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Session 1 Paper - Contemporary Expeditionary Warfare for Scientists and Engineers

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Contemporary Expeditionary Warfare for Scientists and Engineers

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Abstract—Expeditionary forces from many countries have deployed to mitigate the effects of natural disasters and human conflicts. Approaches are usually linked to the nation's maritime strategy. Expeditionary forces provide rapid response to man-made disruptions such as mass casualties by terrorists, vessel hijackings by pirates, murders by drug cartels, and nuclear accidents. Recent examples include Humanitarian Assistance/Disaster Response (HA/DR) and Non Combatant Evacuation Operations (NEO). HA/DR type missions have been planned and executed to mitigate the effects of catastrophic tropical cyclones, flooding, wild fires, and tsunami. NEO missions are focused on the evacuation of a nation's citizens and other foreigners from threatened areas abroad. The need for robust capabilities in this area in both expeditionary warfare and disaster recovery are required so that governments can perform their civil functions. This type of crisis response requires expeditionary forces to be self-sustaining and make data-driven decisions in austere and chaotic environments. Technology solutions have been developed to identify, study and resolve expeditionary warfare and force protection challenges, especially along dynamic coasts that are modified by waves, tides, and shallow water processes. This paper will highlight the impact of waves, tides, and shallow water processes. There are many other environmental factors that are required to support expeditionary warfare.

1. Introduction

Expeditionary warfare involves the deployment of a nation's military to operate away from established bases and training areas. The term "Naval expeditionary warfare" signifies that the involved units are comprised of naval forces, which can be made up of any sea-going service, but are most commonly Navy and Marine Corps units. However, other supporting forces and agencies are often involved in operations that require maneuver in complex coastal regions. For example, the Australian Army plans and executes amphibious operations. Since access to the battlespace may be denied, unmanned systems and remote sensing are essential to obtaining rapid intelligence, especially environmental data that may be assimilated into numerical models to provide an up-to-date picture of the battlespace. However, current efforts to integrate data from remote sensing, instruments, and models to characterize battlespace factors are not fully operational. An example of future research would be coupling models that simulate river and oceanic processes near the mouth of an estuary.

Contemporary methods and technologies to meet expeditionary requirements are very different from those employed during World Wars I and II. Modern concepts are still linked to maritime strategies, but overcome historic challenges, such as obtaining littoral situational awareness, by employing state-of-the-art information technologies. Today's combatants are modernizing constantly to maintain military readiness. They use airborne remote sensors, employ laser-guided weapons, and navigate faster ships which were only envisioned by their 20th century counterparts. Military campaigns have also adapted to technology as evidenced by capabilities such as drones, long-range cruise missiles, stealth platforms, weapons of mass destruction, and the ever increasing flow of tactical, operational, and strategic information. Destabilizing social and political conflicts that include expanding Islamic extremism in coastal regions (e.g., Abu Sayyaf, Al-Qaeda, Al-Shabaab, Boko Haram, and the Islamic State of Iraq and Syria) demonstrates the need to improve expeditionary capabilities. This "long war," a phrase coined by U.S. Army General John P. Abizaid before he retired as head of the Central Command, is being fought within many local regional confines, using what are now referred to as "conventional weapons," typically combined with the use of irregular warfare tactics and applied use of intelligence, especially "geographic intelligence" which includes knowledge of environmental factors such as waves, tides, and currents.

The concept of "battlespace" provides an overarching foundation for the management of information on all significant factors that impact planning for expeditionary operations, including information related to the atmosphere, terrain, sea, and space. Operational areas to consider include a variety of warfare arenas — surface warfare, air warfare, submarine warfare, amphibious warfare, and information warfare. Each area requires specialized platforms and strategies which are used to ensure tactical advantages that may be unique to that area. The battlespace within local regional confines includes temporally and spatially variable environmental conditions that must be understood to successfully apply combat power, protect the force, or complete the mission. This especially includes the impacts of waves on the ability of enemy and friendly forces to maneuver within the coastal areas.

