-size FVL aircraft begins. At that time, the following factors will limit the range, weapons, and capabilities of long-range amphibious operations.

The Bell V-280 Valor utility aircraft is marketed as capable of a cruising speed of 280 knots, a minimum combat range of 500 nm, and an external cargo capacity of up to 10,500 pounds or 14 troops.[39] However, 150 knots is the maximum safe speed a current sling load, which carries equipment underneath a VTOL aircraft using cables, can travel.[40] If the marketed capabilities of the Valor are accurate, then it makes possible the transportation of M777A2 towed artillery, which weigh less than 10,000 pounds, more than twice the range of a King Stallion. The Valor could also allow for the transportation of pallets of external cargo for air resupply more than twice as far as a King Stallion.[41] For instance, one Valor could transport a single M777A2 towed artillery almost half its minimum combat range, around 200 or more nautical miles; one aircraft could transport the eight crew for the weapon; and one aircraft could externally transport 10,500 pounds of artillery projectiles for the weapon through a sling load. It would take three pallets weighing 14 pounds each to transport 10,458 pounds of external cargo.[42] This amounts to 110 high explosive projectiles

weighing 95 pounds each.[43] Thus, it will take at minimum of 18 Valor utility aircraft to deploy a battery of six M777A2 artillery with 110 projectiles each. Of course, artillery resupply for HIMARS and towed artillery will be weight intensive, and there could be a need for thousands of projectiles to take key objectives; for example, consider the 1982 assault by British Commandos on Mount Harriet in the Falkland Islands War, which required 3,000 artillery rounds.[44] HIMARS will need to be supplied by air with launch boxes that contain rockets and missles. There also will be a lack of artillery resupply vehicles for both M777A2 and HIMARS artillery. In addition, setting up 155mm towed artillery will require that troops create a firing position for the artillery to occupy.

It will take 80 minutes for the Valors to reach an amphibious objective area 200 nm away at 150 knots. The tiltrotors will then disembark their external cargo and travel 43 minutes back to the ATF at a cruising speed of 280 knots, where they quickly refuel, embark more cargo, and repeat this sequence. Given this scenario, it may take the Valors more than six hours to complete two external lifts. Ospreys will be well within their combat radius at a range of 200 nm from an ATF, which will give them more time to loiter or the capability to take troops to a second objective. At a maximum cruising speed of 270 knots, Osprey may be able to complete two or even three lifts to an amphibious objective area 200 nm away in an eight-hour period of nautical twilight.

Large numbers of Valors and Ospreys will be required to transport a maximum number of troops, weapons, and logistical supplies within one period of nautical twilight. Long-range amphibious operations will require an attack VTOL aircraft capable of greater combat radius than the AH-1Z Viper. Such necessary specifications will likely require an attack variant of the Valor tiltrotor. The speed of the Valor attack aircraft present opportunities for forcible entry by allowing Ospreys to be escorted to their objective at their maximum cruising speed. It may be possible to transport armored vehicles or logistical vehicles weighing 41,000 or more pounds hundreds, if not thousands, of nautical miles in 2025 using naval VTOL aircraft adapted from the future vertical lift competition for ultra-heavy VTOL aircraft. The goal of the competition is to field a VTOL aircraft in 2025 with capabilities somewhere between those of the Lockheed Martin C-130J Super Hercules and the Airbus A400M Atlas.[45] Such aircraft could conceivably transport medium-armored vehicles of the Stryker family of vehicles and, possibly, the BAE Systems Amphibious Combat Vehicle 1.1. This could add substantial firepower to a landing force operating at long range while providing mobile protection for some units of Marines, which would give commanders greater flexibility to respond to the enemy.

