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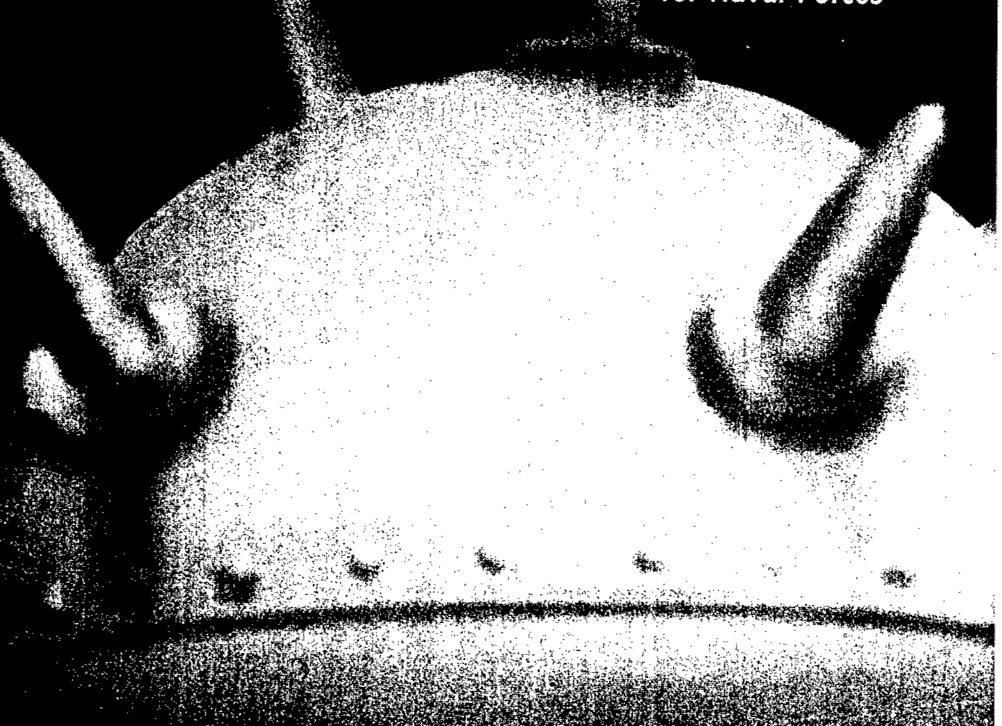

Naval Mine Warfare

Operational and Technical Challenges for Naval Forces

Committee for Mine Warfare Assessment
Naval Studies Board
Division on Engineering and Physical Sciences
National Research Council

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Preface

U.S. naval forces are organized, trained, and equipped to engage in the full spectrum of military operations in the deep sea, the littorals, or inland. Yet today, sea mines in the hands of hostile forces are a growing threat to mobility, as evidenced in the Gulf War. To meet the threat of the proliferation and ever increasing sophistication of sea mines, the Department of the Navy has adopted an integrated approach to countermine warfare[1] that attempts to balance dedicated (special-purpose forces) and organic (multimission, general-purpose forces) capabilities intended to leverage emerging technological opportunities. As with other warfare areas, the mine warfare[2] community also must deal with limited resources and legacy systems. These constraints complicate the process of defining the optimal long-term strategic balance between dedicated and organic assets, the transition path to achieving the objective, and the technological capabilities (and underlying research and development) needed to meet those objectives.

Naval mine countermeasures (MCM) programs for countermine warfare employ a mix of undersea, surface, and airborne systems (including special warfare, marine mammal, and explosive ordnance disposal units). The resulting capabilities, together with support from other command, control, communications, computing, intelligence, surveillance, and reconnaissance (C4ISR) sys-

[1]The term "countermine warfare" is used in this report to include not only local measures to detect and clear mines, but also the intelligence and other support activities important to countering the threat of mines at sea and in the approaches to shore.

[2]The term "mine warfare" is used in this report to include both naval mining and countermine warfare.

tems, are intended to provide the naval forces with minefield intelligence, surveillance, and reconnaissance (ISR) to facilitate minefield avoidance, minefield clearance, mine neutralization, and mine and obstacle removal and destruction. Their operational utility depends also on access to key environmental data, and modeling and simulation systems.

A combination of innovative technologies, platforms, sensors, and training is key to the naval forces' ability to achieve and maintain a robust countermine capability. New countermine warfare systems scheduled for introduction into the fleet in the middle of this decade include the undersea long-term mine reconnaissance system (LMRS) for the nuclear submarine force; the (unmanned) remote mine-hunting system (RMS) employed from some guided missile destroyers; the AN/AQS-20X towed mine-hunting system; the remote-controlled, tethered airborne mine neutralization system (AMNS); the organic airborne and surface influence sweep (OASIS), a towed, shallow water, influence minesweeping system; the airborne laser mine detection system (ALMDS); the gun-based rapid airborne mine clearance system (RAMICS) for the MH-60S helicopter; the mine warfare environmental decision aids library (MEDAL) accessible via the global command and control system (maritime); and a littoral remote sensing (LRS) system that uses sophisticated image gathering and processing techniques for operational intelligence.

In the area of mining, the ability of U.S. (and coalition) forces to shape the future maritime battlefield through precision delivery of mines is being increasingly constrained by the aging of the current stockpile of sea mines. To successfully conduct this component of mine warfare, U.S. forces need a new generation of mines that are covert, robust, lethal, controllable as required, and safe to use.

TERMS OF REFERENCE

As requested by the Chief of Naval Operations (CNO), the Naval Studies Board conducted a mine warfare assessment that examined issues related to both countermine and future sea mining capabilities. The terms of reference for the study are as follows:

- Evaluate present and future threats to deep sea and littoral operations involving mines; evaluate current and projected mine countermeasure capabilities.
- Evaluate current and projected R&D programs aimed at providing the fleet with new and improved capabilities.
- Evaluate R&D opportunities that are not part of the current program of record but which hold promise for meeting naval force needs in the future.
- Evaluate the status of the present sea mine stockpile and mine delivery systems; evaluate R&D efforts to develop next-generation sea mines; and identify associated R&D priorities.
- Place special emphasis on that part of the littoral region that extends from

a sea depth of approximately 40 ft to 200 ft across the beach. With respect to organic mine warfare, the study should consider the implications for organic forces of planned reductions in personnel.

In a letter dated December 11, 2000, to the president of the National Academy of Sciences, General James L. Jones, USMC, Commandant of the Marine Corps, indicated that he also endorsed the study's terms of reference.

COMMITTEE MEETINGS

In responding to the CNO's request, the committee organized itself into three ad hoc panels: (1) Panel 1—Mines and Mining; (2) Panel 2—Offshore Countermine Warfare; and (3) Panel 3—Inshore Countermine Warfare. To integrate the work of these three panels, an integration group was formed that included a lead representative from each panel, as well as the committee chair and vice chair and three additional members of the committee with expertise in Navy and Marine Corps operations, acquisition, and technology.

The Committee for Mine Warfare Assessment first convened in August 2000 and held further meetings and site visits over a period of 9 months:

- August 1-2, 2000, in Washington, D.C. (plenary and integration group). Organizational meeting: Navy and Marine Corps briefings on operational requirements, the mine threat, and procurement processes to meet the threat; Director of Expeditionary Warfare briefing on the current Navy mine warfare program; Program Executive Office for Mine and Undersea Warfare (PEO MUW) briefings on surface mine warfare, mine warfare ship, airborne mine countermeasures, and explosive ordnance disposal systems; and Office of Naval Research (ONR) briefing on the ONR Mine Warfare Technology Program.
- August 30-31, 2000, in Panama City, Florida. Small group site visit to Coastal Systems Station, Naval Sea Systems Command, to view airborne unmanned vehicles in support of very shallow water mine countermeasure operations.
- September 5-6, 2000, in Washington, D.C. (plenary and integration group). Center for Naval Analyses briefing on the MCM Force 21 Study;[3] Office of the Deputy Chief of Naval Operations for Resources (N81X/N87) briefings on integrated warfare architecture, the N87 Mine Countermeasures Study,[4] and

[3]Edlow, Sabrina, John Clifford, Mike Price, John Benedict, Rich Ruzicka, Joe Gezelter, Gene Ward, Michael Jeffers, James White, Kenneth Montgomery, William Whitacre, Richard Nelson, Curtis McVey, Don Almond, J.D. Ivey Smith, Chuck Beckler, and Jose Cuadra. 1999. *MCM Force-21 Study Final Results* (U), Annoted Briefing CAB 99-37, Center for Naval Analyses, Alexandria, Va., June (classified).

[4]Elliott, RADM Thomas J., Jr., USN (Ret.), "N87 Mine Countermeasures Study—Network Centric Warfare Implementation Principles," briefing to the committee on September 6, 2000, Office of the Chief of Naval Operations (N87), Washington, D.C.

breaching by explosive channeling; Marine Corps Combat Development Command (MCCDC) briefing on U.S. Marine Corps land mine warfare requirements; Naval Sea Systems Command (NAVSEA) briefing on Navy sea mines; and Defense Advanced Research Projects Agency briefing on mine warfare technology efforts.

- October 3-5, 2000, in Washington, D.C. (plenary and integration group). Joint Staff (Joint Warfighting Capability Assessment) briefing on Joint Staff mine warfare perspective; Office of the Chief of Naval Operations (OPNAV) Expeditionary Warfare Division (N75) briefings on the Surface Warfare Development Group, amphibious assault plans and requirements, the physical environment from the surf zone to the beach exit zone, and a description of mine and obstacle types; U.S. Mine Warfare Command (MINEWARCOM) briefings on mine warfare training and education, fleet mine warfare concept of operations, and an overview of MINWARCOM; ONR (Code 321) briefings on ISR systems for mine warfare missions and on R&D for breaching techniques; PEO MUW briefings on legacy MCM systems' baseline capabilities and on the capabilities of the organic MCM systems in development; and Naval Surface Warfare Center, Dahlgren Division briefing on the Coastal Systems Station.
- October 18-19, 2000, in La Spezia, Italy. Small group site visit to SACLANT Undersea Research Center.
- November 13-14, 2000, in Washington, D.C. (plenary and integration group). Operational Test and Evaluation Force (OPTEVFOR) briefing on OPTEVFOR role in assessing mine warfare; MINEWARCOM briefing on U.S. Air Force maritime mining support; Navy Warfare Development Command briefing on Navy and Marine Corps experimentation and inclusion of mine warfare; NAVSEA and Naval Surface Warfare Center, Carderock Division briefing on ship protection and ship signatures; general discussion with representatives of OPNAV N75, U.S. Air Force Headquarters Air Combat Command, MINEWARCOM, Office of the Deputy Assistant Secretary for Mine and Undersea Warfare, PEO MUW, OPNAV Air Warfare Division (N78), Multi-Mission Helicopter Program Office (PMA 299), Aircraft Mine Countermeasures Program Office (PMS 210), ONR, MCCDC, and NAVSEA; U.S. Army Science Board/Naval Research Advisory Committee briefing on mine warfare study (unpublished); and ONR briefing on over-the-horizon-delivered countermine and counterobstacle systems.
- November 15, 2000, in Washington, D.C. (Panel 2).
- December 6-7, 2000, in Corpus Christi, Texas (plenary and integration group). Site visit to Mine Warfare Command for briefings on mine warfare threats, force capabilities, force command, control, communications, computing, and intelligence (C4I), meteorology and oceanography, and future mine warfare concepts.

- December 18-19, 2000, in Panama City, Florida. Small group site visit to Coastal Systems Station, Naval Sea Systems Command, for briefings on mine warfare threats, U.S. naval sea mines, mine and undersea warfare science and technology, ARES (a system-of-systems approach to a mine countermeasure architecture), mine warfare analysis, mine warfare modeling and simulation, shallow water MCM, Littoral Warfare Advanced Systems Engineering Laboratory, remote mine-hunting system, and airborne MCM.
- January 5, 2001, in San Diego, California. Small group site visit to Explosive Ordnance Disposal Group One for briefings on very shallow water detachment, explosive ordnance disposal MCM detachment, and MHS-1 demonstration.
- January 8-12, 2001, in Irvine, California (plenary and integration group). Committee deliberations and report drafting.
- February 7-8, 2001, in Washington, D.C. (Panel 3).
- February 14-15, 2001, in Washington, D.C. (Panel 2).
- April 12, 2001, in Washington, D.C. (integration group).
- April 23-24, 2001, in Washington, D.C. (plenary). Committee deliberations and report drafting.

The months between the last meeting and publication of the report were spent preparing the draft manuscript, reviewing and responding to the external review comments, and editing the report.

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Gerald A. Cann, Rockville, Maryland,
Howard M. Choset, Carnegie Mellon University,
James R. Fitzgerald, Applied Physics Laboratory, Johns Hopkins University,
Ray M. Franklin, Port Angeles, Washington,
Alfred I. Kaufman, Institute for Defense Analyses,
Fred N. Spiess, Scripps Institution of Oceanography, and
Robert C. Spindel, Applied Physics Laboratory, University of Washington.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Edward A. Frieman, appointed by the NRC's Division on Engineering and Physical Sciences, who was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests solely with the authoring committee and the institution.

Contents

APPENDIXES

Naval Mine Warfare

Executive Summary

NAVAL MINE WARFARE FOR U.S. NAVAL FORCES[1]

At the request of the Chief of Naval Operations,[2] the National Research Council, under the auspices of the Naval Studies Board, established a committee to assess the Department of the Navy's capabilities for conducting naval mining and countermining sea operations. The Committee for Mine Warfare Assessment first convened in August 2000 and met approximately 2 days a month for 9 months. This report is based on the information presented to the committee during that period and on the committee members' accumulated experience and expertise in military operations, systems, and technologies.

Sea mines have been important in naval warfare throughout history and continue to be so today. They have caused major damage to naval forces, slowed or stopped naval actions and commercial shipping, and forced the alteration of strategic and tactical plans.[3] The threat posed by sea mines continues, and is increasing, in today's world of inexpensive advanced electronics, nanotechnology, and multiple potential enemies, some of which are difficult to identify. The

[1]The term "mine warfare" is used in this report to include both naval mining and countermine warfare (CMW). CMW includes not only local measures to detect and clear mines, but also the intelligence and other support activities important to countering the threat of mines at sea and in the approaches to shore. In this report countermine warfare in inshore waters (<40 ft deep) is addressed separately from CMW in offshore waters.

[2]In a letter dated December 11, 2000, to the president of the National Academy of Sciences, the Commandant of the Marine Corps endorsed the study's terms of reference.

[3]Salient mine warfare historical highlights are noted in the main body of the report and in the appendixes.

largely unregulated sale of sea mines by friends and third parties (e.g., Italy, Sweden, Russia) is contributing directly to this growing threat.

During the Cold War, U.S. naval forces concentrated on guarding against the sophisticated Soviet blue-water, air, and undersea threats. Yet since World War II, U.S. naval forces have suffered significantly more physical damage and operational interference from sea mines than from air, missile, and submarine attacks: 14 U.S. Navy ships have been sunk or damaged by mines, whereas only 2 have been damaged by missile or air attack (see Chapter 1). Because of the low cost and wide availability of modern sea mines, their importance as a threat to shipping and naval force operations is growing rapidly. The threat of air, missile, and submarine attack, while also important, is posed by a much smaller number of countries and nonstate forces than is the threat of mines.

The need for U.S. naval forces to maneuver and project power in the world's littorals is also increasing. Yet U.S. naval forces are not now likely to be able to adequately handle the plausible near-term threat of mines either offshore or inshore. Looking ahead, the Navy's planned mine warfare improvement programs have major shortcomings that need to be addressed now if current risks are to be reduced rather than permitted to continue to grow. In addition, modern sea mines could provide the United States with critically important capabilities that will not be available under current plans.

This report is the latest in a long series of reports by the Naval Studies Board of the National Research Council and by other organizations pointing out that the Navy has assigned inordinately low importance to mine warfare. Based on the committee's review of previous reports and the knowledge and experience of many of its members, it seems clear that the Navy's relative inattention to mine warfare is a natural legacy of its historical focus on blue-water operations, from the battleship Navy prior to World War II through the postwar deep-water carrier/nuclear-powered attack submarine Navy—a focus that was diverted toward near-shore operations only sporadically during the 20th century (except during World War II).

The committee notes that the official Navy focus has been shifting landward since the demise of the Soviet threat. Experience in the Persian Gulf, Red Sea, Taiwan Strait, Sea of Japan, and elsewhere has coalesced under the general organizing principle of "Forward . . . From the Sea."[4] One natural outcome of this decade-long shift of focus has been the beginning of work on the organic mine countermeasures systems described in Chapter 4. Another desired outcome would be the assignment of higher priority to improving the nation's ability to conduct naval mine warfare operations. It is for this reason that the committee

[4]Department of the Navy. 1994. "Forward . . . From the Sea, Continuing the Preparation of the Naval Services for the 21st Century," U.S. Government Printing Office, Washington, D.C., September 19.

believes that the analysis and recommendations contained in this report may be of greater use to the Navy's leadership now than may previously have been the case.

This committee's recommendations are designed to ensure that the deficiencies referred to above receive prompt attention in the Department of the Navy's force, personnel, and equipment management processes. The following recommendations are presented in the order of priority agreed to by the committee. Implementation of the first recommendation would greatly facilitate implementation of the others. The committee emphasizes its belief that all of these recommendations are important, and that implementation of some of them should not preclude implementation of the others.

RECOMMENDATIONS FOR IMPROVING THE OPERATIONAL EFFECTIVENESS OF MINE WARFARE FORCES

Establish Mine Warfare as a Major Naval Warfare Area

The Navy is responsible for protecting all maritime forces, including logistics transport and Marine Corps units, against the mine threat wherever it may be encountered, from the sea lanes, to logistics unloading areas, to the high-water mark on the landing beaches. It is also responsible for providing the inventory of sea mines that may be needed to implement U.S. national security strategy. But these responsibilities were not aggressively pursued until well after the Gulf War.

In its recent efforts to "mainstream"[5] mine warfare, the Department of the Navy has concentrated its efforts on mine countermeasures (MCM) in the offshore regions, including shipping lanes and operating areas. In this offshore region the Navy has focused on two goals: (1) to give carrier battle groups an organic capability (within the multimission, general-purpose forces) to locate minefields and to hunt, sweep, and neutralize mines in offshore operations along the littoral and (2) to maintain a dedicated MCM force, based primarily in the United States, that can deploy when ordered to undertake mine hunting and clearing operations that are beyond the expected organic MCM capability and capacity of the battle groups. Some progress has been made toward these goals by initiating the development of new MCM equipment and through the establishment of the Fleet Engagement Strategy. However, the cost-effective military capability that is potentially available to the United States through the use of modern sea mines is being neglected.

In addition, progress toward mainstreaming mine warfare is being retarded in part because the readiness to conduct mine warfare operations is not now

[5]The term "mainstreaming" as used in this report refers in general to the Navy's efforts at the present time to bring existing mine countermeasures operational knowledge and understanding into the mainstream of naval force planning and, in particular, to help prepare for the introduction of new countermine warfare systems into the carrier battle groups.

highly valued as a component in assessing the readiness of battle groups for deployed operations. In the fleet, mine warfare is practiced only in selected special exercises, and facilities for such practice are minimal. Furthermore, in Navy and Marine Corps school curricula, mine warfare receives little emphasis, and assignments are not ordinarily considered beneficial for naval officers' career advancement.

The Navy budget for mine warfare in total is small compared with that for the other major naval warfare areas, and the Navy budget for mines is negligible compared with the budget for other strike munitions. Within a very few years the current budget plan will essentially remove the option of naval mining from the capabilities the Navy could provide to the theater commanders.

Although significant funding has been allocated for countermine warfare in recent years, about two-thirds of this budget is devoted to (1) operations and maintenance of the dedicated/legacy MCM force and (2) the acquisition of the seven new systems intended for offshore organic MCM. The remainder of the mine warfare budget, approximately $215 million per year, on average, leaves many important elements underfunded. These include improvements to the dedicated MCM force, maintenance of ship signature control, acquisition of modern U.S. mines, and other essential force improvements. The committee estimates that an increase of approximately 30 percent in the mine warfare budget could meet these unfunded needs while also providing for the needed modernization of the current dedicated mine warfare command and support force, as discussed below. The committee could not identify a significant amount of money being inappropriately spent within the mine warfare budget, and, therefore, if the committee's first recommendation is accepted, the Navy will have to allocate additional funds to mine warfare from other warfare areas that have comparable or lesser priority.[6]

In conclusion, several actions will be needed beyond those currently reflected in the Navy program of record in order for mine warfare to be accorded its proper position in the mainstream of naval force planning and operations. Those actions are detailed in Chapters 2 through 5 and are summarized below, in priority order.

Recommendation 1. The Secretary of the Navy, the Chief of Naval Operations, and the Commandant of the Marine Corps should take the steps needed to establish mine warfare as a major naval warfare area. Such an elevation in warfare status will require that the Department of the Navy (a) coordinate and improve the focus of its "mainstreaming" initiatives; (b) upgrade mine warfare-related readiness reporting, certification, training and education, and officer career planning; and (c) program, budget, and execute accord-

[6]Other warfare areas, such as air and submarine warfare, have traditionally enjoyed much higher levels of support than has mine warfare.

ingly. Continual follow-up by these officials will be necessary to ensure implementation. Specifically,

- The Chief of Naval Operations (CNO) and the senior Navy leadership should expeditiously establish an implementation plan that assigns responsibility and accountability to the appropriate officials to bring to fruition the mainstreaming of mine warfare, in particular the introduction of organic mine countermeasures capabilities. Such a plan should include the seven key elements—doctrine, organization, training, materiel, leadership and education, people, and facilities—detailed in Chapter 2.
- The Department of the Navy should establish broad first-order force-protection requirements for naval units that will ensure adequate levels of countermine warfare capability, both active and passive.
- Naval component and other operational commanders should enhance realism in predeployment training, fleet maneuvers, and amphibious warfare exercises by routinely including mine threats, in addition to air and submarine threats, in such exercises and by assigning realistic consequences to poorly planned and executed countermine warfare operations.
- The CNO and the Commandant of the Marine Corps (CMC) should ensure that the routine interdeployment training cycle for fleet battle groups and amphibious ready groups entails the same level of rigor in certifying capabilities for mine warfare and in reporting readiness, in both the ship's operational readiness training status (SORTS) report and the mission capability assessment system (MCAS),[7] as is now the practice for the other major warfare areas. Readiness should include the routine measurement of the acoustic and magnetic signatures of applicable ships.
- The Secretary of the Navy, the CNO, and the CMC should ensure that the growing importance of mine warfare is emphasized in all appropriate Navy and Marine Corps formal education curricula and in officer career development practices. These curricula and career development criteria should place mine warfare expertise on a par with the emphasis given to air warfare, surface warfare, and submarine warfare.
- The Secretary of the Navy, the CNO, and the CMC should increase the priority of funding for mine warfare relative to other warfare areas. The Secretary of the Navy and the CNO should review the allocation of funds by warfare area in the future year defense program (FYDP), with a view to finding ways to increase funding in the mine warfare area to meet the urgent mining and countermine warfare program needs identified in this report.