Expeditionary warfare planners must consider deep-water waves, shallow water hydrography, winds, shallow water waves, tides, surf, and nearshore currents in order to maneuver effectively in coastal waters. For these reasons, leveraging advances in marine science and technology are essential to providing expeditionary forces with updated littoral situational awareness [1], [2], [3]. Recent examples include adopting vessels used in offshore oil exploration and production such as "Alaska-class" tankers into platforms such as the USNS *Montford Point* to facilitate the at-sea transfer and surface delivery of prepositioned assets to units ashore (see Fig. 1). These kinds of maritime operations require (1) exploiting global databases that include information on wave heights, periods, and directions, (2) operating Autonomous Underwater Vehicles or Tactical Hydrographic Survey Equipment to locate obstacles and assess currents and depths, (3) running numerical models such as WAVEWATCH III®, Surface Waves Nearshore (SWAN) and Delft3D to forecast waves, circulation, and surf characteristics, and (4) analyzing airborne imagery to locate features such as eddies, obstacles, characterize trafficability, and find exits off the beach [4], [5], [6]. The delivery of meteorological and oceanographic products from the above information sources must be done rapidly and in formats that directly support the military decision making process [7]. Products should fuse disparate data types at the right scale to help operators understand the significance of environmental factors while they develop Courses of Action (COA), war game with realistic environmental information, compare and select the best COA, develop orders, and then execute the plan.

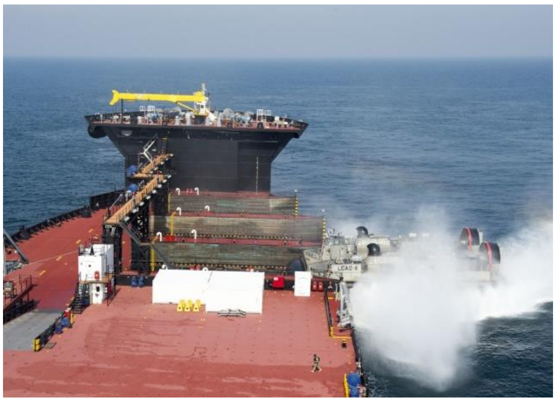

Figure 1. A landing craft air cushion embarks expeditionary transfer dock ship USNS *Montford Point* after departing an amphibious assault ship to conduct a seabasing demonstration in Korea during Exercise Ssang Yong 2016 (Courtesy of US Navy).

2. The Battlespace

Recent threats and conflicts as predicted in the 1992 White Paper "…From the Sea" take place in coastal regions rather than on the open-ocean [8]. Expeditionary operations in this environment encompass the seaward and landward portions of the battlespace. They tend to occur in complex littoral regions where missions range from forward positioning of forces to contain crises to the introduction of amphibious forces to resolve the threat. This is the zone where ocean waves created by storms transition from deep water to shallow water. It is where regional/global ocean models like WAVEWATCH III® may be coupled to coastal SWAN models. As the swells generated by distant storms travel over the open ocean, they shoal in coastal waters where wavelengths decrease and wave heights increase until they finally break on the shore as surf. Actually, wave motion at the bottom of the water column is impeded by friction with the seafloor while the top section of the wave continues to move, relatively unimpeded. These shoaling waves will achieve a maximum height of 78% of the water depth at their breaking point. Surf forecasts by the Navy have been generated using Delft3D. Understanding nearshore and surf zone conditions are essential for navigation and to avoid swamping, capsizing, and broaching of landing craft (see Fig. 2).

Figure 2. LCU-1619 broached while offloading tanks on San Clemente Island, CA. Surf lifted and pounded the hull on a large rock during the rising tide. (1964 picture courtesy of NavSource Naval History).

The effects of seakeeping and ride quality are important considerations for human performance and even vessel survivability. Ocean waves typically impact ride quality and seakeeping for even the simplest of maritime operations. Wave observations and model forecasts are needed to ensure safe execution of Non Combatant Evacuation Operations (NEOs). For example, on February 25, 2011, the United States evacuated 167 Americans and 118 other foreigners from Libya aboard the chartered 68m jumbo catamaran ferry *Maria Dolores* following several days of delay by high winds and heavy seas (15- to 18-foot waves) in the Mediterranean Sea. During this period other countries also evacuated their citizens from Libya. Between February 26 and March 3, 2011, German and British forces including the German frigates *Brandenburg* and *Rheinland-Pfalz* and the supply ship *Berlin*, removed 262 people, including 125 Germans from Libya during Operation Pegasus. Many other countries including China and India planned effective air and sea-bridge evacuations of their nationals. High speed vessels such as the *Maria Dolores* can reach speeds of 36 knots in ideal conditions. However, these types of vessels are vulnerable to wave impacts on the bottom of the cross-deck in bow seas (oblique) and cause bow dive in following seas, conditions that will cause speed reductions and possibly structural damage. High-speed vessels are susceptible to relatively high levels of shock and vibration, which have caused passenger injuries such as lower back compression fractures. In heavy seas, wave slamming events are also known to cause fatigue and structural damage. Mishaps may also result from the reduced capabilities of overcrowded, overloaded and inadequate vessels. Continual monitoring of wind and wave fields would help the mariner to evade large waves and greatly increase the mariner's confidence regarding vessel safety.