Nevertheless, it would be very difficult, if not impossible, to operate such large future vertical lift ultra-heavy VTOL aircraft from an amphibious assault ship due to limited flight deck space. However, given the desired range of ultra-

heavy VTOL naval aircraft, they can deploy from military bases in the region of the amphibious operation with the support of aerial refueling. The range of such aircraft gives them the ability to deploy from the continental United States, avoiding the need for stationing such large aircraft on amphibious ships. That said, there would still be great utility if such large VTOL aircraft could land on the flight deck of an amphibious assault ship, allowing them to embark vehicles and then quickly travel back to the amphibious objective area. Alternatively, if such aircraft could not land on amphibious assault ships, multiple waves of such aircraft could deploy from military bases in the region to disembark forces in tandem with the aircraft of an ATF. Another possible option would be to land such large VTOL aircraft on an aircraft carrier supporting the amphibious operation to embark vehicles for the amphibious operation. However, the logistics of storing Marines and their vehicles on an aircraft carrier could be complex.

Thus, Valor aircraft could transport an M777A2 towed artillery or 10,000 pounds of logistical supplies per lift out to 200 nm or more from an ATF. A Marine Air-Ground Task Force (MAGTF) composited for operations at this range would need to replace most of its King Stallions with Valor utility tiltrotors. Additionally, for operations at such distances, the transportation of LAV variants, HIMARS, JLTVs, and humvees would fall to ultra-heavy VTOL aircraft. Aircraft could also carry the Stryker family of vehicles, variants of the Oshkosh Defense Medium Tactical Vehicle Replacement (MTVR) with possible limitations on weight of payload, and, possibly, the Amphibious Combat Vehicle 1.1. However, for such amphibious operations, there will be a great demand for ultra-heavy VTOL aircraft, which could be very expensive to purchase and difficult to deploy to the area of operations in great number due to a need for refueling. At this range from an ATF, Osprey could still internally transport Growler ITVs, vehicles that may become the primary logistical vehicle in such long-range operations. Despite these drawbacks, such long-range amphibious operations may still be a useful tool against enemies with significant coastal defenses, but a limited number of main battle tanks or other heavy-armored vehicles in the amphibious objective area.

A downside to these solutions is that it will take approximately eight hours for an ATF to reach the shoreline from 200 nm away. The threat of mines and obstacles may greatly delay this already long period of time before surface resupply can occur. This means that Marines will have to fight without the support of Abrams main battle tanks, forcing them to rely on air resupply alone for hours and potentially much longer. Thus, a key aim for the landing force will be to mitigate the threat of coastal hypersonic missiles, antiship ballistic missiles, and antiship cruise missiles to the point that ships can land the rest of the MEB's personnel, vehicles, armor, and logistic support by coming closer to

shore. However, the threat of inland antiship ballistic missiles, antiship cruise missiles, and hypersonic missiles will still exist.

The eventual replacement of the F/A-18E/F Super Hornet with the F/A-XX, if it has a larger combat radius, may allow for even more extreme long-range air assaults from the sea. These air assaults would take full advantage of the 428 nm combat radius of the Osprey to transport lightly armed forces. The cruising speeds of all these VTOL aircraft are not terribly dissimilar, except for an ultra-heavy VTOL aircraft, which will be faster than smaller aircraft, allowing for better options for forcible entry by allowing armed escorts of transport aircraft. Ultra-size aircraft also may have the range to slow down and be escorted by attack aircraft.

Therefore, assuming key acquisitions, the Marine Corps may be able to more than double the distance covered by its long-range amphibious operations that use heavy lift starting in 2028. This would require the acquisition of Marine Corps variants of the Valor utility tiltrotor, of the attack tiltrotor, and the future vertical lift competition for ultra-heavy VTOL aircraft. These capabilities also make it technically feasible for armored vehicles and logistical vehicles weighing 41,000 pounds or more to disembark from aircraft 200 nm or more from their ATF. This will allow for blue-water amphibious operations outside of a state's exclusive economic zone while giving Marines significant fire support from mortars, field artillery, VTOL aircraft, and fixed-wing aircraft; LAVs for reconnaissance and security; and vehicles for logistics beyond just ITVs.

If the Marine Corps procures another tiltrotor, then it also stands to benefit if it seeks to acquire new cargo transportation equipment, which takes full advantage of the speed of tiltrotors. If a Valor could utilize its full air speed, then the tempo of air resupply could increase.