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[7]SORTS is the Joint Chiefs of Staff (JCS)-managed system of reporting the readiness of ships and squadrons to conduct assigned missions. MCAS is a new system that would report the readiness of battle group commanders to conduct their assigned missions.

Place Greater Emphasis on Intelligence, Surveillance, and Reconnaissance

Intelligence, surveillance, and reconnaissance (ISR) is at the heart of mine warfare. It ascertains the technical characteristics of threat mines, identifies where minefields and mines are laid, and helps determine how they can best be countered in the context of the extant environmental constraints. More broadly, ISR helps ascertain the potential mining and countermine warfare capabilities of hostile forces and provides near-real-time indications and warning of mine threats to enable tracking and potential interdiction, as well as to optimize mine avoidance or clearance operations, and it shows where minefields should be placed by friendly forces should that be indicated.

Notwithstanding its importance, ISR for maritime mining and countermine warfare is not in good order, either in the fleet or elsewhere in the joint warfighting and intelligence tasking establishments. The most critical problems are insufficient attention to mine warfare ISR in operational planning; failure to task the ISR agencies for needed information, including analysis and dissemination; a paucity of the environmental data needed to find mines expeditiously; and failure to use the best available modern sensors and signal processing technology to help find mines, including buried mines, and separate them from nonmine, minelike bottom objects to facilitate mine hunting and neutralization.

Recommendation 2. The Department of the Navy should place greater emphasis on the intelligence, surveillance, and reconnaissance needed for mine warfare operations. Increased priority should be given to (a) technical exploitation of threat mines; (b) mine warfare indications and warning (I&W) tasking and disseminaton at all command levels; (c) rules of engagement (ROE) to counter hostile miners; and (d) relevant environmental databases, such as the mine warfare environmental decision aids library (MEDAL) and the INTELINK contingency planning tool. Specifically,

- The CNO and the CMC, through their senior planning staffs, the fleet and fleet Marine force commands, and in joint forums, should take steps to ensure that the ISR needed for mining and countermine warfare is planned and integrated into all naval warfare activities as part of a total system that starts with ISR and ends with successful mine interdiction, mine countermeasures (including avoidance), and U.S. mining activities in critical areas along the littoral.
- The CNO and the CMC should also take steps to ensure that theater Navy and Marine Corps operational commanders are trained in the tasking of the collection and analysis agencies so as to obtain and update mine information and mine warfare-related data and analysis, including the observation of potential opponents' relevant activities, as a routine part of theater warfare planning and operations.
- The CNO should ensure that the Oceanographer of the Navy places increased emphasis on mine warfare-related environmental data collection and

the entry of all existing data into the MEDAL system. Provision also should be made for the collection and automated transmittal of key environmental data from the applicable dedicated and organic MCM sensors as well as from national sensors. Up-to-date MEDAL databases should be "pushed" to ships en route to contingency operations.

Reestablish a Naval Mining Capability

As amply demonstrated in World War II and the Vietnam War, U.S. sea mines can be force multipliers, used both to provide protection against hostile ships and submarines and to extend maritime power in strategic areas that the fleet cannot always guard. The United States is in the process of giving up this potentially critical capability as U.S. sea mining capability is being allowed to rapidly atrophy. With some additional effort focused toward the development of modern sensor and communication technology, sea mines and minefields could be remotely monitored and controlled, thereby enabling their use for coercive purposes in situations short of war, in full compliance with international conventions.

The current U.S. capability to use mines for strategic or tactical military purposes is characterized by small inventories of old and obsolescent mines, no plans for future mine acquisition, declining Navy and Air Force mine delivery capability, and a lack of robust minefield planning capability in the fleet battle groups.

Recommendation 3. The United States should reestablish a naval mining capability that is both credible and joint. Such a capability will require overt, covert, and remotely controllable mining. Specifically,

- The CNO should establish and sponsor for joint approval a prioritized set of joint mining system requirements, giving full consideration to the advanced capabilities outlined in Chapter 3 of this report, and should plan an adequately funded program for acquiring them. These plans should extend from individual weapons to minefields designed to accomplish specific purposes. Ultimately, the plans should include overt and covert (submarine) delivery and be applicable to a broad range of water depths. The plans should reflect the results of a systematic cost-effectiveness study of potential future mines, including mines for water deeper than that suitable for Quickstrike mines. The recommended study should consider joint warfighting needs with jointly agreed concepts of operation and recommended rules of engagement for promulgation by the National Command Authority. The funded program should include explicit plans for retaining a U.S. naval capability, and an associated industrial base, for mine and valid minefield system design, and for acquiring mines deliverable by naval and Air Force aircraft as well as by *Virginia*-class nuclear-powered attack submarines and current attack submarines.

- The CNO should establish a fast-track program to improve the current Quickstrike shallow water mining capability by developing and acquiring joint direct attack munition, extended range (JDAM-ER) delivery and mine fuzing kits that can target modern, small, surface craft and submarines, in addition to traditional surface ship targets, and that can accommodate remote-control features.
- The CNO should ensure that sea mine and valid mining planning tools, including provision for joint mining and minefield control operations, are added to battle group warfare planning capability, and that battle group individual and unit training includes realistic exercises that use mining as an extension of battle group capability.
- The CNO should ensure that the readiness of naval battle group commanders to conduct mining operations is routinely reported in the new MCAS, and that mine delivery is designated a primary mission area requirement reported in GSORTS by appropriate tactical aircraft squadrons.
- In view of the potential importance of maritime mining as a coercive option quite independent of expeditionary warfare operations, the CNO should consider transferring resource sponsorship of naval mining programs to a resource manager with broad policy and cross-platform responsibilities.

Modernize the Dedicated Mine Countermeasures Force

Mine warfare threats may vary from a few mines having mainly nuisance value to major concentrations of sophisticated mines blocking naval force maneuver areas. The opportunities and occasions for encountering such threats are growing.

At some point in the possible spectrum of mine threats, the need for timely clearance of mines and obstacles from both offshore and inshore areas could become essential to providing assured access. In some highly plausible circumstances, such operations could become very demanding, well beyond planned battle group organic MCM capabilities, particularly if it became necessary to divert the battle group's multimission ships away from their other duties.

For these reasons the committee concluded that the specialized capability of a dedicated MCM force will be needed into the indefinite future. Many improvements and upgrades to the current force, detailed in the main body of this report, are needed. The following paragraphs summarize the committee's assessment for each element of the dedicated MCM force.

- *Dedicated MCM support ship(s).* Currently only one dedicated MCM support ship is assigned the responsibility for supporting the surface dedicated MCM ships, airborne MCM helicopters, and undersea MCM detachments—the USS *Inchon* (MCS-12). The *Inchon* cannot deploy with fleet battle groups at their speeds, and for this and reliability reasons would not be readily available for expeditious MCM operations in a large-scale contingency when battle group organic capabilities might well need to be augmented. An aging reserve ship due to be retired within 10 years, the *Inchon* is very expensive to operate, even with its reduced manning. And without a well deck, its ability to support current airborne MCM operations is hampered and to support inshore MCM operations is minimal.

- *Dedicated surface MCM ships.* The Navy has a relatively modern force of 26 dedicated MCM surface ships, stationed mostly in Texas. These ships, both MCM and MHC classes, are not being funded adequately to ensure timely accomplishment of approved combat system upgrades. In addition, they do not have the installed self-protection systems or equipment they need to be fully effective.
- *Dedicated airborne MCM aircraft.* MH-53E MCM helicopters constitute the current dedicated airborne MCM force. These heavy-lift aircraft are uniquely capable of towing the types of heavy minesweeping equipment needed in some threat situations. The minesweeping gear planned for the smaller MH-60S helicopter that will constitute the organic airborne MCM force when fielded will be considerably less capable per sortie than the MH-53E. Despite the advantages of the larger MH-53E helicopters for such sweep missions, the Navy has not allocated funds for their retention or modernization, nor is airborne MCM a visible consideration in Navy planning for meeting its long-term heavy-lift logistics aircraft requirements.
- *Dedicated undersea MCM detachments.* Currently, explosive ordnance disposal (EOD) diver systems and marine mammal systems play key undersea MCM roles in countermine warfare operations. These teams, with the equipment described in Chapter 4, currently constitute the only means for hunting and clearing mines from shallow inshore waters. Small unmanned undersea vehicle (UUV) systems are under development as part of the undersea MCM toolkit and may eventually augment or replace the divers and marine mammals. The major issue with the undersea MCM force is the very small number of existing and planned units, when compared with the potential demands for rapid clearance of an amphibious landing zone. Unless (or until) the Navy fields an alternative system such as UUVs that can find and clear mines more rapidly, reliance on the planned small EOD/very shallow water force structure will either limit the size of future assaults against potentially mined littorals, or add to the time required to support large assaults.

Recommendation 4. The U.S. Navy should modernize its dedicated mine countermeasures (MCM) force. Elements of this modernization should include (a) sustaining and upgrading the current (legacy) elements of the dedicated MCM force; (b) replacing the aging *Inchon* (MCS-12) as soon as one or more suitable replacement(s) can be readied; and (c) planning and programming for follow-on dedicated MCM command and support capability and for follow-on dedicated surface, airborne, and undersea MCM capabilities. Specifically,

• The Secretary of the Navy, the CNO, and the CMC should plan to retain and continually evolve the dedicated MCM force based on an integrated plan that is prepared, updated, and optimized as lessons from the combined dedicated and organic force operations are learned.

• In the short term, the CNO should address the obsolescence issues related to the USS *Inchon* (MCS-12) by planning (and programming) to replace it with one or more ships to ensure a continuing MCM support capability. The near-term replacement ship should have a well deck, for mine countermeasures craft and sweep gear, as well as a flight deck, to provide increased flexibility and efficiency of operation, and to provide optimized support for MH-53E minesweeping operations and increased support for inshore MCM. Meeting this short-term need will most likely require the conversion of an existing hull suitable for this purpose.

• The CNO should consider providing more than a single replacement ship, to permit faster assured crisis response by the dedicated MCM force in both oceans.

• The CNO should plan to retain and modernize a capable, dedicated MCM warfare force that would be available for those situations in which the MCM requirements exceed the available organic MCM capabilities of the deployed battle groups. Such a dedicated force should include:

—Upgraded surface MCM ships and their potential future replacements as discussed in Chapter 4;

—Dedicated MCM helicopters, including retention of the MH-53E helicopter in the dedicated airborne MCM force until it can be replaced by equipment that provides comparable capability, perhaps as a variant of the Navy's next-generation heavy-lift logistic aircraft;[8]

—Augmented EOD/VSW teams and systems designed to help or replace them;

—Continued provision of support for deployed dedicated surface, airborne, and undersea MCM craft that is similar in concept to that provided by the *Inchon* (MCS-12), enhanced by the future evolution of the command and support capabilitiy embodied in the *Inchon*. Such support should be extended to inshore MCM.

—Additional capabilities such as a mine-hunting craft like the MHS-1, as discussed in Chapter 5, and hull forms facilitating the rapid deployment of ships and their operation with battle and amphibious ready groups.

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[8]The decision between retiring the MH-53E force, extending its service life, or acquiring a follow-on dedicated helicopter may need to be made before all the new mine warfare components of the MH-60S host aircraft have been fielded and their overall capability fully measured, depending on the pace of any new heavy-lift helicopter program. In the interim, selected upgrades should be made to the MH-53E aircraft suite (such as adding the AQS-20 mine-hunting sonar, the airborne laser mine detection system (ALMDS), and the airborne mine neutralization system (AMNS) capability, and a greater degree of self-protection).

Improve the Overall Integration of the Seven Organic Offshore Mine Countermeasures Systems

The Navy's plans for making MCM organic to the fleet are embodied in seven systems (described in Chapter 4) currently in development and intended to become operational by 2005.[9] They are intended mainly for operation outside the 40-ft-depth regime, but some of them will also have a limited ability to operate in somewhat shallower water. There are numerous problems with some of these systems, many recognized by the Navy. *The greatest problem, however, is the lack of a systems concept and approach toward integrating these systems into the fleet and using them operationally.* As an example, the MH-60S helicopter is the host vehicle for several of these systems. It is the committee's understanding that the Navy intends to base the MH-60S only on nuclear-powered aircraft carriers (CVNs) and to operate them only in a temporary "lily pad" fashion from some cruisers, destroyers, and amphibious ships. But the DDG-51s are not funded to be qualified to operate the MH-60S helicopter. As an additional example of the lack of an overall mine warfare systems concept, the design of the new LPD-17 amphibious assault ship incorporates antiaircraft defense but only limited passive and no active MCM defenses, such as the remote mine-hunting system (RMS) or the MH-60S, even though it is likely that it will operate in potentially mined waters.

Recommendation 5. The U.S. Navy should improve the overall integration of its seven organic offshore mine countermeasures (MCM) systems that are currently in development. Improvements should include (a) developing and promulgating an integrated countermine warfare concept of operations and a total system architecture, (b) testing and evaluating the resulting integrated capabilities at sea, and (c) extending the application of the new systems to the amphibious force. Specifically,

- The CNO should develop and promulgate a countermine warfare concept of operations and a total system technical architecture that includes all the legacy dedicated MCM systems and the new organic MCM systems and other upgrades that will be fielded. As part of this effort, the planned integration of organic MCM systems into the fleet should be extended to include amphibious ships as well as battle group combatants.
- The CNO should designate a single official to design a detailed program plan for integrating the seven MCM systems that are in development, and others that may follow, into battle groups and amphibious ready groups. The plan should include manpower and training, interaction with other combatant systems, logistics support plans, provision for accommodating MH-60S contingents on CVNs and aviation-capable amphibious ships as appropriate, and qualification of

9Some slippage to 2007 is likely.

all combatants that will have a latent capability to operate the MH-60S to actually do so.

Improve the Capabilities and Clarify the Services' Responsibilities for Inshore Countermine Warfare Operations

The terms of reference for this study direct placing special emphasis on inshore countermine warfare—within the very shallow water (VSW) zone from 40 to 10 ft deep,[10] through the surf zone (SZ) and the craft landing zone (CLZ), to the exit from the beach. The primary goal in the inshore region is to provide an effective method for the assured and rapid detection of both minefields and mine-free areas in order to permit initial entry forces to avoid minefields, or to breach the minefields if necessary. The threat of mines in the inshore region has received considerably less attention by the Navy than has the mine threat offshore. This leaves a potentially significant near- and mid-term deficiency that sharply limits the nation's ability to quickly clear mined approaches to shores that may be important for landing either maneuver forces or logistics support, or both.

A two-Marine expeditionary brigade (MEB)-size landing to protect a major U.S. interest, carried out in accordance with the Marine Corps "Operational Maneuver From the Sea" (OMFTS)[11] and "Ship to Objective Maneuver" (STOM)[12] concepts, could be needed into the indefinite future. (This was roughly the size of the amphibious operation planned in the Persian Gulf during Operation Desert Storm.) Planned amphibious shipping will not permit a larger landing, even in the event that one might be desired. Opposition to a U.S. landing can come in many forms, from opposing forces massed behind a heavily mined and obstructed potential landing beach (which would be bypassed under the new maneuver concepts) to waters and landing zones that are lightly mined and that may or may not be overwatched by protective forces ashore.

Essentially all of the nation's inshore/surf zone countermine warfare capability currently resides in a single Navy VSW detachment, with its divers, mammals, and expectations for UUVs. The force structure and posturing of this unit are not consistent with current operational plans for amphibious warfare in major theater wars. As a result, any actual operations against a mined and defended shore will be dangerous, slow, and subject to enemy detection and attack.

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[10]This report uses English units of measure as a matter of convenience, since these are the units used by the Navy in its mine warfare work.

[11]Headquarters, U.S. Marine Corps. 1996. "Operational Maneuver From the Sea," U.S. Government Printing Office, Washington, D.C., January 4. Available online at <http://www.192.156.75.102/omfts.htm>.

[12]Van Riper, LtGen Paul K., USMC. 1997. "Ship to Objective Maneuver," Marine Corps Combat Development Command, Quantico, Va., July 25. Available online at <http://www.192.156.75.102/stom.htm>.

The Navy and Marine Corps have not worked out future joint concepts of operation (including STOM, OMFTS, and Navy organic MCM) for opposed amphibious landings at any force level, nor developed methods to support subsequent over-the-shore logistic operations in the face of enemy sea mines. And the Navy and Marine Corps have not harmonized the lane clearance width requirements or the navigational accuracy requirements of their respective landing craft in a way that establishes the number and minimum width of landing lanes that would have to be cleared of mines.

The committee recognizes the complex considerations that have recently stopped the Shallow Water Assault Breaching/Distributed Explosive Technology (SABRE/DET) program after 12 years of development aimed at providing a capability for the Navy to rapidly breach from seaward a mined and obstructed beach. The committee reviewed another technical approach, known a decade ago as Harvest Hammer, that may offer a reasonably near-term prospect for the rapid "brute-force" clearance of smooth landing channels through the SZ and CLZ: a line charge analogue that uses large, precisely placed and simultaneously exploded air-delivered explosive charges. This approach, recommended in several studies over the past 10 years, has been opposed by the Navy for various technical reasons, all of which appear subject to resolution in an affordable R&D program. The approach could have the advantage of involving the U.S. Air Force in the delivery of such ordnance in some types of joint operations, thereby saving naval aviation sorties for tactical air support at critical times. Other potential brute-force approaches being pursued by the Office of Naval Research (ONR) appear to be considerably further from fruition than is the Harvest Hammer approach.

In addition, the U.S. Marine Corps has proposed that the Navy take over the Marine Corps responsibility of clearing land mines above the high-water mark (through the CLZ) at some time in the future. In view of the general need for Marine Corps counter-land-mine capability in inland areas, the committee believes that it is appropriate for the Marines to retain responsibility for dealing with such mines on the beach above the high-water mark.

Potentially viable but unbudgeted approaches (described in Chapter 5) have also been previously identified for the mission of clearing the beach above the surf line where landing craft and troops have to operate more efficiently than by using heavy tanks with plows and rollers.

The shallow water environment threatened by mines encompasses more than just amphibious operating areas. In addition to the vulnerability of U.S. military ships and MCM aircraft operating in potentially hostile overseas locations, U.S. ports and waterways are susceptible to mining by terrorists or other hostile forces. A U.S. Navy response to such an attack on the homeland could take up to several weeks, depending on the initial conditions and MCM force dispositions.

The U.S. Transportation Command (TRANSCOM) does not appear to plan realistically for the possibility that its logistics support ships may have to transit mined waters when either leaving or entering ports. More generally, force concentration areas crucial to a rapid response to contingencies are quite vulnerable to mining, and the committee sees little evidence of serious planning for such eventualities.

Recommendation 6. The U.S. Navy and U.S. Marine Corps countermine warfare capabilities for the inshore region should be improved and harmonized, and responsibilities among the Services should be clarified. In general, efforts are needed to (a) improve the utilization of inshore intelligence, surveillance, and reconnaissance (ISR) information in order to better assemble a common operational picture so that maneuver units can avoid mined and obstructed areas, thereby limiting the need to conduct breaching operations; (b) improve U.S. capabilities for rapid breaching operations (when they are needed); (c) expand the focus of inshore countermine warfare to more fully reflect the need to provide assured, timely access for logistics support; and (d) agree that responsibility for countering land mines above the high-water mark should be retained by the U.S. Marine Corps. Specifically,

- The Marine Corps Combat Development Command for the Marine Corps and the Navy Warfare Development Command for the Navy, under CNO and CMC direction, should jointly define and approve preferred concepts of operation (CONOPS) for opposed amphibious operations, the size and operational character of which should form the basis for future landing force size and equipage requirements (including MCM requirements). The CONOPS should be consistent with the available amphibious lift and fire support resources, approved threat scenarios, and the requirements for logistics flows to and across the shore.
- The CNO and the CMC should agree on, and the CNO should ensure that the Navy funds, the programs needed to fulfill the Navy's responsibility to clear minefields from the VSW zone through the SZ that the Marines may have to traverse to make amphibious landings of up to two Marine expeditionary brigades in size against levels of opposition and on the time lines that have been jointly determined and agreed to be reasonable. These programs should include:

—Expansion of the MCM capability supported by the dedicated MCM support ship(s) to include inshore waters;

—Harmonization and funding of the automated navigation systems for Navy and Marine Corps landing craft as needed to minimize the width of the lanes that have to be cleared of mines;

—A joint research, development, testing, and evaluation (RDT&E) program with the U.S. Air Force to develop and refine the Harvest Hammer approach to clearing channels through the SZ, perhaps as a variant of the JDAM weapon system, including expansion of the existing memorandum of understanding with the Air Force to reflect how the technique will be designed and proved, and how the service will be provided when needed; and

—An aggressive program to reevaluate SABRE/DET and other line charge systems concepts.

In addition, the Marine Corps should retain responsibility for clearing the beach above the high-water mark of land mines and obstacles and should aggressively pursue a program to evaluate innovative techniques (such as water cannon) for use in fulfilling this responsibility.

- The CNO should work with the Commander in Chief, Transportation Command to more clearly define the likely requirements for joint countermine warfare activities in support of the planned early arrival in the combat theater of maritime prepositioning ships and others that plan to put unit equipment and logistics supplies ashore, either through ports or over the beach—both of which are subject to inshore mining.

Reduce the Vulnerability to Sea Mine Threats

The vulnerability of all classes of Navy ships to mine warfare is a neglected area of naval force planning. There are many areas where Navy ships, MCM forces, and even U.S. harbors are more vulnerable to mine warfare than they need to be.

The acoustic, magnetic, and electric signatures of many naval ships are designed to minimize susceptibility to influence mine fuzing, but periodic signature monitoring and maintenance are frequently neglected. Some portable signature-monitoring equipment acquired at congressional direction and earmarked for use by MCM ships reportedly remains in storage. Appropriate information on speed and depth vulnerability specific to particular ships, which is needed to operate safely in mined waters, is not kept up to date on the ships, nor is there software available for rapidly establishing the optimal operating parameters for specific waters. In addition, likely countermeasures against U.S. MCM systems are not accounted for in MCM system design. Most MCM ships and helicopters do not have even rudimentary and inexpensive protective measures that could be made available using off-the-shelf technology.

More generally, there is a pervasive lack of attention to mine threats throughout the Navy. This exacerbates the risk inherent in the lack of specific vulnerability-reducing features summarized above.

Sophisticated, hard-to-detect and hard-to-sweep mines can be and are purchased by potential opponents from U.S. friends and allies as well as from nations that might be adversaries. The United States does not aggressively seek to acquire and exploit these modern mines to improve its own defenses, nor does it pursue arms control measures that might limit the proliferation of such weapons.

Recommendation 7. As part of its force protection planning, the Department of the Navy should take further measures to reduce its (and the nation's) vulnerability to sea mine threats. Specifically,

- The CNO should ensure increased attention to the regular measurement and maintenance of the designed acoustic, magnetic, and underwater electric potential signatures of all ships. Continually updated data, charts, and decision aids showing optimum operating conditions to protect against influence mines should also be available on all naval ships.
- The CNO should ensure that MCM ships and helicopters that may have to operate in areas where they are threatened by attack from sea- or shore-based forces are provided with appropriate self-protection.
- The CNO should ensure that the fleet commanders-in-chief and theater naval component commanders extend countermine warfare contingency planning to include transit and operating areas, homeland defense, and critical base defense.
- The Secretary of the Navy should take the lead in urging the Defense and State Departments to initiate international discussions among U.S. allies and other nonhostile nations to institute a mine technology control regime, analogous to the Missile Technology Control Regime instituted in 1987, to help slow the spread of increasingly sophisticated and threatening sea mines.