These NEO examples emphasize that the physical environment is a defining variable needed to plan and execute expeditionary operations. A forecast model such as WAVEWATCH III should be used to determine an "optimal" route to avoid dangerous waves based on forecasted wind and wave fields. Coastal processes affect all aspects of expeditionary operations, including initial covert intelligence gathering, mine clearing, landing operations, and protection and support of the subsequent military operations, both seaward and landward. In the United States, tactical concepts such as Ship-to-Objective Maneuver and Seabasing assume that operators will understand the environment or obtain updated maritime situational awareness to support their decision making [9], [10]. Critical oceanographic and environmental conditions can be obtained from databases, *in situ* sensors, imagery, and models.

Unmanned vehicles such as the Liquid Robotics Wave Glider were used to detect, report, and track a manned submarine during the British Royal Navy's Unmanned Warrior exercise off the West Coast of Scotland during October 2016 (see Fig. 3). Deployment of the Wave Glider and other instrumented unmanned systems (e.g., the British Army's Watchkeeper Unmanned Aerial Vehicle) were networked and used together to provide updated maritime domain awareness. Key to interpreting and using knowledge about critical meteorological and oceanographic conditions (e.g., shallow water hydrography, waves, currents, and surf) to support mission execution is the fusion of often disparate data such as bathymetric retrievals from imagery, deep water wave spectra, wind fields, and nearshore currents.

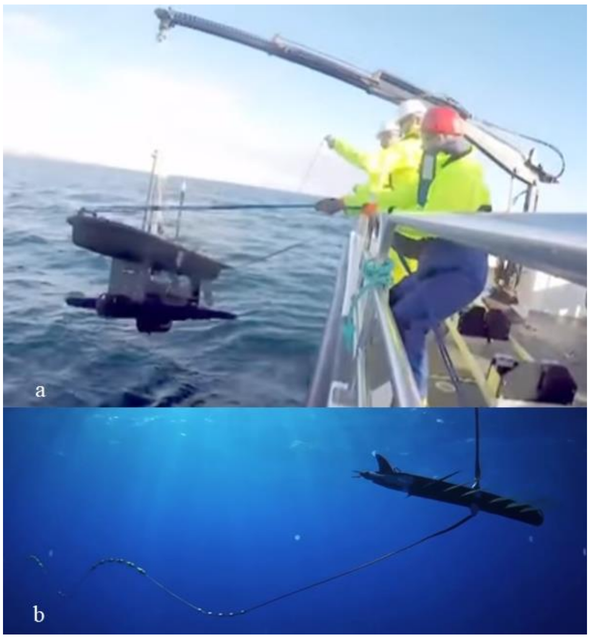

Figure 3. Liquid Robotics Wave Gliders operated 24/7 for 13 days during Exercise Unmanned Warrior. (a) Deployment of a Wave Glider on September 19, 2016. (b) The platform operated in seas of up to 21 feet and was outfitted with temperature, salinity, and acoustic sensors to support anti-submarine warfare missions in the North Sea. (Courtesy of Liquid Robotics).

Technological developments such as ballistic missiles and submarines and their threat to maintaining open sea lines of communication present a challenge to most expeditionary forces. Further, the detection and disabling of mines remains a serious and ongoing concern for any expeditionary forces that operate in shallow waters. Many countries train dolphins and sea lions to carry out a range of military tasks, from mine countermeasures to harbor defense. Autonomous Underwater Vehicles (AUVs) are also in development as intelligence, surveillance, and reconnaissance systems. The AUVs gather environmental information on shallow water hydrography, temperatures, salinity, sea state, mine fields, and obstacles. In the U.S. Navy, various types of unmanned undersea vehicles are employed to provide persistent battlespace awareness that enable anti-submarine, mine countermeasures, and amphibious warfare planning and execution. These unmanned vehicles vary in size and may be deployed from small craft by hand or by ship cranes (see Fig.4).