Furthermore, ultra-heavy VTOL aircraft will provide a lightly armed force of Marines with more vehicles, artillery, heavier logistical vehicles, or heavier armored vehicles weighing 41,000 pounds or more. This equipment will be able to deploy hundreds of nautical miles from regional airbases with the aid of aerial refueling. However, Marines will be entirely reliant on ultra-heavy VTOL aircraft and Ospreys, both carrying internal cargo, for air resupply and medevac. Medevac also may take well more than an hour to transport a wounded Marine to a hospital aboard a ship. Thus, such operations may allow revolutionary capability but will come with some risks.

Finally, on their own, ultra-heavy VTOL aircraft operating from the continental United States, with the support of aerial refueling, could transport reconnaissance units or special operations forces with vehicles anywhere in the world. This could result in new capabilities for forces operating in areas with less sophisticated antiaircraft defenses.

Advantages of Long-Range Amphibious Operations

There are quite a few advantages of long-range amphibious operations. By deploying landing forces 100 nm or more from shore, long-range amphibious operations mitigate the threat of antiship missiles, mines, tactical aircraft, and diesel submarines. They also allow an ATF the opportunity to remain undetected. Thus, long-range amphibious operations reduce the vulnerability of amphibious ships and their escorts. Long-range amphibious operations drastically increase the maneuver space available from the sea compared with amphibious operations that originate closer to shore, possibly allowing an ATF to stay in blue-water ocean outside of a nation's exclusive economic zone. Long-range amphibious operations allow an ATF the ability to threaten thousands of statute miles of coastline in a 24-hour period. This could force an adversary to deploy numerous forces across hundreds of statute miles of coastline to prevent a landing. Even then, the ATF may threaten enough coastline that an enemy finds it unfeasible to defend it all, allowing for unopposed landings, due to the shear amount of threatened coastline. Long-range amphibious operations also allow an ATF to deploy aircraft transporting lightly armed Marines hundreds of nautical miles from shore; this may give an ATF the option to maneuver close to allied military bases and expeditionary advance bases. Deploying from such as distance would also provide greater opportunity for an ATF to stay within reach of friendly land-based antiship weapons and aircraft.

An element of surprise is advantageous to long-range amphibious operations, which allows the amphibious force to dictate when and where to fight along vast amounts of coastline. Furthermore, these operations provide extraordinary mobility using aircraft to transport troops. This allows the landing force to quickly concentrate strength where the adversary is weakest along massive amounts of coastline, and it allows for the vertical envelopment of enemy forces.

The ATF also can easily threaten targets beside the immediate coast; long-range amphibious operations provide the ability to launch an amphibious operation against targets miles inland, even with an ATF positioned far from contested coastline. For instance, an amphibious operation with a range of 200 nm can deploy ships 100 nm from shore and still penetrate 115 statute miles inland. The ability to strike inland, past prepared defenses, allows landing forces to disembark on the flanks of enemy forces, to the rear of enemy forces, and against key targets such as command and control facilities, logistic sites, and lines of communication.[46] Long-range amphibious operations composed primarily of infantry supported by artillery, aerial, and light-armored units may have effective combined arms for military operations on urbanized terrain, though main battle tanks brought by surface connectors would give such operations a more powerful combined arms capability.[47]

Long-range amphibious operations may disrupt an enemy by having the ability to choose where to engage an enemy across vast amounts of coastline and by having the aerial mobility to choose when and where to strike. It may be possible to stretch an enemy's communications, command and control, and intelligence to the point that they can no longer function. Between feints, other forms of deception, preassault raids, and the actual primary thrust of the amphibious assault, an enemy may simply be unable to coordinate or adapt to the challenge of defending vast amounts of coastline. Even if an enemy commander understood where the primary thrust of the amphibious assault was happening, the speed and range of Marine aircraft will allow troops and vehicles to isolate enemy forces, mass where the enemy is most vulnerable, and challenge the abilities of the enemy commanders to adapt.

Long-range amphibious operations enhance the effectiveness of amphibious raids. Such operations give raiders the ability to land a significant number of lightly armed forces to the flanks or rear of enemy positions and against key targets during a period of nautical twilight. The range of raiding could be up to 200 nm while armed with artillery and vehicles weighing 41,000 pounds or more.