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The Mine Warfare Problem

Naval mines can be used strategically, channeling or denying passage through restricted waters and in and out of ports needed for sustenance by littoral nations. They can shape the naval battlespace, the approaches to it, and routes of commerce, setting the conditions of a campaign. Used tactically, they can slow or stop movement to and through narrow straits and to landing zones on beaches, and in so doing can also make a slowed or stopped force more vulnerable. Yet despite the many instances in which mines were important in past conflicts, the U.S. Navy historically has underrated mine warfare as an element of naval warfare.

During the Civil War the Confederate forces at the Battle of Mobile Bay, unable to meet the Union fleet on equal terms, used mines as a defensive barrier. In that battle Rear Admiral David Farragut, the Union commander, using techniques involving surveillance and reconnaissance followed by mine hunting and avoidance of the located minefield—techniques that are similar in concept to those in use today[1]—penetrated the barrier losing only a single ship. This action perhaps helped establish an attitude that has persisted to this day: that mine warfare is principally for the use of weaker naval forces to defend against, and to be overcome by, stronger ones. It was nevertheless at great expense, 80 years later, that German and Japanese minefields had to be overcome both to allow merchant shipping to move in and out of allied ports and to clear the way for offensive landings in both the Atlantic and Pacific theaters of war.

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[1]Uhlig, Jr., Frank. 1996. "Lessons Learned and Operational Experience in Mine Warfare at Sea," *Proceedings of the Technology and the Mine Problem Symposium, Volume II,* Naval Post Graduate School, Monterey, Calif., Mine Warfare Association, pp. 11-3 to 11-9.

Less noticed, mining by the allies had some notable successes in World War II. In the Atlantic war, the Royal Air Force (RAF) flew 20,000 mine-laying sorties over a period of 5 years, sinking 638 ships with the loss of 450 aircraft. This compares with 366 ships sunk directly by RAF torpedoes and bombs over the same period with the loss of 857 aircraft. Only 196 Axis ships were sunk by British submarines and surface ships.[2] Similarly, in the Pacific theater mines dropped by U.S. B-29s in the spring of 1945, together with American submarine warfare, effectively isolated Japan from all overseas sources of food and resources for the rest of the war.[3]

In the more recent past, the United States has not been averse to using sea mines.[4] During the Vietnam War, in May 1972, thousands of magnetic-acoustic mines were dropped in Haiphong harbor and in other harbors along the North Vietnamese coast, virtually stopping the delivery of war materials by sea.[5] Within 3 days, 27 foreign merchant vessels were trapped in port. When peace talks broke down the area was reseeded in November 1972. For 2 more years, without loss of U.S. life, this mining campaign continued to stop shipping into and out of Haiphong and other North Vietnamese harbors, thus interdicting 95 percent of the seaborne logistics resupply to North Vietnam.

A limited attempt to employ mines during the Persian Gulf War proved less successful. On January 18, 1991, four A-6 aircraft dropped 42 mines, but the Iraqis shot down one A-6. Based on the continued Iraqi naval activity following the U.S. mining, it appears that the minefield, which was not reseeded, had no discernible effect on Iraqi operations. This experience highlights the importance of developing survivable means of delivery (and reseeding) in hostile areas such as by standoff aircraft or submarines.

Despite the successes of naval mining both by and against the United States, the U.S. Navy has generally held its use in relatively low regard. Although there was some continuing attention to the Soviet mine warfare threat during the Cold War, the U.S. Navy planned to rely primarily on NATO allies for countermine warfare in the event of maritime hostilities. To help counter the Soviet submarine threat, the Navy did field sophisticated CAPTOR homing mines in the 1970s.

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[2]Uhlig, Jr., Frank. 1996. "Lessons Learned and Operational Experience in Mine Warfare At Sea," *Proceedings of the Technology and the Mine Problem Symposium, Volume II,* Naval Post Graduate School, Monterey, Calif., Mine Warfare Association, pp. 11-3 to 11-9.

[3]Spector, Ronald H. 1985. *Eagle Against the Sun: The American War with Japan,* Vintage Books, New York, November.

[4]McCaffree, Jr., B.C., and John D. Pearson. 1997. *Interviews with: ADM Thomas H. Moorer, U.S. Navy (Retired) and ADM Archie Clemins, CINCPACFLT,* IDA Document D-2054, Institute for Defense Analyses, Alexandria, Va., April; Edlow, Sabrina R. 1997. *U.S. Employment of Naval Mines: A Chronology,* CNA Information Memorandum 506, Center for Naval Analyses, Alexandria, Va., April.

[5]Marolda, Edward J. 1993. *Operation End Sweep: A History of Minesweeping Operations in North Vietnam,* Naval Historical Center, Department of the Navy, Washington, D.C.

MINE WARFARE FOR OPERATIONAL EFFECTIVENESS

Countermine Warfare

More recently, the U.S. Navy's interest in mine warfare took a strong turn upward when the Chief of Naval Operations directed, in a 1995 white paper, that mine countermeasures (MCM)—a critical element of countermine warfare—should receive much more attention and should become organic to battle forces at sea rather than remain exclusively the domain of a separate supporting force.[6]

This increased Navy interest grew out of the Gulf War experience and the growing realization that sea mines are readily available to potential U.S. opponents and are relatively inexpensive. Russia, Italy, Sweden, and others are major suppliers of modern mines to the more than 50 countries that today possess a sea mining capability. Potential U.S. Navy and Marine Corps contingency regions have significant mineable waters, including the Persian Gulf, the Strait of Hormuz, the Taiwan Strait, the Red Sea, the Adriatic Sea, the Yellow Sea, the Korea Strait, and the coastal margins of the Sea of Japan. (See Figures 2.1 through 2.4 in Chapter 2 for illustrative locations of potential minefields in water depths consistent with known mine characteristics.)

During the "Tanker War" in 1987-1988, the USS *Roberts* was heavily damaged by a drifting mine, leading to the embarrassing image of U.S. warships following, rather than leading, the tankers they were nominally protecting. During Desert Storm, Iraqi mines impeded U.S. amphibious assault planning and heavily damaged two U.S. warships—the cruiser *Princeton* and the amphibious carrier *Tripoli*—effectively removing them from further support of the operations.

Mines are particularly valuable to hostile "asymmetric" forces that cannot engage U.S. naval forces directly. Naval mines are more widespread and in many ways more difficult—and certainly more time-consuming—to counter than the likely air and missile threats. Since World War II 14 U.S. Navy ships have been sunk or damaged by mines, whereas only 2 have been damaged by missile or air attack (see Figure 1.1).[7] In all the time since World War II, no U.S. ship has been damaged by submarine action. Of the 14 mine hits on ships, 10 occurred during the Korean War, and North Korea remains a potential antagonist today.

Countermine warfare is much more than mine countermeasures. In the mine

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[6]Boorda, Jeremy M., ADM, USN. 1995. "Mine Countermeasures—an Integral Part of Our Strategy and Our Forces," White Paper, Office of the Chief of Naval Operations, Washington, D.C., December.

[7]The two damaged ships were the USS *Higbee*, DD806, by air attack during the Vietnam War; and the USS *Stark*, FFG-31, by a missile attack during the "Tanker War" in the Persian Gulf. This does not include the *Liberty*, which was heavily damaged in a concerted Israeli air and torpedo attack during the 1967 Arab-Israeli war.

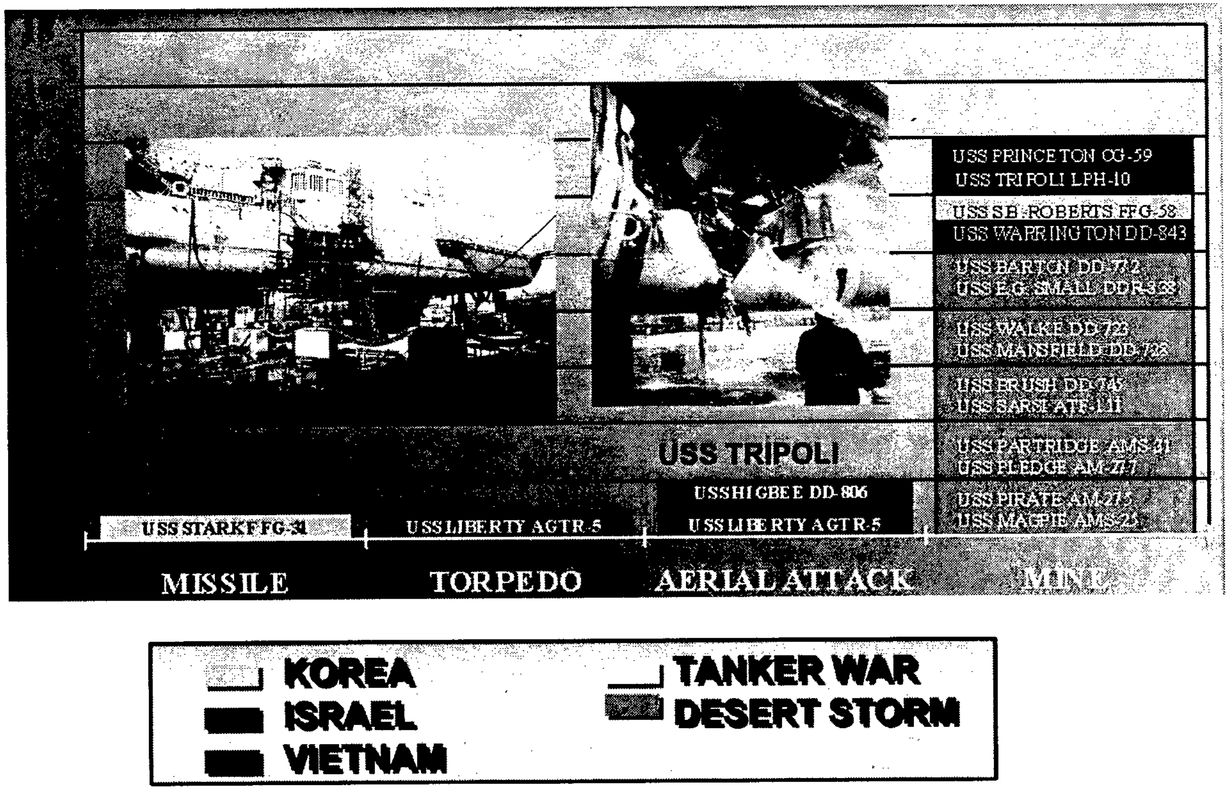

FIGURE 1.1 U.S. ship casualties, 1950 to present. SOURCE: Avery, J. 1998. "The Naval Mine Threat to U.S. Surface Forces," *Surface Warfare,* May/June, pp. 4-9.

warfare framework used by the Commander, Fifth Fleet, countermine warfare involves five phases:

1. Intelligence collection and surveillance,
2. Notification of imminent mining,
3. Interdiction, both on land and at sea,
4. Post-interdiction intelligence evaluation and dissemination, and
5. Mine countermeasures.[8]

The first four phases emphasize measures intended to prevent mines from entering the water. Current carrier battle groups and amphibious ready groups deploy with capabilities to plan and execute the first four phases of countermine warfare. The fifth phase—mine countermeasures—addresses localizing the threat posed by mines already laid or thought to have been laid. Because they have very limited MCM capability, today's carrier battlegroups and amphibious ready groups depend on the specialized support provided by the dedicated MCM forces.

Mining

While the threat of sea mines to U.S. interests is now receiving increased U.S. Navy attention as a significant part of potential antagonists' "asymmetric warfare" arsenal, mines are also an important element of naval power available to the United States. This is particularly true at a time when the U.S. Navy is shrinking but is still being assigned to littoral missions spread progressively more widely around the world. Antiship mines, safely delivered by U.S. submarines or standoff aircraft, could effectively shut down commercial and military shipping as a potentially effective coercive measure in a crisis short of direct combat. They could also be used protectively to prevent interference with U.S. naval force missions, and as an extension of the fleet for such tasks as bottling up an invasion force. Strategically employed, remotely controlled, smart minefields incorporating a distributed sensor system could be a cost-effective counter to the feared proliferation of quiet nonnuclear submarines.

International conventions signed by the United States forbid the laying of armed sea mines in international waters in peacetime unless they are continuously monitored and international shipping is warned of their location. Today, advanced sensor and networking technology, together with advanced ocean surveillance of shipping, could enable remote control of naval mines. This capability could set the stage for their legal use to forestall wider conflict or to set conditions favorable for U.S. naval force operations.

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[8]Edlow, Sabrina R., Joe Janeczek, and A. Matheny. 1998. *Operation Desert Thunder Quicklook: Countermining* (U), CRM 98 60, Center for Naval Analyses, Alexandria, Va., March (classified).

Operational Considerations for Mine Warfare

In reviewing future concepts and possible scenarios, the committee was impressed by the number and diversity of operational drivers basic to the conduct of effective mine warfare activities. The most pertinent operational considerations are the following:

- *Uncertain scenarios.* In planning for future contingencies, the U.S. Navy and the military in general must be prepared to adapt to a variety of scenarios, and to locales that are expected to be increasingly close to shore, in mineable waters, as the Navy continues to implement its "Forward...From the Sea" vision.[9] These contingencies could cross the full spectrum of military operations, from military operations other than war, to small-scale contingencies, to major theater wars.
- *Uncertain allied and coalition support.* A reduced U.S. military overseas infrastructure and varying access to foreign basing place a premium on robust afloat basing plus logistics and maintenance support in-theater that is capable, timely, and available at the right locations.
- *Multimission conflicts.* Declining warship and aircraft squadron force levels combined with increased multimission demands in joint and coalition operations mean that multimission conflicts will occur, and various concepts of operation (CONOPS), including those associated with mine warfare, must realistically reflect expected asset availability.
- *Reduced time lines.* The time allotted to countering the mine threat has decreased. Fast-paced expeditionary and maneuver warfare reduces associated time lines allocated for achieving maritime battlespace superiority (including countering undersea threats such as mines).
- *Limited forces early in contingencies.* Some short-warning situations are inevitable, with the likely result that only a few forces will be in-theater early (prior to the arrival of continental United States-based forces). These limited forces will have to deal with the potential threat from mines, as well as other threats.
- *Dispersed force operations.* In the future, surface warships and submarines may be dispersed throughout the theater doing key task unit operations (strike, fire support, theater air defense, and theater ballistic missile defense) as opposed to operating primarily in close proximity to a battle group. Warships so employed will have to provide much of their own self-protection against various threats, including mines.
- *Network-centric operations.* Future platforms and sensors involved in countermine operations would be nodes in an overall communications network.

[9] Department of the Navy. 1994. "Forward...From the Sea, Continuing the Preparation of the Naval Services for the 21st Century," U.S. Government Printing Office, Washington, D.C., September 19.

A shared picture of operations and fused sensor data, including naval minefield information, would support interactive collaborative mission planning and enhance battlespace situation awareness.

• *Low tolerance for losses.* The objective of an adversary's area-denial strategy may be to produce unacceptable losses (not commensurate with stated U.S. military objectives) and thereby undermine U.S. military involvement and influence. It has been said that the loss of even a single U.S. warship (particularly if it involves a ship sinking and high loss of life) may for some lesser contingencies "inflict enough damage to make the political cost of involvement unacceptably high."[10] Recent military losses in Lebanon (the 1983 Marine barracks destruction) and Somalia (the 1993 firefight in Mogadishu) are examples of such losses that were considered inconsistent with military objectives, resulting in eventual U.S. military disengagement and withdrawal.

FUTURE CAPABILITY—NEXT STEPS

History, the current and future threat projection, and other operational as well as considerations make clear that countermine warfare should concern the planners of future U.S. naval and joint forces at least to the same extent as air or submarine threats. Additionally, because of the great potential benefits to U.S. maritime operations that could result from U.S. employment of modern sea mines, such capabilities are worth preserving. Of particular importance are the intelligence, surveillance, and reconnaissance (ISR) aspects of mine warfare, since that is where mine warfare really starts, regardless of the specific purposes for which such information is ultimately used. It is the considered opinion of this committee that, in order to ensure the capabilities of the U.S. Navy into this new millennium, the priority and attention afforded to mine warfare must be increased dramatically and religiously sustained.

Most of the subsequent discussion in this report deals with problems the Navy must solve and programs the Navy must bring to fruition to ensure having an adequate mine warfare capability later in this decade. This focus on Navy programs is not meant to imply that the Marine Corps, the other military Services, the intelligence agencies, and the unified commands have negligible roles in mine war—they do not. As with most complex military operations, mine warfare operations are inherently joint. The unified commands actually operate the mine warfare forces in-theater; the intelligence agencies provide vital ISR information; Marine Corps units must work closely with the Navy in any amphibious operations and interface with Army mine warfare (and other) operations ashore; Navy and Coast Guard units must work together closely in inshore mine warfare opera-

[10]Johnson, ADM Jay L., USN, Chief of Naval Operations. 2000. *Naval Strategic Planning Guidance with Long Range Planning Objectives,* Washington, D.C., April.

tions both overseas and, should the occasion arise, in U.S. waters; and the Air Force is trained and its bombers are configured to quickly deliver large quantities of naval mines.

In the chapters that follow, mining and countermine warfare are discussed separately. Chapter 3 addresses U.S. capabilities for and the potential advantages of sea mining. The discussions of countermine warfare in Chapters 4 and 5 encompass the two main thrusts of current Navy programs—programs to make mine countermeasures capability organic to the Navy's battle groups, and the continuing need for a dedicated, specialized MCM force. These discussions in Chapters 3, 4, and 5 are preceded by a discussion in Chapter 2 of some cross-cutting, fundamental issues in force integration, such as ISR, that involve both mining and offshore and inshore countermine warfare.

Because the Navy's mine warfare programs are so potentially important, because developments in this warfare area have lagged behind those in other warfare areas, and because of the complexity inherent in establishing a new major area of naval warfare, the committee found it appropriate to offer a larger number of more detailed recommendations than is customary for reports of this kind. These recommendations provide the committee's best judgment on how current mine warfare programs can be strengthened to meet future naval force needs, how additional efforts should be developed to address future capability shortfalls, and how the naval forces can better leverage joint or national assets to meet their objectives. The most important of these recommendations are highlighted in the Executive Summary under seven overarching summary recommendations; the remainder are included in the relevant sections of Chapters 2 through 5.

2

Fundamental Crosscutting Issues

This chapter collects the results of the committee's assessment of five major elements of the nation's mine warfare programs and posture that transcend the specific focus of Chapters 3 through 5 on mining, offshore countermine warfare, and inshore countermine warfare, respectively:

- Mine warfare as a major naval warfare area,
- Intelligence, surveillance, and reconnaissance,
- The dedicated mine countermeasures forces,
- Vulnerability reduction, and
- Joint interests and integrated concepts of operations.

MINE WARFARE AS A MAJOR NAVAL WARFARE AREA

The increasingly recognized importance of mines as a growing threat to the U.S. fleet and its freedom of maneuver, as well as to freedom of the seas generally, has fueled the movement to place mine warfare in the mainstream of naval force planning and operations. The importance of the mine threat is reinforced by the strategic orientation of the naval forces—and U.S. joint forces generally—to expeditionary warfare along the littorals, where battle groups, amphibious forces, and the seaborne logistic support for all U.S. forces overseas will have to operate and where sea mines are most likely to be employed by hostile forces to try to impede U.S. access (see Figures 2.1 through 2.4).

The United States has used sea mines as an instrument of diplomacy, to shape the naval battlespace, and to extend naval power into areas the fleet could not immediately guard on several occasions in recent decades. In the opinion of

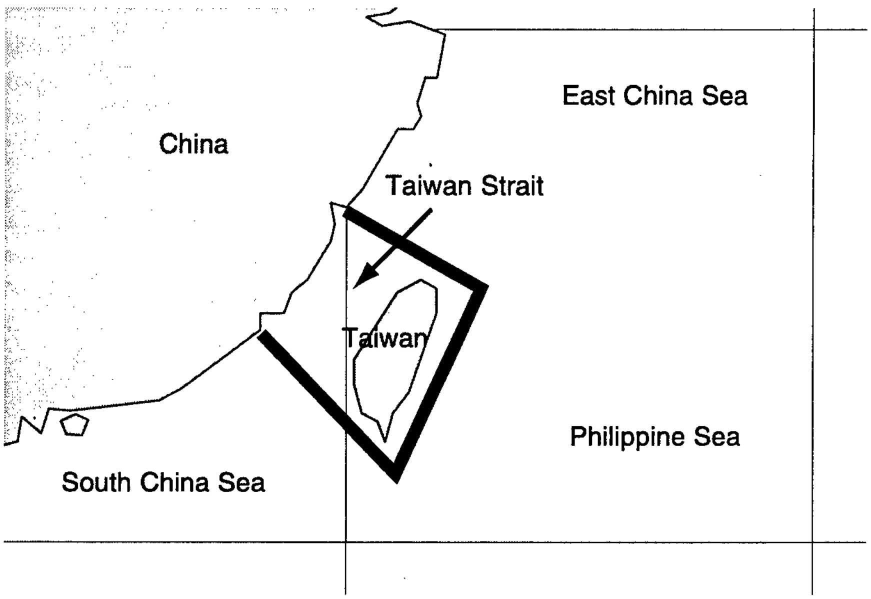

FIGURE 2.1 Taiwan Strait.

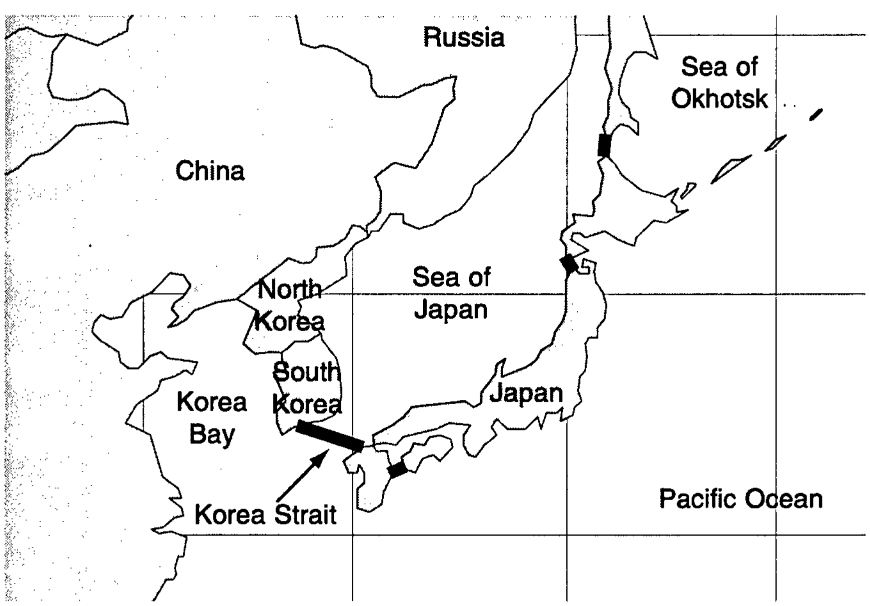

FIGURE 2.2 Sea of Japan and Korea Strait.