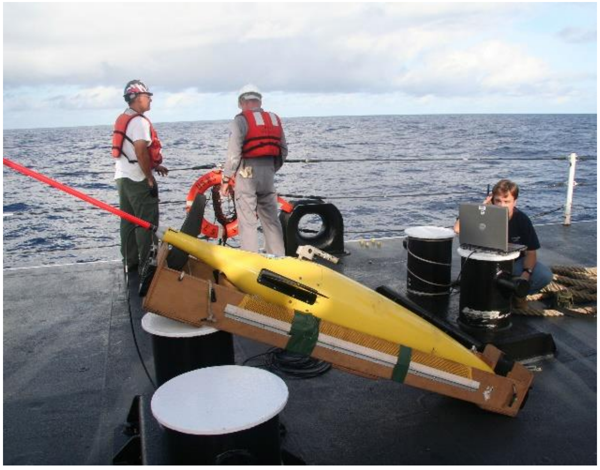

Figure 4. An oceanographer from the Naval Oceanographic Office establishes a satellite connection to the Glider Operations Center before launching the Seaglider™ AUV from the Military Sealift Command oceanographic survey ship USNS *Henson* off the coast of Fortaleza, Brazil (Courtesy of U.S. Navy).

Amphibious operations remain a relevant element for expeditionary warfare as evidenced by their use during Operations Desert Shield/Storm (ODS/S). They were demonstrated and proved to be a successful deception that caused the Iraqi forces to devote approximately 10 divisions to defend fortified positions against the feigned amphibious assault [11]. In turn General Norman Schwarzkopf (1934–2012), who commanded the American-led forces that liberated Kuwait in the 1991 Persian Gulf war, was afforded surprise, momentum, and operational mobility. Further, expeditionary operations during ODS/S were supported by modern seaports and airfields in Saudi Arabia, which may not always be available.

3. Military Planning

Military planning translates guidance into orders to achieve a desired objective or attain an end state. Formal military plans prescribe the conduct of operations. They specify the forces and support needed to execute the plan and the transportation schedule required to move those resources. The planning process should enable leaders to examine cost-benefit relationships, risks, and trade-offs to select an optimal course of action. Contemporary planning procedures could have mitigated some enemy and environmental threats that were faced by World War II Soldiers, Sailors, and Marines. New tactics, techniques, and procedures are available to launch, beach, retract, and recover 21st century amphibious craft. One essential task involves converting raw data to information that contributes to the commander's decision-making process. It is considered "intelligence" when it allows planners to anticipate future situations or illuminates the differences in available COAs.

Traditionally, the strategic level of war is concerned with the art and science of employing national power. It is the echelon that determines force structure and where military campaigns may occur. A maritime component is considered essential for expeditionary warfare since the ocean comprises 70 percent of our globe and megacities, such as Tokyo, Jakarta, and Seoul, tend to be located near major seaports or littoral regions where land and ocean meet. Strategies should be driven in part by natural climate variability (including extreme weather events) and meteorological and oceanographic services that support decision-making concerning the implementation and operation of new maritime technologies such as unmanned platforms.

Sea control and maneuver from the sea are key aspects for a force that operates in an amphibious objective area. For many expeditionary operations, the military has the personnel, equipment, and planning abilities to establish a safe and secure environment that will allow other organizations to accomplish their often longer-term "disaster recovery" missions. Strategic planning requires an understanding of the impact of winds, depths, waves, currents, and tides on these missions. Understanding these variables at the right temporal and spatial scale helps strategic planners synchronize efforts and sequence related operations to achieve decisive strategic effects. Important environmental parameters are usually described as statistics that reveal the extreme conditions as well as the long- and short-term variations in an operating area. These plans must be practiced. Realistic experimentation during exercises such as Rim of the Pacific or RIMPAC provides an opportunity to demonstrate the innovative use of environmental information that improves planning and execution of expeditionary warfare missions.