By deploying aircraft from hundreds of nautical miles offshore, the ATF may gain the option to maneuver close to allied military bases and expeditionary advanced bases. This would provide greater opportunity for an ATF to stay within reach of friendly land-based antiship weapons and aircraft. Most notably, in the event of war with China, U.S. naval ships may be able to stay relatively close to military bases and expeditionary advanced bases built in the closest archipelagos to the Chinese coastline, particularly those that belong to Japan, the Philippines, and Taiwan. Having this option may deter Chinese aggression in the Asia-Pacific region, especially when combined with amphibious demonstrations.

Long-range amphibious operations allow for amphibious demonstrations that may deter adversaries of the United States with access to A2/AD technologies. Deception operations may also be enhanced by long-range amphibious operations. The shear amount of coastline threatened by an ATF operating 100 nm or more from the nearest coastline means that responding to deception operations may mass enemy forces in the wrong locations, creating weak points a commander can exploit.

Finally, long-range amphibious operations will allow U.S. naval ships to deploy assets in a humanitarian operation, while approaching stricken coastline from hundreds of nautical miles away. They will also give commanders the ability to conduct an amphibious withdrawal for many personnel, as well as a limited amount of cargo and vehicles, quickly and from many nautical miles out at sea, while mitigating the threat an adversary has against U.S. naval ships.

Disadvantages of Long-Range Amphibious Operations

The above analysis shows that the type of amphibious operation with the least to gain from long-range capabilities may be an initial amphibious assault, because long-range amphibious operations assume that Abrams main battle tanks, AAVs, the logistics combat element, and the remainder of an MEB or MEU will need a suitable beach landing zone to disembark. Thus, one key goal for the initial landing force, if it wants to push inland with force, will be to seize a coastline and establish a logistic line of supply, with a debarkation of AAVs and Abrams battle tanks. However, if an objective could be taken by forces that are more lightly armed and armored, while supported by air resupply, then ship-to-objective maneuver could be used. However, against any near-peer competitor, armed with a very large number of main battle tanks, this could prove a rare occurrence.

Thus, in a long-range amphibious assault against a heavily defended objective, this military concept relies on the archaic practice of seizing a bridgehead to land more forces and organize for land combat to take an ultimate objective. There also will be a need to clear approach lanes of mines and other obstacles. Additionally, the initial landing force will make for a lucrative target for enemy forces beyond the amphibious objective area. Thus, if the ultimate objective is heavily defended, in order to succeed, the landing force and its fire support must quickly defeat enemy forces on the coastline, isolate the amphibious objective area from reserves, and destroy any weapons on the coast that could be used against their amphibious ships and landing craft. Otherwise, defending enemy forces could force a war of attrition in the amphibious objective area, counterattack from beyond the amphibious objective area, or they could target amphibious ships and their escorts.

Furthermore, medevac will present logistical problems for troops operating so far away from an ATF. The transit time back to a hospital aboard naval vessels may be more than an hour. Thus, the need for medevac aircraft that can swiftly get troops back to a hospital may limit the realistic range of long-range amphibious operations. Another disadvantage is that aircraft are weather dependent and, as such, operations in inclement weather will be impossible. This gives the enemy the assurance that operations cannot take place in bad weather.

Long-range amphibious operations present enormous challenges to such logistical aspects as intelligence, command and control, and communication. For example, the sheer number of intelligence products to sift through, when choosing where to strike along hundreds if not thousands of statue miles of coastline, will be daunting. An amphibious landing more than 100 nm from the nearest amphibious ships will present significant hurdles to overcome for surveillance, amphibious reconnaissance, and naval surface fire support. The distance inherent in these operations presents other issues; the farther an ATF

is from the amphibious objective area, the longer it will take to disembark all troops there, which may rule out a rapid transport of all amphibious troops to the amphibious objective area in one period of nautical twilight.