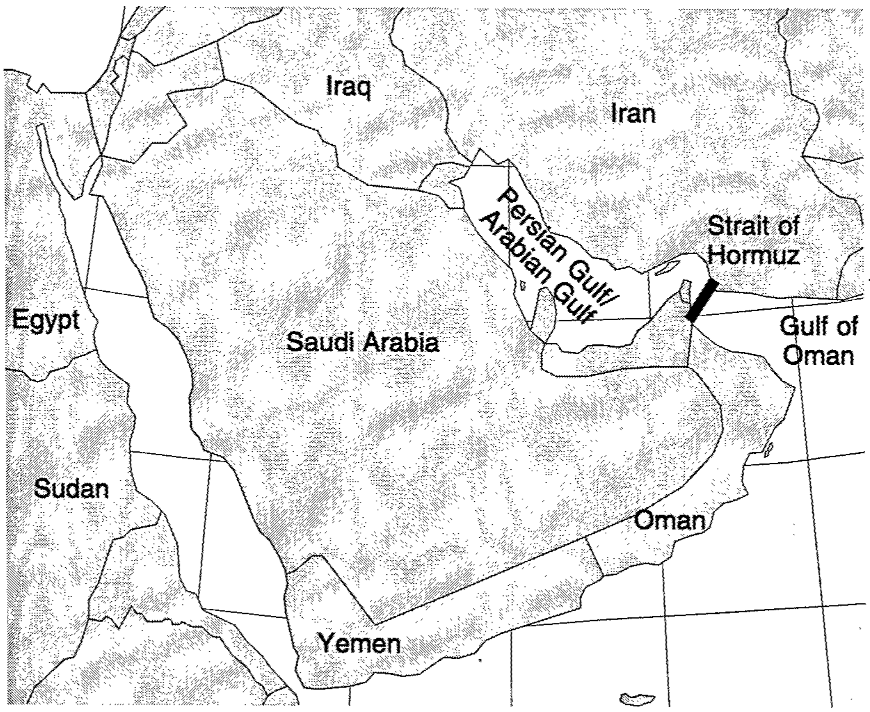

FIGURE 2.3 Persian Gulf.

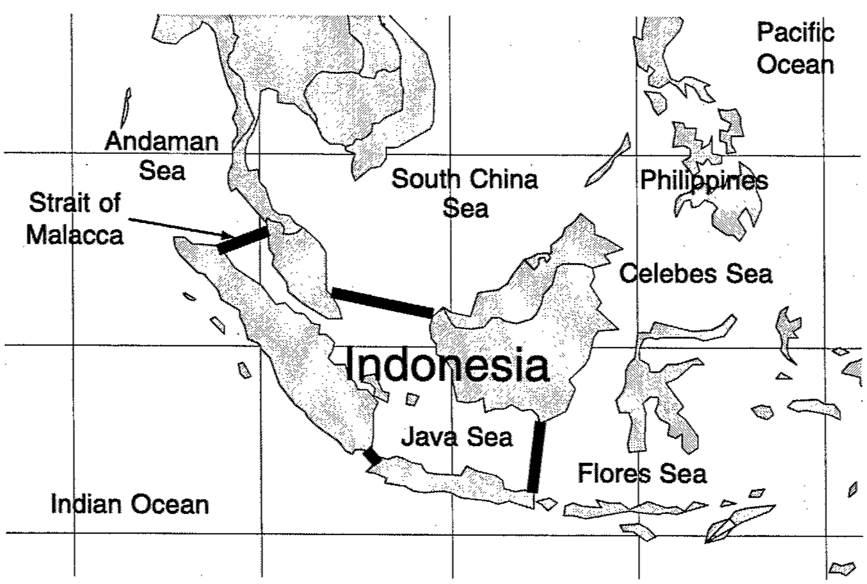

FIGURE 2.4 Indonesia.

the committee, such U.S. use of sea mines should become more prevalent in the future as the potential for technologically advanced minefield surveillance and remote-control techniques could enable effective U.S. use of sea mines while adhering to international conventions in situations short of war.

All of these developments mean that mine warfare has risen to a level of significance that necessitates its designation as a major warfare area, similar in importance to air warfare, surface warfare, and submarine warfare. This requires that current approaches to planning, preparing, and organizing the naval forces be modified in several ways. Naval forces' exercises and the facilities for exercises and for developing new concepts of operation under mine warfare conditions must be enhanced. Personnel education, training, and career development require similar attention. Until naval personnel are fully qualified and knowledgeable in the mine warfare area, and are able to advance their careers from such an orientation, there will be little hope of raising mine warfare into the mainstream. And appropriate adjustments must be made in the budget for mine warfare to more fully meet the needs described in this report. It is important to note that the actions that need to be taken to elevate the importance of mine warfare would not lead to a significant growth of naval force structure, but rather to increased mine warfare capabilities within the force structure that is currently planned or one that emerges from current defense reviews.

Recommendation: The Secretary of the Navy, the Chief of Naval Operations, and the Commandant of the Marine Corps should take the steps needed to establish mine warfare as a major naval warfare area. Such an elevation in warfare status will require that the Department of the Navy (a) coordinate and improve the focus of its "mainstreaming" initiatives; (b) upgrade mine warfare-related readiness reporting, certification, training and education, and officer career planning; and (c) program, budget, and execute accordingly. Continual follow-up by these officials will be necessary to ensure implementation.

The major activities that need to be addressed if this recommendation is to be fully implemented are discussed below. While each of these major activities is addressed separately, the committee believes that they are sufficiently interrelated that substantial progress will be needed in each area if the collective goal is to be achieved.

The Navy Fleet Engagement Strategy

In the fall of 1998 the Vice Chief of Naval Operations (VCNO) and the Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN (RDA)) tasked responsible commands to develop plans of action and milestones (POA&M) to support the four Fleet Engagement Strategy pillars—doctrine and tactics, education and training, industry and technology, and public affairs—with these plans due in March 1999. The committee learned from briefings and reports commissioned by the Navy that as of December 1999, only about half of the plans had been developed and submitted to the Director, Expeditionary Warfare (N75), as designated in the task letters.[1] To date, some additional progress has been made in each of these areas. Navy staff briefed this committee on shortfalls in the Fleet Engagement Strategy and a draft implementation plan intended to both address the shortfalls and define the schedule and the hierarchy of responsibility and accountability for "mainstreaming" mine warfare.[2]

Mainstreaming mine warfare and adding organic MCM capabilities to the fleet is a significant and complex undertaking, critical to the ability of deployed carrier battle groups (CVBGs) and amphibious ready groups (ARGs) to attain and maintain sea battlespace dominance. Primary Navy emphasis is on phase five of countermine warfare (see Chapter 1), MCM, or countering mines after they have been put into the water. However, the roles intended for the dedicated and future organic MCM systems in the expected types of operations remain to be fully defined as experience is gained with organic MCM capabilities.

The proposed hierarchy relies on the existing Navy chain of command and places ultimate responsibility and accountability with the senior Navy leadership, specifically the VCNO. The ASN (RDA) would provide the linkage to the Secretariat and associated program executive offices. The Director, Expeditionary Warfare (N75) would serve as the executive agent for the VCNO, addressing day-to-day issues and monitoring all facets related to mainstreaming mine warfare and facilitating the transition to organic MCM capabilities.

Three key architects would serve the VCNO, including the following:

- A capabilities architect (Commander in Chief, Atlantic Fleet (CINCLANTFLT) components to include the Commander, Second Fleet, supported by the other fleet CINCs and the fleet marine forces),
- A requirements architect (N75, supported by the other OPNAV codes and Headquarters, Marine Corps), and
- An acquisition architect (Deputy Assistant Secretary for Mine and Undersea Warfare, supported by other associated deputy assistant secretaries and program offices).

Although the year 2000 target dates have now all passed unmet, the Navy remains committed to mainstreaming mine warfare and to transitioning organic MCM capabilities to an initial CVBG by 2005.

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[1]Edlow, Sabrina R., and Julia D. Thibault. 2000. *Mainstreaming Mine Warfare and the Transition to Organic MCM Capabilities—Implementation Plan,* CNA Information Memorandum D0000749.A1, Center for Naval Analyses, Alexandria, Va., April.

[2]Lehr, CAPT Steven, USN, "Navy Mine Warfare, the N85 Perspective," briefing to the committee on August 1, 2000, Office of the Chief of Naval Operations (N852), Washington, D.C.

While some progress has been made toward tasks required to implement the Fleet Engagement Strategy, a comprehensive implementation plan has not yet been endorsed by the senior Navy leadership. To be successful, mainstreaming initiatives need to address issues ranging from command structure implications to training and education at both the schoolhouse and waterfront levels. Sustained high-level support is critical for the major cultural changes required for successful, fleet-wide mainstreaming of mine warfare.

Recommendation: The Chief of Naval Operations (CNO) and the senior Navy leadership should expeditiously establish an implementation plan that assigns responsibility and accountability to the appropriate officials to bring to fruition the mainstreaming of mine warfare, in particular the introduction of organic mine countermeasures capabilities. Such a plan should include the seven key elements—doctrine, organization, training, materiel, leadership and education, people, and facilities—detailed below.

Incorporating organic MCM capabilities into the fleet and mainstreaming mine warfare are integrally related. They succeed or fail together. Seven key elements are essential to this success or failure:

- *Doctrine.* Development of countermine warfare (CMW) CONOPS, tactics, and doctrine specifically defining the roles of organic and dedicated MCM relative to joint and naval missions.
- *Organization.* Development of an overall command structure that addresses the role of the mine warfare commander, CVBG and ARG staff billets, and a planned transition from current mine warfare coordinator to mine warfare commander.
- *Training.* Implementation of the needed schoolhouse (operations, intelligence, and Judge Advocate General (JAG)) and fleet training from the system level to the CVBG and ARG interdeployment training cycle (IDTC).
- *Materiel.* Implementation of the maintenance and logistics support plans needed for the transition of organic MCM systems to the fleet.
- *Leadership and education.* Establishment of an education program for developing naval leadership commitment to well-equipped and well-trained mine warfare forces, as well as to the key role of future organic MCM systems.
- *People.* Development of the necessary manning concepts for incorporating future organic MCM systems on multipurpose fleet units (surface combatants, submarines, aircraft), and establishment of attractive career paths for officers in the mine warfare community.
- *Facilities.* Development of various mine warfare-related support facilities to enhance tactical development, training and education, maintenance, logistics, and other facets of mine warfare.

As part of the implementation plan the CNO should assign to one of the fleet

CINCs (perhaps the Commander, Second Fleet, representing CINCLANTFLT) the responsibility and accountability for addressing the waterfront issues for mainstreaming mine warfare and transitioning the battle groups to organic MCM capabilities.

Adequate CVBG and ARG Expertise

Independent of the transition to new organic MCM capabilities, deploying CVBGs and ARGs need to prepare for the likely mine threat by leveraging existing countermine warfare capabilities. For example, the mission areas required for CVBG and ARG certification prior to deployment already formally include the mine warfare mission area. Deploying force command structures currently include a mine warfare coordinator with the CVBG only, rather than a mine warfare commander for the CVBG or the ARG. Effective execution of countermine warfare phases one through four—intelligence collection and surveillance, notification of imminent mining, interdiction, and post-interdiction intelligence evaluation and dissemination—as detailed in Chapter 4, involves not only the mine warfare commander, but also the other warfare commanders (i.e., those responsible for interdiction and for the execution of amphibious operations), the intelligence officer and intelligence support infrastructure, and the JAG staff to facilitate appropriate rules of engagement (ROE).

Currently, specific individual schoolhouse training and prior experience requirements do not include mine warfare, resulting in only limited mine warfare awareness and expertise embedded in CVBGs and ARGs. Each of these combat forces face potentially varied countermine warfare scenarios, particularly when operating apart, with the ARG typically in shallower, closer-to-shore waters than the CVBG units. Although current CVBGs and ARGs deploy with capabilities to plan and execute the first four phases of countermine warfare, the IDTC provides an existing process for expanding these capabilities as part of the mainstreaming initiatives.[3]

The committee notes that the Commander, Second Fleet, has taken meaningful steps toward improving the mine warfare components and assessments in the routine predeployment joint task force exercises and the at-sea certification test for deploying CVBGs and ARGs. Evidence to date indicates that at least sporadic initiatives are under way to improve training. The command structure implications are addressed in the draft concept of operations (CONOPS), which has yet to be implemented, with the exception of Fleet Battle Experiment HOTEL. A more focused effort is required to raise the awareness and expertise of naval personnel fleetwide.

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[3]Edlow, Sabrina R., and Julia D. Thibault. 2000. *Mainstreaming Mine Warfare and the Transition to Organic MCM Capabilities—An Approach for Fleet Accountability Through the IDTC*, CNA Research Memorandum D0002537.A1, Center for Naval Analyses, Alexandria, Va., September.

It would be useful if the CNO assigned a numbered fleet commander the responsibility to continue and broaden initiatives toward mainstreaming and, combining efforts with the opposite fleet, to increase awareness of and expertise about mine warfare in CVBGs and ARGs deploying worldwide.

Fleet CINCs should hold CVBGs and ARGs more strictly accountable for fulfilling the already existing mine warfare mission requirements comparably with other warfare areas. All training establishments should follow suit by better supporting the training requirements as defined by the fleet CINCs.

Predeployment Training, Fleet Exercises, and Readiness Reporting

Realistic scenarios for fleet training exercises are fundamental to instilling proper understanding of the entire mine warfare area. Proper training is as important for senior commanders and staffs as for individual ships or aircraft or personnel. Additionally, the importance of mine warfare to fleet operations means that mine warfare/MCM readiness must be a part of fleet readiness reporting, to the same extent as readiness to engage opposing missile, air, and submarine forces. Defense against mines should become a major element of the Navy's force protection initiative.

Historically, fleet exercises have tended to ignore the effects of mines on an operation: Time lines have been artificially shrunk to overcome the delays caused when mines are encountered, a unit encountering a mine has been "reconstituted" almost immediately, or the encount itself has been ignored completely. These procedures have tended to foster the idea, even if only subliminally, that mine damage is either imaginary or that it can be ignored as a real factor in operating the force.

To ensure development of mine warfare expertise in all participants in a fleet exercise, the likely consequences of an encounter with a mine have to be played out at least to the same degree that encounters with air or submarine attackers are accounted for. This will require a more versatile exercise mine system and procedures such as adjudication of the interaction by on-scene referees, removal of the unit from the exercise, rescue, medical evacuation of the "casualties," and salvage of the damaged ship. The argument that scarce training time will be diverted is perhaps specious, since the training imparted by an artificial response to a mine incident is suspect at best and can be considered to be counterproductive in the long run.

Similarly, readiness to conduct mine warfare must be reported as part of overall unit readiness, especially in view of the growing likelihood of mine encounters in littoral waters and in expeditionary operations. As the new organic MCM systems are introduced into the fleet, MCM readiness associated with those systems should become reportable in the ship's operational readiness training status (SORTS) report by each ship and aircraft squadron. Tactical aircraft squadrons and submarines that have mine delivery capabilities should routinely report their readiness to conduct such missions in SORTS. As the new mission capability assessment system (MCAS) is introduced, battle group commanders should begin reporting the collective readiness of their units to conduct mine warfare operations.

The mine warfare readiness and effectiveness measurement (MIREM) program (modeled after the SHAREM program for antisubmarine warfare (ASW)) has been under way for several years. The primary emphasis to date has been on evaluating the performance of dedicated MCM forces. The performance of existing organic MCM capabilities on current warships (surface combatants, submarines), such as their on-board high-frequency sonars and their signature control capabilities, have largely not been evaluated as part of MIREM exercises to date.

The committee concluded, based on examination of all these needs, that the mine warfare portions of fleet and subunit exercises and readiness reporting are not given the status of other warfare areas. Their relegation instead to secondary and unrealistic auxiliary positions fosters an inappropriate and inaccurate concept of the roles and importance of mine warfare in maritime operations among the officer corps from their most junior years.

Recommendation: The Department of the Navy should establish broad first-order force-protection requirements for naval units that will ensure adequate levels of countermine warfare capability, both active and passive.

Recommendation: Naval component and other operational commanders should enhance realism in predeployment training, fleet maneuvers, and amphibious warfare exercises by routinely including mine threats, in addition to air and submarine threats, in such exercises and by assigning realistic consequences to poorly planned and executed countermine warfare operations.

Recommendation: The CNO should have the MIREM program examined and upgraded, including increased emphasis on warship self-protection measures and emerging organic MCM systems.

Recommendation: The CNO and the Commandant of the Marine Corps (CMC) should ensure that the routine interdeployment training cycle for fleet battle groups and amphibious ready groups entails the same level of rigor in certifying capabilities for mine warfare and in reporting readiness, in both the ship's operational readiness training status (SORTS) report and the mission capability assessment system (MCAS),[4] as is now the practice for the other major warfare areas. Readiness should include the routine measurement of the acoustic and magnetic signatures of applicable ships.

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[4]SORTS is the Joint Chiefs of Staff (JCS)-managed system of reporting the readiness of ships and squadrons to conduct assigned missions. MCAS is a new system that would report the readiness of battle group commanders to conduct their assigned missions.

Mine Warfare Battle Laboratory

The committee concluded that there is an urgent need for a mine warfare battle laboratory (1) as an essential adjunct to the ongoing effort to bring mine warfare into the mainstream of naval force planning and (2) to provide a facility for exploration of fleet mine warfare-related operational concepts and capabilities, to assess fleet mine warfare operational issues and doctrine, and, in war games and other exercises, to provide the means whereby mine warfare can be practiced realistically, accurately, and in real time by the war game or exercise participants.

Such a facility ideally must be a true extension of the fleet and should be sponsored, tasked, and controlled by a senior fleet operational entity. While the Navy's R&D centers and laboratories must naturally be involved with and supportive of the technical side of the battle laboratory, the primary sponsor and customer of the laboratory must be the operational side of the Navy. It is the consensus of the committee that the mine warfare battle laboratory should report to the numbered fleet commander(s) and should be located in, or be accessible to, a fleet concentration center such that it is visible, used, and useful to the fleet operators, directly or indirectly. A location in Ingleside, Texas, while not in geographic proximity to fleet centers, could be feasible, if funding and manpower resources are made available to clearly support robustly linking the laboratory with other fleet and R&D sites. Also, to ensure adequate and appropriate attention to inshore countermine warfare, the Marine Corps would have to be a participant in battle laboratory activities, along with amphibious force commanders.

Recommendation: The CNO and the CMC together should establish a mine warfare battle laboratory under the auspices of the numbered fleet commander(s) and provide the resources necessary to ensure its effective utilization.

Individual Education, Training, and Career Development

For mainstreaming of mine warfare to be fully effective, officers must perceive expertise in mine warfare as career enhancing. To this end a desirable promotion path is needed for officers who have devoted career time to gaining expertise in mine and countermine warfare. At present such paths exists only to the 0-6 level, and only in the MH-53 airborne MCM and explosive ordnance disposal (EOD)/very shallow water (VSW) detachment communities. Such viable career paths also need to be established in the surface warfare and MH-60 helicopter communities. Selection of flag officers should increasingly value mine warfare knowledge and experience, which should become an explicit prerequisite for such key operational commands as Commander, Mine Warfare Command. Currently, such experience tends to be discounted, and there is a well-justified belief among many officers that assignment to a mine warfare post detracts from promotion prospects. If attention to mine warfare is increased by making it a warfare area on a par with other warfare areas, this "second class" status for mine warfare officers is likely to disappear, but the issue needs continuing command attention at the highest levels of the Navy and the Navy Department until the change is securely in effect. The Navy has reportedly recently made a step in this direction by deciding to assign some of its most promising junior officers to command each of the 26 small mine-hunting and minesweeping ships.[5] The extent to which the future assignments of these outstanding officers to additional tours in mine warfare billets would be considered appropriate has not been discussed with the committee.

Another facet of the Navy's mine warfare mainstreaming initiative also needs to be strengthened. There should be clear educational curriculum requirements for mine warfare disciplines, just as there are for naval surface, air, and undersea warfare, as well as much greater emphasis on mine warfare in officers' professional schools. Currently, for example, instruction in mine warfare history, technology, and operations constitutes a very minor part of the curriculum in the Naval Academy and the Naval War College, and it is given but 20 percent of the time that is given to antisubmarine warfare in surface warfare school. Aviation MCM training relies on on-the-job training. The need to incorporate mine warfare into the mainstream of naval force training and education is noted above, and the current state of inadequate attention to the necessary personnel planning and training for integration of the organic MCM systems into the fleet is noted in Chapter 4 in connection with offshore countermine warfare.

Recommendation: The Secretary of the Navy, the CNO, and the CMC should ensure that the growing importance of mine warfare is emphasized in all appropriate Navy and Marine Corps formal education curricula and in officer career development practices. These curricula and career development criteria should place mine warfare expertise on a par with the emphasis given to air warfare, surface warfare, and submarine warfare.

Mine Warfare Budgets

The committee attempted a detailed examination of the budget devoted to mine warfare, in comparison with that devoted to other warfare areas. Assembling the budget for a warfare area is a notoriously difficult task, since it requires allocating the costs of large, multimission systems, such as Navy ships, into components devoted to each of the warfare areas. This, in turn, requires ascer-

[5]Rempt, RADM Rodney P., USN. 2001. "Providing Safe Access Overseas," speech presented at "Regaining Focus on USW Primacy: Missions, Tools and Training," 2001 Joint Undersea Warfare Spring Conference held on March 20-22 at the Space and Naval War Systems Center and sponsored by the National Defense Industrial Association, Arlington, Va.

taining the multiyear costs of several levels of subsystems and component equipment, and making judgments as to their specific applicability, by warfare area. Cost research to this level of detail did not prove possible within the resources available to the committee, even with the excellent support that the Navy furnished for the committee's deliberations.

However, the results of the committee's explorations in this area were sufficient to indicate that (1) the total Navy budget for sea mine warfare is small relative to that for air and missile defense, and (2) the budget for mines and mining, as part of that, is trivially small compared with that for strike warfare weapons (a few million dollars compared with several billion over the future year defense program (FYDP)), and may soon drop to zero. The budget that the Navy identifies with mine warfare, approximately $4.6 billion over the next 7 fiscal years, is devoted almost entirely to countermine warfare. Roughly one-third of the countermine warfare budget is for operations and maintenance (O&M) of the existing fleet of dedicated mine warfare forces, and another third is for ongoing development of the seven organic MCM systems described in Chapter 4 of this report. This leaves a little over $1.5 billion over the 5-year FYDP period to meet all the other needs for mine warfare described in detail in Chapters 3, 4, and 5 of this report.