Military strategies are implemented at the operational level of war, where planning is conducted to execute campaigns. Missions and objectives that are set at the operational level occur over a large geographic area or theater of operations. A case in point is the HA/DR operation that was conducted following the March 11, 2011, 9.0 magnitude earthquake and tsunami that damaged the Fukushima nuclear power plant and created radioactive leaks. Immediate environmental factors impacting the operation were severe winter weather and an evolving radiological crisis. Operational planners were able to mobilize approximately 16 U.S. naval ships, Marines from Okinawa, Japan, and eight Military Sealift command ships. Owing to the magnitude of coastal destruction, the seabase provided the hub for disaster response. Maneuver in these circumstances was impacted by a variety of environmental conditions (e.g., temperature, waves, debris, radioactive plumes), which if not accounted for could contribute to mechanical failures, collisions with shallow water obstacles, navigation errors, and exposure of people and equipment to high radiation levels. Fig. 5 depicts a U.S. naval barge loaded with freshwater leaving Yokosuka, Japan. Barges were eventually towed by Japan Maritime Self-Defense Force ships such as the JS *Amakusa* to help cooling efforts at the damaged Fukushima Dai-ichi nuclear power plant. In planning to tow a vessel, especially in storm conditions, it is necessary to estimate the actual sea state in terms of significant wave height, direction, and period, because wave drift forces acting on the towed vessel increase as the wave height increases and then usually decrease as the wave period increases. Climatological data, imagery, circulation models, and the use of unmanned sensors would have provided essential information for the initial rapid response. Training for these types of amphibious operations may also improve political cooperation.

Figure 5. U.S. Navy Barge YON-287, filled with 225,000 gallons of fresh water, being pushed by landing craft from Fleet Activities Yokosuka on March 26, 2011 (Courtesy of U.S. Navy).

Maneuver and engagements are planned at the tactical level in order to accomplish goals that are set at the operational level. Actions that are conducted can be extremely sensitive to the changing battlespace, where decisions include the here and now, future operations (possibly the next 48 hours), and future planning (on the order of a few weeks). In the dynamic coastal zone, the environment impacts operational approaches and subsequent planning efforts. Obtaining the right data at the right time is essential to building products that support decision makers. Obtaining rapid and accurate environmental information supports navigation, close quarter maneuvering and helps to avoid mishaps such as collisions, grounding, capsizing, and broaching. For example, wave information needs to be delivered at the appropriate scale and should complement specific steps in the military decision making process (e.g., COA analysis) that may be occurring aboard ship. Understanding surf and nearshore current characteristics is critical to selecting optimal locations for surf zone breaching. Errors in reconnaissance such as collecting littoral intelligence at high tide and then navigating through an estuarine entrance at low tide, contributed to the capsizing of 9 of 17 U.S. Marine Corps rubber raiding craft in heavy surf during Exercise Valiant Usher 1989 in Australia.

4. Information Dominance

For expeditionary warfare, a combination of new operating concepts that include innovative technologies such as unmanned surface vehicles, running coastal wave models aboard ship, and the continued proficiency and confidence of Soldiers, Sailors, and Marines is essential. Information needs are expanding at the land-sea interface where combat swimmers may surge ashore using the power of the waves to landing craft or connectors using mechanical power to breach the surf zone—each are impacted by the force of large waves and wave-induced longshore currents. Waves also impact the laying and clearing of mines. Further, the launching and recovery of boats is especially dangerous in rough seas. Information on waves and currents should be applied to improve ride quality and seakeeping. The installation of coastal structures is also sea state limited**.** Information on surf zone characteristics is critical to selecting landing locations for surf zone breaching. For regions without a port, today's Joint Logistics Over the Shore (JLOTS) operations require specialized sea state limited equipment, including the Army's floating causeway or Trident Pier. Without frequent and accurate weather forecasts, JLOTS operations cannot be conducted in a safe and efficient manner. Fig. 6 depicts installation of the Trident Pier in Korea. Wave erosion can erode sand ramps that must be rebuilt in order to use the pier to offload rolling stock across the surf zone onto a beach. For this reason, operational oceanographers need to support construction efforts with ongoing monitoring of the wind field, wave field, bathymetry, nearshore currents, and surf. Such phenomena may be measured remotely by overhead sensors, *in situ* with unmanned platforms, buoys or bottom-mounted instruments, or forecasted using numerical models. Timely and accurate information aids decision makers and ensures operational effectiveness and safety, especially as vehicles and people are being embarked or offloaded.