Resupply will present obstacles as well. The only avenue of resupply will be aircraft until a suitable beach landing zone can be created. In addition, the tempo of air resupply may be slow due to the distances involved and may present hurdles that will limit the range of these types of amphibious operations. Furthermore, Osprey and ultra-size aircraft will require landing zones to gain access to their internal cargo. These long transit times for additional troops and supplies, combined with the fact that most Marines will be on foot, may make it difficult to achieve and hold the initiative beyond the first wave of Marines.

We must also consider logistical issues with enemy defensive capabilities in littoral combat zones. For example, A2/AD capabilities include air defenses, and they will need to be suppressed before the landing can occur.[48] The ground maneuver element will be completely reliant on man-portable mortars and aircraft for fire support until artillery is flown in. Naval gunfire support cannot always be relied on, and massed enemy armor could overwhelm the landing force, due to its lack of main battle tanks, such as the danger armored units presented to airborne troops in World War II.

Yet, three major differences can be seen between modern-day actions and those in the Second World War. Man-portable antitank weapons have evolved considerably since World War II; lightly armed Marines possess weapons capable of defeating a main battle tank; and close air support has become significantly better. The Marines of the landing force may be able to fend off armored units through a combination of the antiarmor firepower they possess as well as artillery fire support. Marines may overwhelm armored units with the precision firepower provided by close air support, which could use ordnance such as the CBU-97 Sensor Fuzed Weapon. Of course, the opposite is also possible—that the landing force is defeated by massed armor.

While aircraft can help maneuver warfare and the massing of troops at weak points, the lack of main battle tanks and AAVs will slow the advance of troops when opportunities present themselves. Most of the landing force will likely be foot mobile Marines, who simply lack the speed to exploit every advantage that presents itself. This may result in a reduced ability to strike at an enemy's critical vulnerabilities and centers of gravity.

The former Commandant of the Marines, General James F. Amos, has referred to the Marines as "a middleweight force. We are light enough to get there quickly, but heavy enough to carry the day upon arrival."[49] Conversely, the amphibious landing force presented in this future military concept is a more lightweight force. This drastic change of doctrine may in fact blunt the chief advantages of the U.S. Marine Corps. Thus, long-range amphibious operation

will offer considerable advantages, but also considerable limitations, and such operations carry their own risks. Regardless of all these disadvantages, the quality and capabilities of Marines on foot and the quality and capabilities of the lightweight forces and aircraft supporting them determine how effective long-range amphibious operations can be.

The Benefit of More Flight Deck Space in the U.S. Navy

When analyzing long-range amphibious operations, a key limiting factor was the number of aircraft transported by an amphibious task force. In the aforementioned long-range amphibious operations, which rely on air assault, it should be noted that amphibious assault ships are far more valuable than *San Antonio*-class or *LPD Flight II*-class ships.

It takes around six *San Antonio*-class or *LPD Flight II*-class ships to equal the utility of one additional amphibious assault ship in terms of the number of aircraft that can be carried. Conversely, this means that adding an amphibious assault ship to an ATF results in adding the same number of aircraft found on six *San Antonio*-class or *LPD Flight II*-class ships. This reality for long-range amphibious operations exacerbates the need for more amphibious assault ships.

In addition, in 2015, a Rand report proposed the idea of a common mobile air platform that can interchangeably be used as a Navy carrier air wing or Marine Corps MEU support unit.[50] This platform would be larger than the *America*-class ships and would provide the MEU and MEB with more air capability than these vessels.[51] Such a ship would not have a well deck, which requires any cargo or equipment needing surface capability to be displaced onto ships with well decks.[52]

Another proposal set forth by Center for Strategic and Budgetary Analysis, MITRE Corporation, and the Navy is to alter the *America*-class amphibious assault ships into true aircraft carriers by making them larger and adding a catapult assisted take-off but barrier arrested recovery system for launching and arresting naval aircraft.[53] Likely weighing between 40,000 and 60,000 tons, these light aircraft carriers could deploy Northrop Grumman E-2 Hawkeye aircraft, which would provide an airborne early warning capability to any amphibious or surface action force they join.[54] They would also have the capability of operating Boeing EA-18G Growler aircraft, while also having substantially expanded flight deck and hangar space.[55] If armed primarily with F-35 Lightning II aircraft, a CVL could contribute a powerful sea control and power projection role for an ESG. And, if armed primarily with VTOL aircraft instead of F-35s, CVLs could function as a larger version of *America*-class ships during an amphibious operation, expanding the air combat element of an ATF.