As indicated in those chapters, there are many unfunded or underfunded needs in the mine warfare area. These deficiencies include, to reiterate but a few major examples:

- No funding to acquire a very shallow water and assault breaching system to support amphibious landings in this decade;
- Lack of funding to remedy important equipment shortfalls on the MCM and MHC classes of MCM ships;
- Inadequate funding for technologies (including advanced signal processing techniques) to find buried mines, and to support the objective of removing people and other mammals from the minefields—e.g., bottom-penetrating sonars, electric field sensors, and synthetic aperture sonars;
- Inadequate funding to maintain and verify the reduction of ship magnetic and acoustic signatures;
- Insufficient funds to populate the databases for the mine warfare environmental decision aids library (MEDAL), information that is essential for mine hunting and clearance in littoral waters and in ports important to U.S. and allied shipping;
- Lack of funding for necessary upgrades to the systems on the mine warfare command ship *Inchon* to replicate and extend such a capability to fully and effectively meet the needs of a two-ocean navy;
- Phasing out of the MH-53 helicopter needed for heavy-duty minesweeping because funds are not available, rather than for technical and operational reasons;

- Lack of funded preplanned product improvement programs for the organic MCM systems now being developed and soon to be entered into service;
- Disappearing funds for mines and mining capability;
- Inadequate funding to adequately exploit foreign mines as needed to design effective countermeasures; and
- Restriction of organic MCM to carrier battle group ships, leaving even new amphibious ships such as the LPD-17 with no active defenses against mines.

Shortfalls such as these must be funded if the Navy is to meet all of its mining and countermine warfare responsibilities in the face of the shrinking Navy and the growing mine warfare threat. The committee's explorations suggest a serious imbalance in the allocation of funding among the various warfare areas. If mine warfare is to become a partner comparable in importance with air, surface ship, and submarine warfare in the naval forces' panoply of systems to enable expeditionary warfare, some redress of this imbalance is needed.

The committee did not have the budget analysis resources to make credible, detailed estimates of how much additional funding would be needed. However, it is estimated very roughly that the most important unfunded needs might be met by approximately doubling the budget remaining after the O&M funding for the dedicated forces and the organic system developments are accounted for over that period—in the neighborhood of an additional $1.5 billion over the next 5 years—about a 30 percent increase in annual spending on mine warfare. A detailed budget plan would show the extent to which part of this increase, or further funding beyond it, would be needed to meet the requirement for continuation or expansion of the mine countermeasures command ship concept (the mine control ship (MCS)-12, *Inchon* and/or its replacement(s)) discussed below in this chapter. Most such MCS funding would be needed later in, and beyond, the FYDP period.

The committee could not identify large amounts of mine warfare money that appeared to be allocated inappropriately or was being spent wastefully, so that shifting funds within the mine warfare complex of systems cannot solve the problem of serious shortfalls. It therefore appears to the committee that the Navy will have to allocate additional funds to mine warfare from other areas in the Navy budget by deferring some expenditures intended to meet threats that are less imminent.

Recommendation: The Secretary of the Navy, the CNO, and the CMC should increase the priority of funding for mine warfare relative to other warfare areas. The Secretary of the Navy and the CNO should review the allocation of funds by warfare area in the future year defense program (FYDP), with a view to finding ways to increase funding in the mine warfare area to meet the urgent mining and countermine warfare program needs identified in this report.

INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE

Intelligence, surveillance, and reconnaissance (ISR) activity is at the heart of mine warfare. Notwithstanding its importance, ISR for maritime mining and countermine warfare is not in good order, either in the fleet or elsewhere in the defense establishment. *Improvement in ISR for mine warfare can have a greater impact on naval forces mine warfare capability than any other step that might be taken.* This does not necessarily mean that good ISR can make the avoidance of minefields always feasible, although that might be a desirable ultimate goal. It does mean that good ISR can make mine warfare far more efficient and timely than it can be if the current weak approach to mine warfare-related ISR continues. This section discusses ISR in support of offensive mining and mine countermeasure interdiction, and for defensive MCM in threat determination, environmental characterization, and integration with the naval C4ISR system, and includes an example of the use of ISR in planning and executing a Marine Corps amphibious landing operation.

With regard to mining, ISR is needed to define target areas for laying maritime minefields by observing opposition activity and maneuver, and for monitoring the condition of the minefields and managing them—e.g., activating and deactivating mines to interdict belligerent but not neutral or friendly traffic. It is needed to determine when it is necessary to replenish minefields and which parts to replenish based on observed opponents' MCM and mine hits on opponents' ships. It is needed to observe and analyze the minefields' effects on opponents' war-making capacity and capability, and to observe and counter opponents' countermine activity.

The technical characteristics and likely operational employment patterns of potentially hostile mines must be determined through intelligence in order for the United States to be able to field countermeasures that can neutralize the mines efficiently and effectively without casualties to U.S. and friendly forces. Exploitation of foreign mines has lagged; only 10 percent of foreign mine models have been analyzed, and tactics can be fully developed only against exploited mines. As mine technologies evolve to microprocessor settings and logic mechanisms, traditional means for exploitation need to evolve to enable microprocessor exploitation.

Beyond exploitation of foreign mines, ISR is needed to observe mine acquisition and stockpiling activity, the removal of mines from storage, and the transport of mines to areas intended to be mined so that military forces can interdict such mine stockpiling, transporting, and mine-laying activity whenever possible after the onset of hostilities. If interdiction is not possible (e.g., for ROE-related reasons), then ISR is needed to locate and define the boundaries of minefields and the distribution of mines within them by observation of mining activity, and to identify areas most likely to be free of mines. This, in turn, enables friendly forces either to avoid hostile minefields or to effectively concentrate countermine warfare assets to facilitate hunting, sweeping, or other means of neutralizing the mines when established minefields must be penetrated. To this end, ISR is needed to monitor and determine the success of friendly mine-hunting and minesweeping activities, to help meet and counter hostile interference with countermine activity, and to help guard against reseeding of minefields.

The ISR task from the beginning of a campaign through preparation for a Marine Corps landing is illustrated in Figure 2.5. It will be noted that although many of the ISR-related systems are within the naval forces, there are also many essential capabilities that come through joint forces, other Services' force components, joint task force (JTF) and CINC headquarters, and national agencies, and such systems are therefore an essential part of the overall ISR system for mine warfare.

Although mine warfare-related activity may be observed by overhead assets as other information is sought, the data will not routinely be extracted and sent to the operating forces unless the collection agencies are explicitly tasked for the purpose. Such tasking has not been done regularly. Pre-landing surveillance to select littoral penetration zones and sites depends on national surveillance assets that combine to form a littoral surveillance system (LSS) (see Appendix A) that is currently being evaluated by the Navy. However, provision of information on mine warfare activity that has been derived from national collection systems has been more in the nature of a demonstration rather than a result of routine tasking. Clandestine reconnaissance assets in the fleet can be cued by the surveillance data received. ONR's ongoing assessment of the concept of MCM in support of STOM (see Appendix A) with the development of small unmanned undersea vehicles (UUVs) and sensors through the MCM future naval capability (FNC), is making excellent progress for clandestine reconnaissance inside the 40-ft lane. Unmanned undersea vehicles that have a variety of capabilities and are affordable will play an important role in future MCM.

A new littoral remote sensing (LRS) capability developed by ONR that fuses data from several sources enables estimates of beach and Marine landing zone conditions and detection of near-surface mines, minelike objects, and obstacles, and it can transmit such information to the fleet. However, the full potential and capabilities of both the LSS and the LRS are not widely known in the operating forces.

MCM ships and fleet combat ships do not routinely have on board the environmental data needed for efficient MCM operations, from simple avoidance to active mine hunting and minesweeping. Knowledge of environmental conditions is essential both for mining and for countermine warfare. The needed parameters include hydrographic conditions so that estimates can be made of sound propagation, tide and wave movements, and the composition, hardness, and roughness of the ocean bottom and beaches where mines are laid. Knowledge of water movement through mined areas and detailed knowledge of objects on the bottom that might look like mines to detection instruments but are not mines (nonmine,

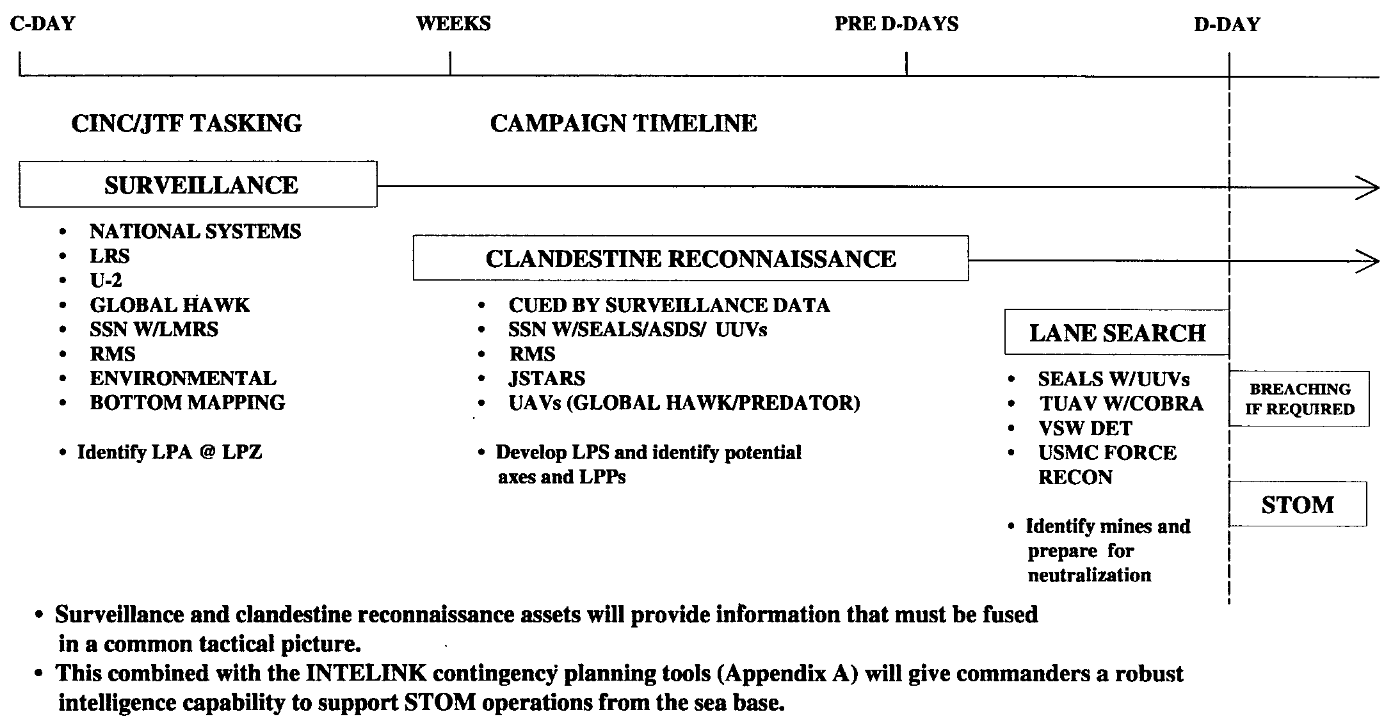

FIGURE 2.5 ISR assets for mine countermeasures in support of Ship to Objective Maneuver (STOM) (2000 to 2010). See Appendix F for definitions of acronyms used.

minelike bottom objects (NOMBOs)) are also needed. Indeed, accurate geolocation of bottom objects and features at the highest affordably achievable resolution is of greatest interest. The ability to anchor or bury mines on the bottom and the speed and effectiveness of mine hunting and mine neutralization activity all depend on such prior knowledge of the environment. Today, such knowledge is scant for areas where U.S. Navy mining or countermine activity may be needed: along the littorals in potential contingency areas and in U.S. homeland, allied, or critical base area ports and waterways that may be mined by terrorists in peacetime or by opposition forces in wartime.

Environmental data collection means not only the overt and clandestine collection in areas of immediate operational interest during a contingency, but also the retention, storage, and cataloguing of data obtained by mine-hunting sonars during exercises and routine operations. Obviously, it is also necessary to repeat data gathering in areas of special interest since bottom conditions and especially the kinds and distribution of NOMBOs can be expected to change over relatively short time scales in some areas. But the time-series observations that are needed to establish appropriate resurvey rates in key areas have yet to be made. Accumulation of environmental data over the years will give some sense of the density and rates of change of bottom features and NOMBOs, and will therefore greatly assist detection of change and enhance the rate of mine hunting.

The Navy has developed a viable system for cataloguing key environmental data and promulgating the database to operating forces. This mine warfare data access system now also provides related mission-planning functions based on the environmental data it has stored for areas of interest in the mine warfare environmental decision aids library (MEDAL). However, the level of effort for populating this mine-environment data system has been kept low by a lack of funding and a lack of collection priority, so that with some limited exceptions the database is essentially empty. The U.S. Marine Corps is developing an INTELINK contingency planning tool that will gather baseline infrastructure data from various databases and "preposition" the intelligence for each Marine expeditionary force (MEF) area of responsibility (see Appendix A). This system along with MEDAL has the potential for providing situational awareness quickly for power projection missions of the future.

If mine warfare is to become a warfare area comparable with air, surface, and undersea warfare, all the information collection discussed above must be considered part of the naval forces' expansion of their fundamental design and operational techniques into the network-centric warfare mode.[6] Mine warfare cannot be treated as a merely collateral responsibility for the naval and joint forces' command, control, communication, computing, intelligence, surveillance, and

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[6]Naval Studies Board, National Research Council. 2000. *Network-Centric Naval Forces: A Transition Strategy for Enhancing Operational Capabilities,* National Academy Press, Washington, D.C.

reconnaissance (C4ISR) system—it must be made into an intrinsic part of that system.

Additional details about current and future mine warfare ISR capabilities and needs are given in subsequent chapters of this report. Although the details presented there are in general pertinent to the main subjects of the chapters, the reader will understand that ISR is a continuum, not easily partitioned among mining and offshore and inshore countermine warfare.

Recommendation: The Department of the Navy should place greater emphasis on the intelligence, surveillance, and reconnaissance needed for mine warfare operations. Increased priority should be given to (a) technical exploitation of threat mines; (b) mine warfare indications and warning (I&W) tasking and dissemination at all command levels; (c) rules of engagement (ROE) to counter hostile miners; and (d) relevant environmental databases, such as the mine warfare environmental decision aids library (MEDAL) and the INTELINK contingency planning tool.

Recommendation: The CNO and the CMC, through their senior planning staffs, the fleet and fleet Marine force commands, and in joint forums, should take steps to ensure that the ISR needed for mining and countermine warfare is planned and integrated into all naval warfare activities as part of a total system that starts with ISR and ends with successful mine interdiction, mine countermeasures (including avoidance), and U.S. mining activities in critical waters along the littoral.

Recommendation: The CNO and the CMC should also take steps to ensure that theater Navy and Marine Corps operational commanders are trained in the tasking of the collection and analysis agencies so as to obtain and update mine information and mine warfare-related data and analysis, including the observation of potential opponents' relevant activities, as a routine part of theater warfare planning and operations.

Recommendation: The CNO should ensure that the Oceanographer of the Navy places increased emphasis on mine warfare-related environmental data collection and entry of all existing data into the MEDAL system. Provision also should be made for the collection and automated transmittal of key environmental data from the applicable dedicated and organic MCM sensors as well as from national sensors. Up-to-date MEDAL databases should be "pushed" to ships en route to contingency operations. Additional and supporting steps would include:

- Relaxing the current cap (or fence) on mine warfare R&D funding such that mine-hunting systems can be upgraded to use the most advanced currently available sensors (such as synthetic aperture sonars) and data processing capabilities to find and identify both exposed and buried mines and NOMBOs for rapid clearance of ship and landing craft channels;
- Supporting and expanding the LRS capability and making its capabilities

more widely known to the fleet, with provision for fleet use of those capabilities during near-shore and amphibious operations, including exercises; and

- Upgrading the *Inchon* and any follow-on or successor ships, and other seaborne MCM units (MCM and MHC ships) to a Link-16 capability so that they can communicate and transmit data among each other and with other Navy and joint force elements, as part of a battle force's overall combat capability.

THE DEDICATED MINE COUNTERMEASURES FORCES

Close-to-shore and inshore mine clearance is needed in support of battle force and amphibious operations and for over-the-shore logistic support of joint forces; to clear approaches to ports through hostile or potentially hostile waters; and to clear mines—even mines that the United States or its allies may have deployed—from such waters after a conflict. These could be enormous tasks that require detailed clearance of mines from offshore operating areas, and of mines as well as obstacles from inshore and beach operating areas. Such tasks require specialized capabilities that in some cases will likely be well beyond the organic capabilities that will be routinely resident and available in the deployed battle groups. Indeed, amphibious task forces and over-the-shore logistic support ships, as well as ships moving to secured ports to support combat forces ashore, are more likely than the battle groups to have to operate in heavily mined waters. Timing of countermine warfare will be critical for both the amphibious forces and for ensuring access by the maritime prepositioning ships on which the Army, Air Force, and Marines rely for early combat capability in littoral theatres. Sustained follow-on logistic support by the TRANSCOM transport fleet, following any landing, will be crucial for successful operation of any forces ashore.

From another perspective, some of the new organic MCM systems (RMS and MH-60S capability) will add still another mission onto the DDG class of ships (together with antiair warfare, antisubmarine warfare, naval surface fire support, and potentially, theater ballistic missile defense (TBMD)) and SSNs (together with antisubmarine warfare, Special Operations Command support, and land attack). Under many operational conditions it will be necessary to prioritize these mission areas in ways that could place demands on ship operation that preclude carrying out the MCM missions at critical times. In addition, flight deck spots for MCM helicopters would compete for space with battle group combat aircraft on CVNs and with assault helicopters/tilt rotor aircraft and close air support vertical takeoff and landing (VTOL)/short takeoff and vertical landing (STOVL) aircraft on amphibious ships. If the footprint of the needed airborne MCM capability is too large for accommodation with the other necessary loading of battle group and ARG ships, then the deck space will have to be augmented.

From all the above considerations, it is clear that even after the organic MCM systems are integrated into the fleet, the mine warfare capability and capacity of the battle groups and the amphibious forces will logically need to be augmented in some—perhaps many—important situations. A suitably sized, capable, dedicated MCM force, including MCM craft and ships, helicopters that provide more capability than the battle group's MH-60S, and the current and, subsequently, a future version of an MCS appears likely to best meet this need.

Today, that dedicated force includes the *Inchon* (MCS-12), 14 MCM- and 12 MHC-class ships, and 20 MH-53E helicopters assigned to that force. As is indicated in the subsequent paragraphs, the MCS and airborne MCM components of the dedicated MCM force are aging and face serious maintenance and upgrade needs. Even more to the point, the composition and functionality of the dedicated MCM force will be in flux as the organic systems come into the fleet and more is learned from experience about the operational modes and the complementary of the tasks that each part of the total MCM system is found to be capable of undertaking.

Recommendation: The U.S. Navy should modernize its dedicated mine countermeasures (MCM) force. Elements of this modernization should include (a) sustaining and upgrading the current (legacy) elements of the dedicated MCM force; (b) replacing the aging *Inchon* (MCS-12) as soon as one or more suitable replacement(s) can be readied; and (c) planning and programming for follow-on dedicated MCM command and support capability and for follow-on dedicated surface, airborne, and undersea MCM capabilities.

Recommendation: The Secretary of the Navy, the CNO, and the CMC should plan to retain and continually evolve the dedicated MCM force based on an integrated plan that is prepared, updated, and optimized as lessons from the combined dedicated and organic force operations are learned.

Mine Warfare Support Ship

The previous USS *Inchon*, an LPH-12 amphibious ship, was converted to be a mine control ship in 1996 and became the USS *Inchon* (MCS-12). The *Inchon* possesses a reasonably modern C4ISR suite to support mission planning and evaluation for the MCM commander. It can host, maintain, and logistically support an airborne MCM squadron of MH-53E helicopters; it can host and support explosive ordnance disposal (EOD) MCM detachments; and it can provide maintenance and support for up to four surface MCM ships. Using the *Inchon* in this way improves interoperability and sustainability among these diverse MCM assets.

The *Inchon* is a unique ship, homeported in Ingleside, Texas; it could take weeks for it to be made ready when called and to sail to an overseas contingency region. Additionally, given the advanced age of the ship, maintenance requirements have frequently reduced the ship's availability and readiness. Finally, as is indicated in Chapter 5, neither the current dedicated MCM forces supported by the *Inchon* nor the planned organic MCM systems provide a satisfactory capability for rapid mine clearance in very shallow water and from there through the surf zone and onto the beach.

The *Inchon* needs upgrading; it will soon be ready for replacement, and the capability it represents is needed for more rapid deployment to contingency areas than is currently possible with this unique ship. In addition, the capability of a ship like the *Inchon* or a future replacement should be extended to clearing inshore waters in support of amphibious assaults and over-the-shore logistics operations. Finally, a ship with expanded capabilities would be able to house and operate the remote mine-hunting system (RMS) that will be a key fleet organic MCM system, allowing it to augment a battle group's organic capability when battle group ships may have other assignments.

Given the demonstrated utility of the USS *Inchon* (MCS-12) in supporting dedicated MCM operations and considering the widely dispersed theaters where mine countermeasures operations could be likely, having a force of at least two MCS units (at least one per major fleet) would reduce the risk of an untimely response.

The age and obsolescence of the *Inchon* suggest the need for a more modern, supportable platform in the near future to perform the MCS function. To facilitate current operations the ship should have a well deck, as well as a flight deck, to be able to launch RMS and VSW DET teams, mammal mine-hunting teams, and other systems that may be developed for inshore MCM.

For the longer term (i.e., beyond the lifetime of the above short-term *Inchon* replacement ships), the anticipated continuing need for larger-scale MCM capabilities than those planned for the battle groups, as well as the need for better support to inshore MCM, indicates a prospective need for more capable forward-deployed, dedicated MCM forces to avoid the long deployment times. However, as the organic capabilities are proven and, perhaps, some of the MCS command functions are absorbed into or duplicated in ships of the battle group, the relative roles and capability needs for the organic and dedicated forces, and therefore of the MCS, will change. As this experience is gained, it will facilitate the design of the optimum mix of capabilities in the future dedicated MCM forces, including the MCS, and the new generations of MCM and mine hunter, coastal (MHC) ships that will replace the current ones when their service lives end.

Also, any mine warfare support ship design that emerges from the above considerations for the dedicated MCM force must be able to operate regularly with an ARG and/or battle group deployed forward. It may be found that higher-speed hull forms currently under consideration by the Navy could be adapted to the MCS function, augmented for inshore MCM, as described in Chapter 5. Ideally, for this purpose, there would have to be three such ships on each coast—one in maintenance and shoreside training, one in exercises and training in home waters, and one deployed forward with the ARG or battle group in a contingency area. At a minimum, three appear essential—one each with the Atlantic and Pacific fleets, and one in the maintenance cycle.

Recommendation: In the short term, the CNO should address the obsolescence issues related to the USS *Inchon* (MCS-12) by planning (and programming) to replace it with one or more ships to ensure a continuing MCM support capability. The near-term replacement ship should have a well deck, for mine countermeasures craft and sweep gear, as well as a flight deck, to provide increased flexibility and efficiency of operation, and to provide optimized support for MH-53E minesweeping operations and increased support for inshore MCM. Meeting this short-term need will most likely require the conversion of an existing hull suitable for this purpose.