Modern expeditionary warfare is focused on developing and applying digital tools and technologies to enhance warfighting effectiveness. The goal involves obtaining and maintaining decision superiority. This process should start at the strategic level where databases, climatologies, data from ocean observing systems, imagery, and numerical models are used to describe the current state of the coastal battlespace to aid in planning and making critical force structure decisions. At the operational level, data bases should be updated, imagery collected, *in situ* sensors deployed, and models run aboard ships to provide forecasts that support operational planning teams concerned with the selection of landing force objectives, maneuver, targeting, etc. Information products should be created that directly support expeditionary warfare planning. Templates that highlight the impact of environmental factors such as surf on employment of combat swimmers would support decision makers by providing windows and restrictions for operations. Environmental information is crafted into products that support tactics, techniques, and procedures. For example, imagery-derived shallow water bathymetry could be used to run hydrographic models that reduce the chances of small boat grounding and compromise during advanced force operations. The end state involves providing planners and operators with information that incorporates an accurately predicted environment with respect to operational capabilities. Such environmental intelligence supports the military decision-making process by helping leaders quantify risks and opportunities at strategic, operational and tactical levels. Toward this effort, the U.S. Naval Oceanographic Office has been involved in bilateral arrangements in western Africa that includes hydrographic surveys. Field collection, data processing, and on-scene production during Rapid Environmental Assessment 2001 in Ghana supported emergent real-world operations, exercises and exigencies (Fig. 7). Expeditionary warfare today is different than in the past owing to methods that use actionable battlespace information to enable planners to make a range of recommendations from force allocations to the selection of littoral penetration points, decisions that directly enhance safety and accomplishment of the mission.

Figure 6. U.S. Soldiers with the 331st Transportation Company install a section of the Trident Pier causeway in preparation for ship-to-shore unloading operations on April 15, 2013, in Pohang, South Korea (Courtesy of U.S. Army).

5. Technology Insertion

Expeditionary warfare is complex and heavily dependent on numerous technologies related to ships, craft, remote sensing, robotics, and weapons. To meet modern warfare threats research and technologies tend to focus on ocean acoustics, underwater weapons, and naval engineering [12]. However, the inevitable need in conventional warfare is for technologies that facilitate rapid response by expeditionary forces that require combatants to be self-sustaining and able to make data-driven decisions in austere and chaotic coastal environments. Continual innovation will require

Figure 7. A Rigid Hull Inflatable Boat trying to breach the surf zone in Ghana during Rapid Environmental Assessment October 2001 (Courtesy CDR Blake McBride).

experimenting in military exercises with new approaches that ultimately strengthen combined and joint operations. Advances will not occur on the battlefield without the smart exploitation of scientific and technical solutions. A process might start with better instrumentation and monitoring programs in training areas, i.e., deployment of sensors and setting up models to build a battlespace that is useful for expeditionary warfare planning. Developing fully-integrated and operational databases should not only support base management, but serves to improve the ability of military decision makers to make data-driven or informed decisions. *In-situ* sensors and models that are used in an area of operations should also be used in training areas. Autonomous Underwater Vehicles that can be used to assess shallow water regions to support mine detection should also be employed to survey shallow water bathymetry to support beach nourishment projects at locations such as the Onslow Beach training area. Navy ranges provide a prime location where scientists and engineers can work with operators to better understand military requirements. Ranges where Combat System Ship Qualification Trials occur should be fully-instrumented to better assess innovative models, unmanned platforms, and tactical decision aids that are being transferred from the science and technology community. Participation by researchers in the military's S&T planning process is critical to ensuring that technology actually meets future needs.

6. Conclusion

Expeditionary warfare requires a focus on maneuver from the sea to inland landing force objectives. The force needs to adapt to maritime terrain and hydrography. The ability to control key maritime terrain and chokepoints requires a complete understanding of environmental factors that includes natural barriers such as wave fields, nearshore currents, surf zones, and coastal morphology (channels, cliffs, barrier island systems, reefs, etc.). High technology equipment and adjustments to the supporting infrastructure are some of the major improvements in ship-to-shore movement since World War II. Planners rely on meteorological and oceanographic information to characterize the environment to gain an operational advantage and ensure the safety of operational forces. Military planning for expeditionary operations should be based on data from historical archives, remote sensors, *in situ* instruments, and models. These data should be fused together aboard command and control ships and developed into decision aids for specific missions. New equipment and techniques should be exercised in fully-instrumented training areas and ranges to assess the utility. These observing systems, that may be comprised of sensors and models at bases, ranges, or training areas, should also be available for deployment in areas of operation. It is also entirely conceivable to see unmanned surface vehicles working as floating dumps or used in towing, especially in support of floating causeway assembly. Contemporary expeditionary warfare is better enabled to deal with issues related to amphibious reconnaissance, mine warfare, amphibious lift, and naval fire support through the application of updated databases, spatially extensive imagery, sensors, and model output that fills information gaps.

7. Acknowledgment

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