These two proposals are potentially beneficial, and the utility of each should be explored by the U.S. Navy and Marine Corps. The goal would be to gauge

which proposal, or even an innovative idea to come, may best expand the number of aircraft, type of aircraft, and long-range amphibious operation capabilities available to amphibious forces.

Recommendations

The following recommendations are intended to decrease the deficiencies of long-range amphibious operations as outlined in this article. The Marine Corps should acquire an externally transportable sling load to take full advantage of the speed of tiltrotors; it should acquire both an attack and utility variant of the Bell V-280 Valor, if it performs as marketed, to provide the fire support and carrying capacity needed; and it should acquire a naval version of the future vertical lift competition's ultra-heavy VTOL aircraft to transport artillery and vehicles weighing 41,000 pounds or more in long-range amphibious operations. In addition, the Marine Corps should seek further innovative ideas for acquisition to overcome the surveillance, amphibious reconnaissance, communication, command and control, intelligence, and naval surface fire support hurdles for long-range amphibious operations. A key issue is the limited communication ranges for various small unmanned aerial vehicles.

The U.S. Navy should procure HVP rounds for its Mark 45 gun and make them the standard ammunition for naval gunfire support of amphibious operations. The U.S. Navy needs to acquire a long-range interim replacement for the Mark 45 gun for current destroyers and cruisers to provide longer-range naval gunfire support of amphibious operations, before the EMRG is fielded on future surface combatant destroyers. The U.S. Navy should either acquire additional amphibious assault ships faster, acquire ships to act as either a Navy carrier air wing or a Marine Corps MEU support unit, and/or redesign the *America*-class ships to operate as true light aircraft carriers. Finally, the Navy should seek a greater combat radius than the F/A-18E/F with its future F/A-XX aircraft to increase the range of extreme long-range amphibious operations to 428 nm with lightly armed Marine forces.

Conclusions

The goal of this analysis is to assess the technological capabilities, limitations, and vulnerabilities of long-range amphibious operations through the year 2028. For long-range amphibious operations using the CH-53K King Stallion, it is feasible to use an air combat element to transport, provide fire support for, and provide air resupply for Marines, batteries of M777A2 towed artillery, HIMARS, LAVs, JLTVs, and humvees deployed by air from an ATF up to 110 nm from shore. Starting in 2028, this capability could include vehicles or artillery weighing 41,000 pounds or more and extend out to 200 nm or more with the right acquisitions.

However, the transportation of Abrams main battle tanks and, possibly, AAVs was found to be unfeasible by VTOL aircraft in the near future. To provide these vehicles and heavy logistic support to the landing force, it would require a fleet of amphibious ships close to approximately 100 nm to shore to launch surface connectors from long range. However, there is no way to provide large numbers of armored vehicles without sending a number of amphibious ships close to shore, potentially obviating many of the advantages of long-range amphibious operations.

In addition, adding naval gunfire support to such long-range amphibious operations requires that a fleet of large surface combatants come close to shore while using HVP ammunition, and possibly Excalibur N5 ammunition, exclusively, until there is widespread use of a replacement to the Mark 45 gun. The current replacement to this method of support will likely be EMRGs on future surface combatant destroyers, which will not be fielded until the early 2030s. Therefore, it was determined that a long-range interim naval gun is needed for destroyers and cruisers.

Furthermore, a key limiting factor for long-range amphibious operations is the size of the air combat element. This problem is best addressed by increasing the air combat element through the expedited purchase of more amphibious assault ships, as well as acquiring ships to act as either a Navy carrier air wing or a MEU support unit—or to make the *America*-class ships into true light aircraft carriers. The ultimate purpose of this potential military concept is to incite further discussion on future strengths and limitations of long-range amphibious operations. The untested concepts here will require testing by strategists and commanders long before use in simulations and wargames.

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