Recommendation: The CNO should consider providing more than a single replacement ship, to permit faster assured crisis response by the dedicated MCM force in both oceans.

The CNO should, at the appropriate time, initiate long-term planning for a next-generation (beyond *Inchon* and its short-term replacement) mine warfare support ship able to carry out the MCS functions for the dedicated mine warfare force. Hull forms facilitating rapid deployment of the ships overseas and operation with battle groups and ARGs should be considered in this long-term planning.

Status of the Surface, Airborne, and Undersea MCM Components

The surface, air, and undersea MCM components of the dedicated mine warfare forces discussed in detail in Chapter 4 are not unique to offshore MCM. Because of their additional role in logistic support closer to shore and in inshore MCM in support of amphibious landings and their relationship to current and planned capabilities of the MCS discussed above, their essential capabilities and shortcomings are summarized here, leading to the future of the dedicated mine warfare forces. Detailed recommendations regarding these force components individually are contained in Chapter 4.

The reports of the MCM Flag Oversight Committee detail many maintenance and upgrade items needed for the MCM- and MHC-class ships.[7] These vary from fixing cracked bedplates for on-board machinery or enhancing aft deck machinery reliability, to improving communications bandwidth and operator consoles, to enhancing some critical training activities. Some of these deficiencies have been carried forward without full resolution since 1998, or even in a few cases, 1995.

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[7]For a summary of such items, see the 13th Mine Countermeasures Flag Oversight Council Action Item Summary Resource Center Web site online at <http://www.cnsl.spear.navy.mil/mcmfoc/13th/viewall.asp>.

Beyond these problems, the current surface MCM ships will not start to reach the end of their service life until about 2022, so there is time available to properly plan the next generation of surface MCM ships and craft. Such plans will have to account for changes in the distribution of functionality as the organic and dedicated parts of the Navy's total MCM capability gain experience in working together. This planning process should consider including innovative surface MCM craft such as the MHS-1 discussed in Chapter 5.

The MH-53E (Sea Dragon) constitutes the current airborne MCM component of the dedicated mine warfare force. It is a multipurpose helicopter employed for both vertical replenishment and airborne MCM. Two airborne MCM squadrons of 10 aircraft each are operating today, one based at Corpus Christi with the Mine Warfare Command and the other at Norfolk with the Atlantic Fleet. In the airborne MCM role, the MH-53E can tow a mine-hunting sonar or a variety of minesweeping and countermeasures gear, some of which (e.g., the large Mk 105 magnetic influence hydrofoil sled) cannot be towed by the MH-60S. The MH-53E has a greater than 4-hour mission capability (compared to less than 3 hours for the MH-60S) and can support greater than 25,000 lb of tow tension load (perhaps 4 times greater than the MH-60S). It is capable of rapidly deploying to a theater and achieving high area coverage rates (towing systems at speeds on the order of 25 knots). Overall, with suitable off-board support for its large sweep gear, the MH-53E can achieve a level of minesweeping effort much higher than that of the MH-60S with the planned organic airborne and surface influence sweep (OASIS) system.

However, infrastructure and support costs for land-based or large-deck-ship-based MH-53E operations are very high. Partly for this reason, there are currently no plans for extending the service life of the MH-53E helicopters beyond 2010; without an extension they will be phased out of the inventory at that time. If they were to be retained in service, many technical upgrades (described in detail in Chapter 4) would be necessary or desirable. Alternatively, it may be found more cost-effective to replace them with a follow-on helicopter having greater capability than the MH-60S, but possibly different and better performance in critical details that will be ascertained as the dedicated and organic force elements work together. In any case, this decision will be affected by the naval forces' need for a continuing heavy-lift capability such as that embodied in the CH-53E helicopter and its follow-ons. The committee saw no evidence that an airborne MCM mission is being considered for the Navy's next-generation heavy-lift support helicopter.

Such dedicated airborne MCM aircraft and their subsystems could be operated from a ship like the *Inchon* or a follow-on ship such as that discussed above (or from a temporary base on a CVN, if conditions warranted), and would provide a significant extension of mine-hunting and minesweeping capability when needed, beyond that which will be afforded by the organic systems.

Currently, explosive ordnance disposal (EOD) diver systems and marine mammal systems (MMSs) play key undersea MCM roles in offshore mine warfare operations. EOD MCM attachments are employed to identify, neutralize, and exploit mines as well as to participate in post-interdiction intelligence collection. Exploitation of hostile sea mines recovered by divers supports responsive, effective, threat-oriented influence sweep operations.

These teams, with the equipment described in Chapter 4, also currently constitute the only means for hunting and clearing mines from shallow inshore waters and for hunting buried mines. Small unmanned undersea vehicle systems that are under development as part of the undersea MCM toolkit will eventually augment or replace the EOD divers for detection, reacquisition, localization, and neutralization of mines, particularly in the very shallow water regions. These and other system developments (AMNS, RAMICS) may also augment or replace divers in the mine neutralization role.

Currently MMSs have relatively low nominal area coverage rates compared to surface MCM and airborne MCM sonar systems, but their unique detection and discrimination capabilities make them indispensable, particularly against buried mines. Divers are limited by the number of deep dives they can perform over a given period and are more adversely affected by strong currents or other environmental factors.

The major issue with the EOD/VSW diver and MMS force is the very small number of existing and planned units, when compared with the potentially large demands for rapid clearance of an amphibious landing zone. Unless (or until) the Navy fields an alternative system such as UUVs that can find and clear mines more rapidly, reliance on the planned small EOD/VSW force structure will either limit the size of future assaults against potentially mined littorals, or require additional time to support large assaults.

Recommendation: The CNO should plan to retain and modernize a capable, dedicated MCM warfare force that would be available for those situations in which the MCM requirements exceed the available organic MCM capabilities of the deployed battle groups. Such a dedicated force should include:

- Upgraded surface MCM ships and their potential future replacements as discussed in Chapter 4;
- Dedicated MCM helicopters, including retention of the MH-53E helicopter in the dedicated airborne MCM force until it can be replaced by equipment that provides comparable capability, perhaps as a variant of the Navy's next-generation heavy-lift logistic aircraft;[8]

[8]The decision between retiring the MH-53E force, extending its service life, or acquiring a follow-on dedicated helicopter may need to be made before all the new mine warfare components of the MH-60S host aircraft have been fielded and their overall capability fully measured, depending on the pace of any new heavy-lift helicopter program. In the interim, selected upgrades should be made to the MH-53E aircraft suite (such as adding the AQS-20 mine-hunting sonar, the airborne laser mine detection system (ALMDS), and the airborne mine neutralization system (AMNS) capability, and a greater degree of self-protection).

• Augmented EOD/VSW teams and systems designed to help or replace them;

• Continued provision of support for deployed dedicated surface, airborne, and undersea MCM craft that is similar in concept to that provided by the *Inchon* (MCS-12), enhanced by the future evolution of the command and support capabilitiy embodied in the *Inchon*. Such support should be extended to inshore MCM.

• Additional capabilities such as a mine-hunting craft like the MHS-1, as discussed in Chapter 5, and hull forms facilitating the rapid deployment of ships and their operation with battle and amphibious ready groups.

VULNERABILITY REDUCTION

Ship and MCM Force Vulnerability Reduction

Particular attention reportedly is being given to the signatures of the new *Zumwalt*-class destroyer and the *Virginia*-class submarine, as it has been given to some current fleet combatants. Nevertheless, attention to the existing signature control measures to reduce susceptibility to diverse mine fuzes has been lagging for most existing ships.

For combatants to retain their designed signatures their equipment must be well maintained and their magnetic signatures measured periodically by Navy measurement and degaussing ranges. A half dozen measurement ranges are located at various CONUS bases plus Hawaii and Yokuska, Japan, with two portable degaussing and acoustic ranges located overseas (in Sasebo, Japan, and in Bahrain) for surface MCM units (MCM-, MHC-class ships); four additional portable ranges have been purchased at congressional direction, but they have not been activated. These signature maintenance facilities have not all been kept in good working condition.[9] Additionally, for warships operating in mineable waters, it is generally recommended that they operate at low speeds (< 5 to 10 knots) to reduce their acoustic and pressure signatures. However, the mine-ship interaction profiles that show safe ship speeds are not aboard or current on many combatants.

In addition, the MCM ships and helicopters will be vulnerable to enemy action in the form of antiship and antiaircraft missiles as they perform their missions within range of such weapons. When deployed, MCM ships have no

[9]Schilt, Michael P., Naval Surface Warfare Center, Carderock Division, Bremerton Detachment, Bremerton, Wash., "SSRNM Fleet Status" (Slide 11) and "Impact of Ship Operating Conditions on Acoustic Signature" (Slide 12) in the briefing "Point-Defense FACDAR: Mines, Signatures and Ships" presented to the 12th Mine Countermeasures Ship Flag Oversight Committee (MCMFOC) September 26-27, 2000, indicating funding shortfalls; Schilt, Michael P., Naval Surface Warfare Center, Carderock Division, Bremerton Detachment, Bremerton, Wash. 2001. *MIW Ship Vulnerability Identification Program (MIW-VIP)*, draft presentation to ADM Robert J. Natter, USN, Commander in Chief, Atlantic Fleet, indicating funding shortfalls not yet remedied.

self-defense capability; a combatant in company generally must protect them. Further, they have no self-contained "early warning" and no passive protection measures against threats other than mines incorporated in their designs. While they cannot be expected to be as fully outfitted as some other warships, they could incorporate a degree of infrared (IR) suppression, minimal radar threat early warning, and some basic chaff and IR/radar decoy capability, in the interest of passive defense to ease the task of defending the MCM ships close-in by an escort.

The airborne MCM helicopters, when operating in hostile waters, almost always without escort, are particularly susceptible to attack by aircraft, helicopters, small craft, and, in inshore areas, by shore-based units, any of which could fire machine guns or antiaircraft missiles at them. These vulnerabilities could be eased by incorporating an electronic support measures suite, chaff, and readily available IR countermeasure equipment. Finally, the EOD/VSW teams work in waters where wave action, breaking surf, and enemy surveillance from the beach can both place them in great danger and give warning of impending amphibious action. The VSW mine-hunting systems, including any UUVs that may replace the swimmers and mine-hunting mammals, must thus be kept as low-observable as possible.

More generally, beyond the threat of enemy shore defenses discussed above, there seems to be a general inattention, in planning MCM and, more broadly, in developing overall countermine warfare systems, to potential obvious, low-cost enemy countermeasures to many ongoing U.S. MCM programs. Such countermeasures could include the use of nets or cables against UUVs, LMRS, RMS, and other towed sensors; self-burying mines; and acoustic surveillance of mine fields for MCM activities. It will be easier to build resistance to such countermeasures into the systems at the initial design phase than after the threats become obvious when the systems are operational.

Recommendation: As part of its force protection planning, the Department of the Navy should take further measures to reduce its (and the nation's) vulnerability to sea mine threats.

Recommendation: The CNO and fleet commanders should ensure continuing attention to and maintenance of design acoustic, magnetic, and underwater electric potential signatures of all hulls. Updated data, charts, and decision aids showing operating conditions to protect against influence mines should also be available and understood on all naval platforms. This effort would require routine signature measurement and assessments of individual hulls as well as an understanding of signature expectations for ships of a class, and correction of signatures that noticeably increase the risk from mines.

Recommendation: The CNO should ensure that MCM ships and helicopters that may have to operate in areas where they are threatened by attack from sea- or shore-based forces are provided with appropriate self-protection.

Recommendation: The CNO should ensure that requirements for the new countermine systems reflect the need to overcome obvious, low-cost enemy countermeasures well before system designs are finalized.

Homeland, Critical Base, and Logistic Sea Lane Countermine Defense

Planning for the defense of U.S. ports such as New York and San Francisco against mines was essentially stopped in 1993 as part of the post-Cold War reorientation of U.S. military planning. However, in view of subsequent experience with terrorist attacks and the resulting heightened concern and anticipation of terrorist threats against the United States coming from various quarters and in various guises, the possibility of a terrorist release of mines in a major U.S. port or waterway should not continue to be neglected. A credible "peacetime" mine threat could quickly close a U.S. port or waterway, not only because of ships' immediate concerns about damage, but also because ships entering mined waters would not likely be insured.

Clearly, a credible terrorist mine threat against a U.S. port would create a major economic problem. Current capabilities and plans would have airborne MCM and EOD teams operational within 2 to 4 days[10] in ports such as New York or San Francisco after notification of a credible mine threat. Surface MCM augmentation would likely be needed to reduce the clearance time line to an economically acceptable level and to achieve the necessary degree of certainty that the port is actually clear of mines. Deployment of surface MCM to New York or San Francisco from their homeport on the Gulf Coast would take at least 15 or 45 days, respectively; these times might be reduced if Canadian surface MCM resources were ready and could be called in. Actual mine hunting and clearance times could be extended appreciably by lack of current data on bottom and NOMBO conditions in U.S. ports.

In the future, the new organic MCM systems that will become available on each coast later in the decade could reduce the initial response time now needed to move an airborne and surface MCM capability to the threatened area from Corpus Christi. However, depending on the size and technical complexity of the threat, movement of such specialized forces may well be needed. The committee found little evidence of current planning for such "homeland defense" contingencies.

In addition to homeland defense, the dependence of U.S. forces on the maritime prepositioning force (MPF) to support most sizable U.S. military responses to contingencies in the littoral areas is well known. Covert sowing of mines in waters adjacent to the MPF anchoring area and in sea lanes it must transit,

[10]Response times noted here are based on data furnished by the Mine Warfare Command in unofficial correspondence with the Naval Studies Board.

possibly leading to loss of an MPF ship, could seriously interfere with an urgent contingency response. Finally, as noted above, continuing mine clearance operations to clear the way for and to protect the U.S. Transportation Command's (TRANSCOM's) follow-on logistic support shipping will be necessary while U.S. and allied forces operate in a contingency area. Such protection will be necessary near shore whether TRANSCOM uses ports or logistic-over-the-shore offloading. Responses to the committee's inquiries suggested that these problems have received little attention in contingency planning.

In all these situations, countermine warfare efforts and capabilities of U.S. allies can be of great help. To take full advantage of this potential, U.S. and allied countermine warfare forces will have to be highly interoperable, requiring standardized countermine warfare data structures and data links. NATO channels and procedures offer major opportunities for such standardization.

Recommendation: The CNO should ensure that the fleet commanders-in-chief (CINCs) and theater naval component commanders extend countermine warfare contingency planning to include transit and operating areas, homeland defense, and critical base defense.

Recommendation: The CNO should take steps to ensure that TRANSCOM contingency planning for expeditionary operations includes clearing and defense of the sea lanes, ports, and logistics-over-the-shore landing areas needed by TRANSCOM to support expeditionary operations ashore.

Recommendation: The Secretary of the Navy, the CNO, and the CMC should take steps, as appropriate, to ensure that allied countermine capabilities and forces are enlisted and incorporated in mine warfare contingency planning. These steps should include standardization of data structures and data links, using existing NATO channels and procedures for the purpose, and expanding such connections with other allies such as Japan and the Republic of (South) Korea.

Proliferation of Advanced Mines

As noted in Chapter 1, sea mines can be a "poor man's naval force" capability that is being proliferated widely, including to nations and organizations hostile to the United States and its allies. The mines themselves range from World War I vintage to modern, self-burying, hard-to-find mines with sophisticated fuzing that is becoming increasingly difficult to counter.

Even the poorest countries and hostile organizations may be able to acquire highly advanced mines. Such mines are being sold by U.S. allies such as Italy and friendly Western nations such as Sweden, in addition to Russia and other members of the former Soviet Bloc. This proliferation is quite dangerous to U.S. and allied interests and is much less visible than the proliferation of ballistic missiles.

A serious, if not wholly successful, attempt to inhibit the proliferation of ballistic missiles is contained in the Missile Technology Control Regime instituted in 1987.[11] Twenty-four nations, including the United States and representing much of the world's advanced missile design capability, are members of this voluntary (nontreaty) agreement to limit the spread of advanced ballistic missile technology, and several others have indicated their willingness to adhere to its export control guidelines. There are no sanctions for not keeping the promise to adhere to them, and violation of the voluntary agreement is suspected in many cases. Nevertheless, many of the most capable nations do adhere to it, and it is believed to have limited the spread of ballistic missiles having advanced performance capability.

A similar regime for mine technology, if it could be arranged among the exporting nations with which the United States is allied or has friendly relations, might similarly limit the threat of advanced mines that may be used against the U.S. fleet or shipping critical to the United States and its allies. Little would be lost in trying to arrange such an agreement, and much might be gained.

Recommendation: The Secretary of the Navy should take the lead in urging the Defense and State Departments to initiate international discussions among U.S. allies and other nonhostile nations to institute a mine technology control regime, analogous to the Missile Technology Control Regime instituted in 1987, to help slow the spread of increasingly sophisticated and threatening sea mines.

JOINT INTERESTS AND INTEGRATED CONCEPTS OF OPERATION

Although the Navy has the responsibility for clearing mines from the sea lanes and the inshore areas that must be traversed by amphibious and logistic support shipping, much of mining and countermine warfare is of joint interest and involves joint forces. For examples, see below:

- Mining can be a strategic weapon system. Therefore, it must be a part of joint strategic planning processes.
- ISR for mine warfare is supported by surveillance and reconnaissance assets from both the Navy and the Air Force, as well as by national assets.
- Information about mining by hostile adversaries and the potential interdiction of that mining, gained from all sources, is of key interest to the Joint Chiefs of Staff, the joint regional CINCs, and the National Command Authority.
- Assured access to beaches for joint logistics over the shore (JLOTS) and for access to ports is of vital interest to TRANSCOM as well as the other Services whose forces must be supported by the logistics flow.

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[11]Arms Control Association. 2001. "The Missile Technology Control Regime," *Arms Control Association Fact Sheet,* Washington, D.C. Available online at <http://www.armscontrol.org/FACTS/mtcr.html>.

- The Air Force and the Navy have mine warfare mission requirements and will be involved in delivery of sea mines as part of overall strategic naval warfare planning.
- The Navy and the Air Force engage jointly in air defense suppression operations close to hostile shores.
- The importance of the Navy to Marine Corps amphibious warfare operations is such that the two Services' responsibilities in amphibious warfare are essentially inseparable.
- Additionally, rapid mine and obstacle clearance from amphibious assault channels using the Harvest Hammer explosive channeling technique (Chapter 5) is likely to involve Air Force bombers for delivering the explosive charges.

Despite all these joint interdependencies, joint concepts of operation have not been developed in any of the areas noted above. Indeed, there are, as yet, no approved concepts of operation in the overall mine warfare area, as noted in Chapters 3, 4, and 5. Specifically, these chapters point out the need for the following:

- A concept of operations that links all the organic MCM systems into an architecture, couples them to joint ISR assets, and provides guidance on how they will be used in concert;
- A joint Navy and Marine Corps concept of operations for amphibious operations against opposition, using the new MCM systems and also involving the Air Force in the case of explosive channeling; and
- Joint concepts of operation for mine delivery in contingency areas, with families of sea mines that are compatible with both Navy and Air Force means of delivery.

All of these concepts of operation must be developed as an essential element of the integration of mining, countermine warfare, and all the subordinate systems and activities into naval force and joint force activities. As an essential step in these developments, the CNO and the CMC should see to establishment of the connections to the other Services and the national agencies that will enable subordinate naval force commands, such as the Marine Corps Combat Development Command (MCCDC) and the Naval Warfare Development Command (NWDC), and the analogous commands or offices of the other Services and national agencies to engage in the effort from a common, joint basis of understanding.

Recommendation: The CNO and the CMC jointly should take the lead in establishing connections and memoranda of understanding as needed among the Navy, Marine Corps, the other Services, and other appropriate joint and national agencies, to enable development of joint concepts of operation and, where necessary, equipment interface standards in support of mining and countermine warfare.

Recommendation: The CNO and the CMC should assign MCCDC and NWDC the joint responsibility for developing concepts of operation for countermine warfare in support of amphibious operations. These concepts of operation should be extended to involve the Air Force in delivering the explosive charges for explosive channeling to rapidly enable amphibious landings opposed by mines and obstacles. They should involve TRANSCOM in any aspects of logistic support operations that TRANSCOM must attend to in order to benefit from Navy countermine warfare support to protect logistics shipping and offloading.

3

U.S. Naval Mines and Mining

The committee assessed the capabilities of the United States to employ sea mines and found, first, that, contrary to the U.S. Navy's published mine warfare plan,[1] current capabilities are extremely limited and, second, that the trend is toward having essentially no mining capability in the future. The committee then considered possible underlying reasons for this situation and identified potential advantages that could be provided by reestablishing a robust U.S. mining capability. Finally, the committee addressed the issues of how to determine the kinds of mines that would best serve U.S. interests, and how an effective mining program might be implemented.

CURRENT STATUS OF U.S. MINING CAPABILITIES

A naval minefield is a significant physical and psychological threat that can cause attrition to enemy ships and submarines or limit ship movements by forcing delays and diversions because of perceptions and fears, both real and exaggerated.[2] Any suspected minefield must be treated as a serious danger, thereby forcing a ship's commander to make decisions with incomplete information of the true threat, little information on the relative merit of the available choices, and dire consequences if a wrong choice is made.

[1]Johnson, ADM Jay L., USN, and Gen James L. Jones, USMC. 2000. *U.S. Naval Mine Warfare Plan, 4th Edition, Programs for the New Millennium,* Department of the Navy, Washington, D.C., January.

[2]Doctor, Michael A., and Victor S. Newton. 1998. "Making Mining Relevant in the Twenty-First Century," *Proceedings of the Third International Symposium on Technology and the Mine Problem . . . to Change the World,* Naval Post Graduate School, Monterey, Calif., Mine Warfare Association, pp. 11-3 to 11-9.

U.S. Naval Mining: The Vision and the Reality

The Vision

The *U.S. Naval Mine Warfare Plan* acknowledges that the sea mine remains "an exceptionally powerful and cost effective tactical weapon that deserves a prominent position within any naval arsenal" (p. 27). The sea mine is a classic low-cost force multiplier that should be especially important at a time of declining fleet size. Sea mines can be used by any country that aspires to extend its reach and influence to areas and at times where it cannot deploy a requisite force. The U.S. naval sea mining vision is (1) to develop, procure, maintain, and deploy a modern family of sea mines optimized for potential future military encounters in littoral regions and (2) to develop a comprehensive understanding of U.S. adversaries' sea mine designs in order to successfully counter them. By revitalizing its own mining program the United States can remedy shortcomings in its current mining capability and also better understand new threat mine designs.

According to the *U.S. Naval Mine Warfare Plan*, in order to realize this mining vision the Navy will support the mines that are in the current inventory and also aggressively support development of new sea-mine technology and operational capabilities. In particular the Navy's published mine warfare plan, which differs sharply from its funded programs, calls for a capability for remote control of sea mines, a standoff mining capability, and a full-water-depth mining capability. These are all required in order to mine effectively against a wide range of targets with adequate safety.

To ensure the effectiveness of future forces, the *Mine Warfare Plan* states that it is necessary to develop and maintain an inventory of modern weapons, integrate mining into the overall planning to shape the battlespace, and ensure the availability of a variety of delivery platforms in sufficient numbers to execute approved plans. The plan notes that during conflict, it may be necessary to protect and replenish minefields and, when hostilities have ceased, to provide for the safe, timely, and cost-effective neutralization and/or removal of mines.

The Reality

The current U.S. naval mining capability is in woefully bad shape with small inventories, old and discontinued mines, insufficient funding for maintenance of existing mines, few funded plans for future mine development (and none for acquisition), declining delivery assets, and a limited minefield planning capability in deployed battle groups. A key indicator of the decreasing U.S. Navy mine development effort is the decline in the government workforce for mine-related efforts. In 1987 about 240 mine-development person-years of effort were funded. This number decreased to 36 in 2000 and is scheduled to be zeroed in 2002. With no significant research, development, testing, and evaluation (RDT&E) program and no prospects for procurement, the nongovernmental industrial base for mine development and production has also precipitously declined.

Current U.S. Naval Mine Inventory

The present U.S. inventory[3] of naval mines includes:

1. Quickstrike—a family (Mk 62 (500 lb), Mk 63 (1000 lb), and Mk 65 (2300 lb)) of air-dropped, relatively shallow water (< 300 ft), bottom mines based on general-purpose bombs, using variable-influence sensors to detect submarines and surface ships.
2. Mk 60 (CAPTOR)—an obsolescent, air-dropped, 2000-lb, medium-depth (150 to 600 ft), moored mine employing an Mk 46 homing torpedo and specifically designed in the 1970s for use against the high-speed, deep-operating submarines of the day. The majority of the inventory is being withdrawn, with a small number being retained for an indeterminate period.
3. Submarine-launched mobile mine (SLMM) Mk 67—a bottom mine using obsolete 1960s technology. It combines a modified Mk 37 torpedo with a mine warhead. Launched from a submarine torpedo tube, it is the only mine in the U.S. Navy stockpile that can be covertly delivered from standoff ranges. A small number of SLMMs is being retained in inventory.

Future Mine Development

The Navy has no funded plans to acquire any new mines in the next 7 years. A replacement mine for the Mk 60 has been proposed, called the littoral sea mine (LSM), which would be designed for intermediate water depths of about 150 to 600 ft. It was to have been air-, surface-, or submarine-launched and would be used against surface or subsurface targets. There is no funding for continued development or acquisition.

A planned target detection device (TDD) Mk 71 has been developed but is not being acquired. The Mk 71 TDD would provide an improved sensor and fusing device for the Quickstrike series of mines that would enable these mines to be programmed to respond to emerging threats such as quiet diesel electric submarines, small submarines, fast patrol boats, and air-cushioned vehicles. There is no further funding for development or acquisition.

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[3]Hewish, Mark. 2000. "Sea Mines, Simple But Effective," *International Defense Review*, November, pp. 45-48; Naval Studies Board, National Research Council. 1997. *Technology for the United States Navy and Marine Corps, 2000-2035, Vol. 7, Undersea Warfare*, National Academy Press, Washington, D.C.; Johnson, ADM Jay L., USN, and Gen James L. Jones, USMC. 2000. *U.S. Naval Mine Warfare Plan, 4th Edition, Programs for the New Millennium*, Department of the Navy, Washington, D.C., January.

A planned improved submarine-launched mobile mine (ISLMM) Mk 76 was being developed to replace the SLMM Mk 67, providing conversion to an Mk 48 torpedo body, with two mines per torpedo, longer range, and more versatile delivery routes. There is no further funding for development or acquisition.

An armed sensor field concept called deployable autonomous distributed system (DADS)[4] has been proposed. Again, no further development or acquisition funding is planned to provide this capability.

Mine Delivery Platforms[5]

Aircraft are the main U.S. mine delivery platform. They include the Navy F-14 to deliver Quickstrike Mk 62 mines; the F/A-18, P-3C Orion, and Air Force B-52H to deliver Mk 56 and all Quickstrike series mines; the B-1B to deliver Quickstrike Mk 62 and Mk 65 mines; and the B-2 to deliver Quickstrike Mk 62 mines. Current attack submarines can deliver SLMM Mk 67 mines. The new *Virginia*-class SSNs are not scheduled to have a mine delivery capability.

International Law Governing Naval Mine Warfare

Although some appear to have the impression that international law severely limits the applicability of mining, it is generally agreed that international rules for mining in peacetime, or during a crisis, indicate the following:[6]

- Nations can lay armed or controlled mines in their own internal waters at any time without notification to others, and in archipelagic waters and territorial seas during peacetime, with notification of minefield location, to meet temporary "national security purposes."
- Nations cannot lay armed mines in international straits or archipelagic sea lanes during peacetime.
- Nations can lay controlled mines in their own archipelagic waters or territorial sea without notification.
- Nations can lay controlled mines in international waters, without notification, as long as they do not constitute an "unreasonable interference" with other lawful uses of the seas.
- Armed mines cannot be laid in international waters prior to an outbreak of armed conflict, except under special circumstances. If laid, prior notification of

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[4]Hewish, Mark. 2000. "Sea Mines, Simple But Effective," *International Defense Review,* November, pp. 45-48.

[5]Johnson, ADM Jay L., USN, and Gen James L. Jones, USMC. 2000. *U.S. Naval Mine Warfare Plan, 4th Edition, Programs for the New Millennium,* Department of the Navy, Washington, D.C., January.

[6]Greer, W.L. 1997. *A Summary of Laws Governing the Use of Mines in Naval Operations,* IDA Document D-2055, Institute for Defense Analyses, Alexandria, Va., April.

their location is required, and an on-scene presence must be maintained during peacetime to ensure that warning is given to all approaching ships. When the imminent danger has passed, such mines must be rendered harmless or be removed.

Summary of Status of U.S. Mining Capabilities

Although the above discussion emphasizes the mines themselves for a range of applications, an effective mining capability requires attention to all of the additional elements listed here:

- Means of delivery,
- Trained operators (exercises),
- Knowledgeable commanders (e.g., joint force commanders),
- Operational minefield planning capability (e.g., types, positions, settings),
- Realistic planning tools,
- Effective organization for execution (integration into force),
- Intelligence support (environments, signatures, counters), and
- Logistics support.

Despite the expansive vision contained in the *U.S. Naval Mine Warfare Plan*, the present funding for sea mines is essentially limited to maintaining the Quickstrike family, an air-dropped bottom mine with only shallow-depth capabilities. There are no funded plans to provide a standoff delivery capability for Quickstrike-type mines such as by developing a mine version of the joint direct attack munition (JDAM) standoff weapon. There are no funded plans for new medium- or deep-water mines. Currently available mines are not effective against new target types in littoral waters; there are insufficient inventories to execute existing mining plans; the number and variety of delivery platforms continue to decline due to reduction in forces; training for mining missions is unduly limited; there are long-standing controversies regarding the correctness of the current methods used by the Navy to gauge minefield effectiveness and assess mine design;[7] and the U.S. technical industrial base for mine design and fabrication is about to disappear.

In short, the U.S. capability to conduct naval mining operations is vanishing.

WHY THE LOW STATUS FOR MINING?

The precipitous decline in U.S. naval mining capability follows from the fact that mine warfare in general has had a low priority within the Navy's budget, and

[7]Naval Studies Board, National Research Council. 1997. *Technology for the United States Navy and Marine Corps, 2000-2035, Vol. 7, Undersea Warfare,* National Academy Press, Washington, D.C., p. 78.

mining has the lowest priority within the constrained mine warfare budget. Unlike mine countermeasures, which the Navy has employed as recently as the Gulf War, significant mining has not been attempted since the mining of Haiphong and other North Vietnamese harbors in 1972.

Although naval mining proved extremely effective in World War II, its use has been held in low regard by the U.S. Navy since then. Within the Navy there is a general perception that, at a tactical level, mining is unexciting (i.e., results are slow) and that its relatively indiscriminate targeting limits the mobility of U.S. naval forces as much as that of an adversary. In a Navy that measures effectiveness primarily by the actual attrition of enemy forces, minefields that stop traffic without sinking or even damaging a ship have been viewed by some as a weakness rather than a strength.[8]

There is also a mistaken perception that considerations of national policy or international law would likely sharply limit the circumstances for use of naval mines, particularly in international waters. This is in spite of the fact that, during the height of the Cold War, the United States built a large inventory of deep-water mines (CAPTOR), intended primarily for deployment in allied and international waters as a counter to Soviet nuclear submarines.

Since the collapse of the Soviet Union, the decline in the hostile blue-water submarine threat has resulted in low interest in medium- to deep-water mines, which were considered to be primarily antisubmarine warfare (ASW) weapons.

Another contributor to the low priority of mining is a lack of specific sponsorship. Mines are weapons that contribute to control of the surface and undersea environment, but their delivery (with the exception of the small inventory of SLMMs) is done entirely by air—with Air Force bombers being the primary platforms for high-volume delivery. Although mines have many of the characteristics of strike warfare weapons, the nominal Navy sponsor for mining is the Director for Expeditionary Warfare, who quite properly is more concerned with the mine countermeasures shortfalls discussed in Chapters 4 and 5.

Finally, the cost of developing new mining systems (including delivery as well as the weapons themselves) is seen as excessive given that the Navy attaches a low priority to mining. In a climate in which mining capability is viewed as unimportant, the mine development community (both government and industry) is viewed by some as proposing unaffordable systems.

SHOULD THE UNITED STATES HAVE A MINING CAPABILITY?

In recent years, while not explicitly asserting that it does not need a mining capability, the Navy has consistently concluded that other investments deserve a

[8]Kaufman, A.I. 1997. *Cultural and Ethical Underpinnings of the Navy's Attitude Toward Naval Mining,* IDA Document D-2057, Institute for Defense Analyses, Alexandria, Va., April.

higher priority. However, several recent studies have concluded that a U.S. mining capability should be sustained.[9]

Scenarios

The single common feature of scenarios involving the use of sea mines is that there are maritime assets (either surface ships or submarines) to be targeted. Beyond that there is great variability. Surface targets may range from large combatants to merchant shipping or small craft. Submarine targets may range from SSNs to mini-submarines or unmanned undersea vehicles. The level of conflict may range from full-scale war through peacetime security or economic sanctions. The desired effect of a single encounter may range from simple detection to tagging, stopping, disabling, or, most traditionally, sinking. The objective of the mining effort may be to control the movement of a single ship, to stop all penetration attempts, to cause attrition, or to protect friendly areas.

There are two critical differences between traditional thinking about mine warfare and thinking about its usage in the 21st century. The first is the changed geo-strategic environment. Traditionally mines have been thought of as weapons used in unrestricted warfare to interdict enemy shipping or otherwise shape a maritime battlespace. Now the United States should consider a range of other potential uses of naval mines in a less-than-full-scale-war scenario, such as the imposition of economic sanctions, or, more generally, calibrated coercive threats to shipping of many types. The second critical difference is changing technology. Just as new roles for mining are opening up, new technologies are emerging that may enable the needed capabilities. For example, the possibility of controlling mines remotely and/or using nonlethal warheads opens up the potential for new missions.

Some Potential Contributions of Sea Mining

The major contributions that sea mining can make to U.S. capabilities are the following:

- *Low-cost force multiplier.* Mines can relieve other platforms in maintain-

[9]Naval Studies Board, National Research Council. 1997. *Technology for the United States Navy and Marine Corps, 2000-2035, Vol. 7, Undersea Warfare,* National Academy Press, Washington, D.C.; Kaufman, A.I. 1997. *The Future of Naval Mines,* IDA Paper P-3326, Institute for Defense Analyses, Alexandria, Va., August; Defense Science Board. 1998. *Joint Operations Superiority in the 21st Century: Integrating Capabilities Underwriting Joint Vision 2010 and Beyond, Volume II, Chapter 3, Exploiting the Littoral Battlespace,* Defense Science Board 1998 Summer Study, October; Fanning, J.W., D.M. Reda, S.W. Smith, and C. Guastella. 1998. *Warfighting Payoff of Current and Projected U.S. Naval Mining* (U), CSS/TR-98/22, Coastal Systems Station, Naval Surface Warfare Center, Dahlgren Division, Panama City, Fla., May (classified).

ing static defenses such as antiship or antisubmarine barriers that create sanctuaries, establish blockades, or prevent enemy combatants from leaving (or returning to) ports. In an era of decreasing size of U.S. naval forces, this ability to enhance the coverage provided by each platform, and thereby enhance the reach of naval power, becomes increasingly valuable.

• *Reduced risk.* Since they are unmanned, naval mines reduce the risk to friendly personnel. This constraint is becoming increasingly important because in limited contingencies, for example, casualties inflicted on U.S. personnel may lead to undue popular pressure for withdrawal and a consequent failure to achieve the national objectives that motivated U.S. involvement.

The risk to high-value, multipurpose units is also reduced through the use of mines as a first line of defense. This, too, is becoming more important since the loss of such a unit could discourage continued pursuit of U.S. national objectives in a limited contingency.

• *Battlespace shaping.* Aircraft-delivered mines can deny enemy access to areas that are also denied to U.S. surface or subsurface ships, or to areas where U.S. forces are unavailable. For example, preemptive mining could be used before the arrival of a naval force to prevent enemy surface or subsurface craft from mining a prospective U.S./allied landing zone or operating area.

The principles of maneuver warfare hinge on the ability to understand the situation and to shape the battlespace by putting the enemy in a restricted, disadvantageous position faster than he can react. Naval mines can provide such a capability to a joint force commander faced with a maritime threat by either creating restricted areas or by slowing the enemy down.

• *High-endurance weapon.* Naval mines can remain on station around the clock for long periods.

• *Diplomatic leverage.* Naval mines employed in the "gray" area between peacekeeping missions and open hostilities can prove useful to U.S. diplomatic objectives by, for example, enforcing sanctions without initiating open conflict. As tools of coercion naval mines may contribute to achieving objectives without actually striking enemy targets—if an enemy is warned that mines are present and still chooses to proceed, he shares in the responsibility for any losses.

• *Support to mine countermeasure efforts.* An active U.S. mine program will support U.S. expertise in mine design, mine countermeasures, and mining tactics. It therefore also supports U.S. abilities to understand the designs of, and find counters to, foreign mines and enemy mining efforts.

• *Support to allies.* U.S. mines and expertise may be made available to allies in situations that otherwise might require direct U.S. intervention. The defense of Taiwan might be an example should the United States become involved in such a contingency.

• *Rapid reaction for limited contingencies.* Modern naval mines could be delivered rapidly anywhere, anytime with limited risk to friendly personnel. They require neither a complex build-up and deployment period nor the establishment of a support base in the forward area. Thus, they may be used for rapid responses in limited contingencies, e.g., to shut down shipping, barricade potentially hostile naval units, or otherwise demonstrate resolve.

Based on its review of the foregoing contributions of sea mining, the committee concluded that the United States should revitalize its naval mining capabilities.

WHAT TYPES OF MINING CAPABILITIES ARE REQUIRED?

Possible Mining Missions

If the United States is to revitalize its naval mining capabilities, the character of the future mines must be responsive to a range of potential military applications and at the same time must be affordable. Before considering the technical characteristics of such new weapons, it is important to first ascertain the missions to be accomplished by minefields and the overall context in which the United States might wish to employ them. Some considerations are as follows:

- Is the primary application antisubmarine warfare, antisurface warfare, or both?
- What degree of lethality is desired? Sinking? Mission abort? Mobility impairment?
- What depth regime is to be covered?
- What standoff delivery range and accuracy are required? From what platforms?
- What in-water endurance is expected?
- Will likely adversaries have significant mine countermeasures (MCM) capability?
- What is affordable for development, procurement, and deployment?
- What degree of controllability of mines and minefields is needed?
- What degree of minefield planning capability should be resident in the battle group and/or other headquarters of the joint force commander?

Enabling Technologies

Advances in technology are making it possible to incorporate a number of features into mines that in the past were not feasible, or at least were not practical. Such features may be cost-effective in some operational situations but not in others—depending on the specifics of the missions to be performed. Some examples are as follows:

- Minefields can be controlled remotely—either by an autonomous central controller or by a man-in-the-loop. Functions to be controlled could range from simple on/off/sterilize to the possible tuning of target signature parameters based on updated intelligence data. Depending on geopolitical circumstances, control could be from a nuclear-powered attack submarine (SSN) or other platform. The principal technology enabler is an acoustic communication link.

- Standoff, precision delivery by aircraft, based on JDAM or JDAM-like capabilities, could greatly increase the survivability of launch platforms, increasing the likelihood of safely conducting effective mining missions.
- Various combinations of target influence (acoustic, magnetic field, electric field, pressure) can be incorporated into sensors much more readily than in the past, allowing for greater target selectivity, countermeasure resistance, and adaptation to new threats such as fast surface craft or small submarines.
- Submarines provide a covert, standoff launch platform. Key enabling mine technologies include autonomous navigation systems, size reduction, and external carrying systems.
- Vertically mobile warheads, propelled by simplified torpedoes or rocket motors or even buoyancy, can greatly enhance the depth coverage of mines with simple anchoring devices when planted in medium-depth waters.
- A number of less-than-lethal weapons are currently under development for land warfare, and analogous systems could be adapted to sea mines. Examples include devices for fouling propulsors, damaging electronic systems, or tagging.
- By using distributed sensor fields similar to those in development for ASW, some, or all, of the target-sensing function can be physically separated from the warhead function. This approach may potentially increase minefield performance and endurance while decreasing the complication and cost of individual weapons and easing the implementation of controllability of the minefield.
- The size of mines can be reduced using miniaturized electronics, smaller power supplies, warheads based on higher-yield explosives, or homing devices to reduce warhead yield requirements. Smaller mines ease delivery burdens and enhance stealth.
- Capabilities such as self-burying or periodic movement to relocate from a previous location on the bottom could enhance minefield endurance, countermeasure resistance, and performance. Also, mobile mines can be used to threaten areas and even stationary ships or submarines.
- Mine countermeasure resistance can be enhanced by improved target sensors and firing logic, stealth, and the use of antisweeper mines in the minefield.
- A capability for minefield planning can readily be made resident in the battle group, allowing for a rapid, flexible response to operational situations. Such a capability could be available either onsite or via reach-back capability to a minefield planning center.

It seems clear to the committee that the theater commanders, the Navy, and the nation would benefit by having a robust mining capability. The committee concluded that the Navy, perhaps in conjunction with the Joint Forces Command, should conduct objective analyses to determine a prioritized set of mining requirements. Analysis of technical alternatives should not start until a clear understanding of missions and operational concepts, informed by strategic and operational considerations, is in place. Also, the full range of emerging technological possibilities should be assessed.

Pending completion of the foregoing recommended analysis, the committee believes that the Navy should take immediate steps to establish and protect an option to develop and acquire an operationally significant number of JDAM mining kits that would extend the Quickstrike program by providing a standoff delivery capability.

How Might an Effective Program Be Implemented?

Mining can be a strategic weapon, and mines are joint assets that would be employed by commanders of joint operational forces. Therefore, the establishment of overall U.S. requirements for mines should be coordinated at the highest level of the theater joint warfighting commands. The emphasis has to be top-down in order to ensure that the nations's needs are well understood and clearly defined before naval system designers start to work on new mines and mining systems. As noted in Chapter 2, the committee recommends the establishment of a mine warfare battle laboratory, to include competence in mining, in an effort to bring realism to the process. The Navy program and budget process must provide consistent funding support, rather than the "sustenance-or-starvation" funding traditional in mining programs. Funding for developing and deploying proper mining capability is not likely to survive without continued attention from the highest levels of the Navy.

FINDINGS AND RECOMMENDATIONS

Basic Findings

1. The United States has growing strategic interests in the littoral regions of the world where naval mining could be highly effective. Therefore the U.S. Navy has a responsibility to maintain an adequate U.S. mining capability for potential employment as may be directed by the highest levels of national decision making.

2. U.S. capabilities for conducting an effective mining operation are vanishing. The Navy consistently gives little or no priority to mining, and there is no coordinated concept of operations for the use of modern mines. The decline of the U.S. mining capability is evidenced in the aging and decreasing inventories of mines, the absence of an effective mining capability beyond shallow depths, the termination of all mine acquisition programs, the dramatic decline in develop-

ment activity at Navy laboratories, the loss of an industrial base, and the lack of training and exercises.

3. Mine warfare is at a great organizational disadvantage in the Navy and the Department of Defense, and the mining component of that warfare area is at more disadvantage still.

4. Advances in technology now allow for enhanced utility and effectiveness of naval mines, should they be acquired.

Recommendations

Recent budget and programmatic history indicates that the Navy places little value on having a naval mining capability. If mining is not, and will not be, a factor in performing the Navy's mission, then the present decline of capability is appropriate and the inventory and delivery capability should be eliminated in an efficient manner.

However, the committee views mining as an effective and efficient contributor to the Navy's mission and recommends the following.

Recommendation: The United States should reestablish a naval mining capability that is both credible and joint. Such a capability will require overt, covert, and remotely controllable mining. Specifically,

- The CNO should establish and sponsor for joint approval a prioritized set of joint mining system requirements, giving full consideration to the advanced capabilities outlined in this chapter, and should plan an adequately funded program for acquiring them. These plans should extend from individual weapons to minefields designed to accomplish specific purposes. Ultimately, the plans should include overt and covert (submarine) delivery and be applicable to a broad range of water depths. The plans should reflect the results of a systematic cost-effectiveness study of potential future mines, including mines for water deeper than Quickstrike mines. In particular, a new systematic cost-effectiveness study is needed of potential future medium-depth mines for 21st-century missions using 21st-century technology. A new mine is needed to replace the obsolete Mk 56 CAPTOR. The Littoral Sea Mine program was recently canceled and replaced by an unfunded SUBSTRIKE mine program that would be limited to submarine targets.

The recommended study should consider joint warfighting needs with jointly agreed concepts of operation and recommended rules of engagement for promulgation by the National Command Authority. The analysis of this issue should address a full range of missions and a full range of possible mine designs (moored, rising, and so on), including both simple and high-capability mines. Such analyses should be conducted by organizations with no vested interest in the results and should address minefield performance and use measures of effectiveness directly related to the (possibly new) missions, in the context of the Navy's overall concept for undersea warfare and sea control. Consistent with the findings of previous NSB studies,[10] such analyses should fully reflect the configural nature of minefield effectiveness.

The funded program should include explicit plans for retaining a U.S. naval capability, and an associated industrial base, for mine and valid minefield system design, and for acquiring mines deliverable by naval and Air Force aircraft as well as by *Virginia*-class nuclear-powered attack submarines and current attack submarines. If restored, the recently canceled improved submarine-launched mobile mine (ISLMM) could prevent the planned gap in submarine delivery capability. Covert, standoff mining could become an increasingly important tool for 21st-century contingencies.

- The CNO should establish a fast-track program to improve the current Quickstrike shallow water mining capability by developing and acquiring joint direct attack munition, extended range (JDAM-ER) delivery and mine fuzing kits that can target modern, small, surface craft and submarines, in addition to traditional surface ship targets, and that can accommodate remote-control features. A standoff delivery capability for the Mk 62 and Mk 63 Quickstrike-type mines is needed to reduce the risk to aircraft and crews that was evidenced in the Gulf War. Remote control is critical for dealing with issues of policy and legality, for use during crises, or when mines are to be coupled with surveillance of the mined area. Target recognition enhancements are needed to provide a capability against small, high-speed boats and small submarines. Additional algorithm development for, and procurement of, the Mk 71 target detection device would permit engagement of such targets.
- The CNO should ensure that sea mine and valid mining planning tools, including provision for joint mining and minefield control operations, are added to battle group warfare planning capability, and that battle group individual and unit training include realistic exercises that use mining as an extension of battle group capability. The CNO should also reinforce the role of the U.S. Air Force in high-volume mining missions and update the Navy-Air Force MOU to that end.
- The CNO should ensure that the readiness of naval battle group commanders to conduct mining operations is routinely reported in the new mission capability assessment system (MCAS), and that mine delivery is designated a primary mission area requirement reported in GSORTS by appropriate tactical aircraft squadrons.
- In view of the potential importance of maritime mining as a coercive option quite independent of expeditionary warfare operations, the CNO should consider transferring resource sponsorship of naval mining programs to a resource

[10]Naval Studies Board, National Research Council. 1997. *Technology for the United States Navy and Marine Corps, 2000-2035, Vol. 7, Undersea Warfare,* National Academy Press, Washington, D.C., p. 78.

manager with broad policy and cross-platform responsibilities. He should also establish a senior-level implementation agent within the Department of Defense. Key elements of an implementation plan would be operational-level sponsorship by one or more theater CINCs and senior budgetary sponsorship within the Navy, Joint Staff, and the Office of the Secretary of Defense. The existing program executive officer structure should be adequate for budgetary execution.

4

Offshore Countermine Warfare

INTRODUCTION

Today, virtually all U.S. countermine operations focus on waters ≥40 ft in depth. Current carrier battle groups (CVBGs) and amphibious ready groups (ARGs) deploy with capabilities to plan and execute the first four phases of countermine warfare which involve measures intended to prevent mines from entering the water. However, for the most part, these countermine warfare capabilities have not been fully recognized or leveraged, owing primarily to limited mine warfare awareness and expertise in the fleet forces. Most Navy countermine warfare (CMW) effort has been oriented toward the fifth phase—mine countermeasures (MCM).

Seven organic MCM systems are currently under development and planned for fielding with CVBGs and ARGs in the 2005 to 2007 time frame. These planned organic systems, along with current, dedicated MCM systems, are intended to provide the operational commanders with capabilities needed to deal with the mine threat in the littorals and in the operational context described in Chapter 1.

The purpose of these organic systems is to provide an on-scene MCM capability sufficient to attain and maintain sea battlespace dominance across the spectrum of potential conflicts, at times in concert with supporting forces. Additional necessary forces include not only dedicated MCM forces but also joint and fleet assets such as intelligence sources and strike elements. These systems are intended to place an MCM capability in the mainstream of naval warfare, in the same way that antiair and antisubmarine warfare are.

In this chapter, the committee briefly describes and assesses each of these dedicated and organic MCM systems, including its particular operational niche plus any apparent technical and operational issues or constraints. In addition, this chapter addresses shortfalls potentially affecting current and planned CMW systems, and it briefly describes other technical improvements for augmenting fleet offshore MCM capabilities.

Importance of Environmental Data

A few of the key environmental parameters affecting mine warfare operations include:

- *Bathymetry.* Bathymetry determines options for addressing mine threats and can constrain various MCM techniques. For example, there are limits to the water depth at which explosive ordnance disposal personnel can operate, and bottom depth, slope, and roughness conditions affect the ability of mechanical sweep systems to counter close-tethered mines.
- *Sound propagation.* Complex thermal distributions and sound velocity profiles and losses at the boundaries (bottom, sea surface) significantly affect acoustic propagation and hence the detection ranges achievable with various types of sonars.
- *Bottom type and composition.* Bottom type (e.g., hard rock, firm sand, soft mud) largely determines the levels of bottom reverberation, clutter, and roughness, and bottom sediment type and thickness (along with bottom currents) establish the likelihood of mine burial.
- *Nonmine minelike bottom object (NOMBO) density.* Debris and small bottom features influence the mine densities perceived by various active sonars. If too many minelike bottom objects are present in an area and alternate routes are not feasible, hunting there with sonars or mammals is likely to be very slow and sweeping may be necessary. This parameter is highly sensitive to the characteristics of individual sonars including their spatial resolution and signal processing algorithms.
- *Tides and currents.* Currents and tidal conditions can affect the performance of divers or remote vehicles, or even the ability of warships to do controlled, slow-speed maneuvers to avoid detected objects that may be mines. Tidal currents and turbulence also cause natural fluctuations in pressure that can trigger pressure influence mines and promote mine burial.
- *Sea state.* High sea state and wind conditions can increase ambient noise and surface reverberation and clutter; high sea states can also hamper seakeeping and MCM operations by various units and associated systems.
- *Water clarity.* Optical sensor performance (airborne or undersea) can vary appreciably depending on the optical clarity of the sea (e.g., affecting laser propagation and the use of cameras and/or divers to identify minelike objects as either mines or nonmines).

Access to accurate, up-to-date information on environmental features and conditions is essential to effective mining and countermine warfare operations. Mine warfare-specific environmental databases for many areas where the naval forces are most likely to encounter mines have yet to be assembled with the appropriate resolution and made ready for fleet use.

In particular, NOMBO density is not well known in many locales and could vary significantly for a given locale depending on the attributes of a particular sonar. Because of the importance of the NOMBO density parameter, efforts are under way to "bottom map" critical contingency sea lines of communication, port approaches, and operating areas. These efforts are intended to provide detailed bottom characterization as well as NOMBO density data, but partly owing to a lack of funds they have yet to contribute significantly to the overall mine warfare-related database.

An emerging potential use for even more detailed bottom mapping data is in "change detection." This concept envisions the establishment and maintenance of bottom maps that show the precise location of existing nonmine minelike objects in areas of interest. While still in the early stages of development and evaluation, a capability for detection of change may offer significant improvements in operational time lines by allowing MCM forces to quickly discount previously mapped nonmine minelike objects.

Data Collection and Environmental Data Library

Because the effectiveness of countermine warfare is closely tied to knowledge of the environment, the Navy has developed a viable system for cataloguing the environmental data important to mine warfare and is fielding a system for promulgating the database to operating forces. This environmental data access system now also provides mission planning functions, based on the environmental data it has stored for the area of interest in the mine warfare environmental decision aids library (MEDAL). However, because of the newness of the program and the limited resources devoted to data collection, the database is expected to remain relatively sparsely populated for an extended period.

The current mine warfare environmental data collection efforts are largely constrained to specialized Naval Oceanographic Office (NAVOCEANO) survey ships. Although the existing airborne MCM sonar can contribute to these efforts, the current MCM ship sonars have not been adapted for this purpose (e.g., with a capability for recording). For the foreseeable future, NAVOCEANO survey ships will be severely limited in their ability to collect the required data.

As a general matter, CVBGs and ARGs should be equipped (with retrievable systems such as the battlespace profiler) and tasked to collect appropriate temperature, conductivity, water clarity, bathymetry, hydrography, and bottom sediment data on a continuing basis to build the essential, operationally accessible database as rapidly as possible. Forces with organic MCM sonar systems should use these systems continually to collect environmental and sonar data to develop bottom mosaics and locate existing minelike objects and areas with too much clutter for effective mine hunting. With a robust level of such activity, this should be accomplished in a reasonable number of years for possible future operational areas. Similar data should also be collected in denied areas when possible. Finally, bottom mapping initiatives have to incorporate factors such as timeliness, limits on navigational variability, and perishability of the data to "operationalize" this capability. Necessary areas of work to incorporate environmental data in the Navy's mine warfare toolkit are given in Chapter 2.

TECHNICAL CAPABILITIES OF CURRENT AND PLANNED SYSTEMS FOR OFFSHORE MINE COUNTERMEASURES OPERATIONS

Current Dedicated MCM Forces

In 1992, the Navy established a base at Ingleside, Texas, as the homeport and support center for its dedicated mine warfare forces. Repeated concerns have been expressed about potential problems posed by the remoteness of this location. Indeed, the time needed to deploy the most capable U.S. mine warfare forces from the U.S. Gulf Coast to likely areas of urgent need was a major factor in the decision to outfit Navy CVBGs and ARGs with an organic MCM capability. The committee was therefore pleased to note how well the consolidation of the surface MCM force in Ingleside, Texas, has progressed.

The Navy has sponsored and/or conducted recent studies to examine possible follow-on options to the MCM- and MHC-class ships. These relatively new ships are not scheduled to begin phasing out until around 2022, and the committee believes that the most important issue with the dedicated force is the likely need for, and characteristics of, a follow-on mine control ship (MCS) that provides *Inchon*-like capability (see discussion in "Mine Warfare Support Ship" in Chapter 2).

Current Surface MCM

Current surface MCM ships support all of the mine-hunting functions—detect, classify, identify, and neutralize. Only the MCM-1-class ships provide minesweeping capabilities—both mechanical sweeping against moored mines and magnetic/acoustic combination influence sweeps against moored and bottom influence mines. Most of these ships are homeported in Ingleside, Texas, with two MCM-1-class ships homeported in Sasebo, Japan, and two MCM-1 ships and soon-to-be two MHC-51 ships forward-based in Bahrain. Efforts are under way to homeport these four ships in Bahrain.

The relatively new MCM-1 and MHC-51 classes of MCM ships have matured considerably over the past decade after several initial problems were corrected. The officers and crews are competent, knowledgeable, motivated, and well trained. While some ship-class problems do persist and several important planned upgrades have not been adequately funded and thus not implemented, the committee was generally pleased and very impressed with the surface MCM force and how far it has come over the past decade. There remain, however, several issues worthy of note.

Surface MCM Capabilities. The MCM-1 (Avenger class, 14 ships) has the AN/SQQ-32 mine-hunting sonar (in a variable-depth body) for mine detection and classification. It relies on the AN/SLQ-48 tethered mine neutralization system (MNS) to identify and render inoperative any sea mines detected or classified by the AN/SQQ-32 or other mine-hunting sonar system (e.g., the AN/AQS-14 and 20, discussed below in this chapter).

The AN/SQQ-32 mine-hunting sonar is not optimized for harsh littoral environments against stealthy bottom mines. High-frequency sonar upgrades are being considered for these classes, leveraging program developments for SSN-688-class submarines.

Recommendation: The Chief of Naval Operations should continue investigation of the utility and consider incorporation of high-frequency sonar capability in AN/SQQ-32 sonar upgrades if and when deemed advisable.

The AN/SLQ-48 is an unmanned, recoverable, submersible MNS that receives its power and commands from the host ship via a 3500-ft umbilical cable. The AN/SLQ-48 carries high-definition sonar for reacquisition and a low-light-level TV plus floodlights for identification of the target. This MNS places an explosive charge near the bottom or moored mine target in order to destroy the mine in place. Both of these systems, the AN/SQQ-32 and the AN/SLQ-48, are also found on the MHC-51 (*Osprey* class, 12 ships).

For the MCM-1 platform, two minesweeping systems can also be employed for cases in which mine hunting is of limited effectiveness (unfavorable mine-hunting environment) or is not sufficient (unacceptable mine burial given the local bottom type and current assessments). The first sweep capability is the AN/SLQ-37 combination acoustic and magnetic influence sweep system that can be employed in several sweep configurations. This represents the deepest and most powerful influence sweep capability currently available to the Navy. The second sweep capability is the AN/SLQ-38 mechanical sweep capability for cutting the cables of buoyant moored mines that are located relatively close to the surface. A single AN/SLQ-38 sweep width is 250 yd at a speed of about 8 knots and a sweep depth of 5 to 40 fathoms.

In addition, a closed-loop degaussing system (CLDG) is being developed for the MCM-1 that is intended to both lower the ship magnetic signatures and reduce the frequency of calibration at degaussing ranges. The CLDG performance goals will have to be met in order for the Navy to proceed with installation plans.

Finally, an integrated combat weapon system (ICWS) is in development for the MCM and MHC classes that will upgrade the core signal-processing and display equipment to a common console (commercial off-the-shelf open architecture) and integrate all systems on a fiber-optic local area network. This will reduce overall system costs, weight, and space plus improve reliability, maintainability, availability, and C4I interoperability. ICWS represents a relatively low technical risk.

Surface MCM Technical Issues. Development of the ICWS upgrades to MCM-1 and MHC-51 classes of MCM ships has languished and has repeatedly slipped further in the out-years due to resource constraints and lack of sufficient priority. The planned ICWS upgrades to the MCM-1 and MHC-51 classes would significantly improve the overall reliability and mission effectiveness of the ships. A CLDG system to lower and control a ship's magnetic signature is under development for the MCM-1-class ships, but the status of development and the planned installation program appear neither firm nor clear. The operational value of ICWS upgrades and CLDG installation (where applicable) appears to have been underestimated and therefore underfunded.

To remedy this shortfall, the CNO should ensure that the Department of the Navy fully funds, completes development where applicable, and rapidly implements the installation of ICWS in MCM-1 and MHC-51 classes of MCM ships, and CLDG in the MCM-1-class MCM ships.

The MHC-51 *Osprey*-class minesweeper underwent class shock trials in 1995 to 1996, revealing several unexpected shock vulnerabilities, the details of which are generally not well known and not well understood by members of ships' crews (apparently due to a lack of effective dissemination of information). These vulnerabilities appear to remain unresolved. Certain units of the MHC-51-class MCM ships are reported to be particularly vulnerable to lightning strikes at sea, and—related or unrelated—some have a unique and pernicious floating ground problem within the ship. Evidence of this was apparent from the unusual and nonstandard network of grounding wires connecting most equipment on board the ship visited by the committee.

Thus, the committee noted evidence of some lingering, unique, and potentially dangerous materiel problems associated with the MHC-51-class MCM ships that were considered to require immediate attention and clarification.

Recommendation: The Commander, Mine Warfare Command, should investigate the status and arrange to provide permanent corrective action to resolve the floating ground problem on units of the MHC-51-class MCM ships, and to promulgate information on shock vulnerabilities to crews of MHC-51-class MCM ships and formally resolve any outstanding deficiencies shown in shock trials.

Surface MCM Follow-on. The Navy has recently sponsored and/or conducted studies to examine possible follow-on options to the current MCM and MHC classes of ships scheduled for phasing out beinning around 2022. But the committee regards the studies as somewhat premature and believes that the requirements and characteristics for a follow-on MCS and the role of organic MCM systems should be resolved before future requirements and characteristics for other elements of the dedicated force are firmed up as part of a total force structure that incorporates the lessons learned from implementation of organic MCM systems.

Current Airborne MCM

The MH-53E (Sea Dragon) is a multipurpose helicopter employed for vertical replenishment and airborne MCM, with two squadrons of 10 aircraft each operating today. In the airborne MCM role, the MH-53E can deploy the following systems:

- AN/AQS-14 side-looking mine-hunting sonar, capable of mine detection and classification (not identification).
- A variety of minesweeping systems, including the following:
  —Mk 103 mechanical sweep,
  —Mk 104 acoustic influence sweep,
  —Mk 105 magnetic influence hydrofoil sled,
  —Mk 106 combination acoustic and magnetic influence hydrofoil sled,
  —AN/SPU-1/W Magnetic Orange Pipe magnetic influence sweep (for shallow water),
  —AN/ALQ-141 dual acoustic sweep,
  —A/N 37U deep mechanical sweep, and
  —Mk 2(G) acoustic influence sweep.

At less risk from mines than are surface MCM units, the MH-53E often conducts precursor sweeps and reconnaissance operations before surface units are employed. Infrastructure and support costs for operations conducted from a land base, a large-deck ship-base (the *Inchon*), or on a deck of opportunity are very high, especially given the variety of sweeps supported by airborne MCM. Reportedly, these high operating costs have been a principal motivator for moving toward an organic airborne MCM capability using the MH-60S helicopter planned to be routinely deployed with CVBGs and ARGs. However, the sweeping capabilities planned for the MH-60S are relatively sparse in comparison with the capabilities available with and towable by the MH-53E. The MH-53E has a mission time capability in excess of 4 hours per sortie, compared to less than 3 hours for the planned replacement aircraft, the MH-60S. The MH-53E can support more than 25,000 lb of tow tension load, perhaps four times greater the load handled by the MH-60S. The MH-53E can be deployed reasonably rapidly into a theater and, when there, can achieve high area coverage rates with towing speeds on the order of 25 knots.

Airborne MCM Technical Issues. Unless service life extension plans are established to extend its life beyond 2010, the MH-53E helicopters will be phased out of the inventory at that time. Between now and 2010, the MH-53E could effectively employ some planned new organic systems such as the AQS-20 (in place of the AQS-14) and the airborne mine neutralization system (AMNS). Provision of an AQS-20-type mine-hunting capability is particularly important in view of the increasing threat of pressure mines that are not susceptible to magnetic or acoustic sweeping and must therefore be hunted. The AMNS would provide the MH-53E with a neutralization capability. Planned upgrades to the AN/AQS-20X with its electro-optic identification sensor will provide mine identification capability.

However, the MH-60S helicopter has not yet been proven capable of adequately replacing the MH-53E. It would be premature to retire the MH-53E before the MH-60S has been adequately demonstrated as a replacement. Thus the decision to extend or retire the MH-53 in the 2010 time frame will and should be influenced by the success and viability of the MH-60S in the airborne MCM role, and by program decisions related to Navy and Marine Corps heavy lift.

In the interim, the MH-53E aircraft suite should be upgraded selectively (such as by adding the AQS-20 mine-hunting sonar and the AMNS that is in development) and provided with a degree of self-protection (addressed in the next section of this chapter), and its current minesweeping suite should be reduced to its most essential and unique elements (such as the Mk 106 combined magnetic/acoustic sweep and the ALQ-141 dual acoustic sweep).

Airborne MCM Operational Issues. Current airborne MCM systems have a number of operational constraints that limit their flexibility and ease of use. At present, the MH-53E has only mine-hunting reconnaissance capability (no identification and neutralization capability) and therefore must work with surface MCM or other assets (e.g., explosive ordnance disposal) to conduct mine-hunting and clearance operations. For hosting from land or a large-deck ship, significant personnel and equipment are needed to conduct and sustain MH-53E operations, which results, for example, in a high number of maintenance hours for each hour actually flown. Daytime-only operation (the MH-53E does not currently conduct airborne MCM operations at night) and potentially long transit distances (associated with land basing) also reduce overall area coverage rates achieved. In addition, the MH-53E does not currently have beyond-line-of-sight data transfer capability, so that largely postmission analysis must be conducted of its mine-hunting sonar contact data.

Several of these operational constraints (limited basing options, mine clearance capability, data transfer constraints) for the present MH-53E will be resolved by planned upgrades to the MH-53E or, in the case of basing constraints, by fleet introduction of the organic MH-60S.

These airborne MCM helicopters have significant vulnerabilities. They are particularly vulnerable to attack because they are constrained in maneuverability when towing. They must sometimes operate within easy range of well-hidden shore-based, hostile units. When towing they are constrained to a fixed altitude and speed, forming an easy target for even rudimentary surface-to-air weapons. Their survivability can be enhanced by the incorporation of any of several available systems, such as an electronic support measures suite, that will provide warning of such attacks. The general trend toward naval operations in littoral waters suggests that current and future helicopters for airborne MCM will be increasingly subject to attack by hostile aircraft, helicopters, small craft, and shore-based antiaircraft units equipped to fire heat-seeking or radio frequency (RF) homing missiles. The vulnerability of these helicopters could be mitigated by the addition of self-protection equipment such as chaff, flare, and decoy dispensers, and active infrared (IR) and RF countermeasures, that are readily available and standard equipment on many other types of helicopters.

Existing Undersea MCM Capabilities

Currently, the explosive ordnance disposal (EOD) diver system and marine mammal system (MMS) play key roles in offshore mine warfare operations. EOD MCM detachments are employed to identify, neutralize, and exploit mines as well as participate in post-interdiction intelligence collection. The recovery and exploitation of hostile sea mines support responsive, effective, threat-oriented influence sweep operations.

Key diver equipment includes the Mk 16 underwater breathing apparatus and the AN/PQS-2A diver hand-held sonar. The MMSs are bottlenose dolphins specially trained for mine detection and neutralization. The Mk 4 dolphins detect, classify, and attach charges for neutralization on the cable of buoyant, moored mines; the Mk 7 MMS variant detects, classifies, locates, and marks or neutralizes bottom mines. The Mk 7 also provides the only currently operational (and reliable) buried-mine detection capability in existence anywhere.

Undersea MCM Technical and Operational Issues. Small unmanned undersea vehicle (UUV) systems that are under development as part of the undersea MCM toolkit will eventually augment or replace the EOD divers for detection, reacquisition, localization, and neutralization of mines, particularly in the very shallow water regions. These and other systems in development (AMNS, RAMICS) may also augment or replace divers in the mine neutralization role.

Compared to surface MCM and airborne MCM sonar systems, MMSs currently have relatively low area coverage rates. However, because of their excellent discrimination capabilities, MMSs can do certain MCM tasks very well (e.g., ensure a high probability of detection, operate in the VSW region, detect buried mines, and operate effectively in areas with high NOMBO densities). The MMSs require unique logistics support, including food to sustain the mammals. Divers, on the other hand, are limited by the number of deep dives they can perform over a given period and are more adversely affected by strong currents or other environmental factors.

The major operational issue with the EOD/VSW diver and MMS force is the very small number of existing and planned units, compared with the potentially large demands for rapid clearance of an amphibious landing zone. Unless (or until) the Navy fields an alternative system such as UUVs, reliance on the planned small EOD/VSW force structure will either limit the size of future assaults against potentially mined littorals, or increase the time required to support large assaults.

Finally, mine exploitation, a unique EOD capability, is critical to support operational planning (by determining mine settings and actuation mechanisms on recovered mines) and to enable development of future MCM system capabilities against an evolving threat. As mine technologies evolve to include microprocessor settings and logic mechanisms, traditional means for exploiting mines must likewise evolve (as discussed in the section "Science and Technology Initiatives" below in this chapter).

Naval intelligence must give mine exploitation efforts greater priority than is apparent today to ensure that the widest possible information base is available for developing effective minesweep capabilities and to provide on-scene mine-setting information critical to operations.

Seven Planned Organic MCM Systems

The seven planned organic MCM systems and their capabilities are summarized here.

Long-term Mine Reconnaissance System

The long-term mine reconnaissance system (LMRS) is a submarine-deployed (through the torpedo tubes) autonomous UUV that will be capable of mine reconnaissance. LMRS relies on ahead-looking search and side-looking classification sonars; there currently are no plans to add an optical sensor for mine identification. The system also employs RF and acoustic data communications on a limited basis (with most data collected by LMRS not available until the vehicle is recovered by the host platform). LMRS represents the only fully clandestine mine reconnaissance capability among the organic MCM initiatives. Depending on the reliability of other intelligence information concerning the existence and location of hostile minefields, LMRS could prove critical for reconnaissance prior to an amphibious assault (e.g., in $\geq$40 ft of water inside the ground-based radar horizon of a potential adversary) in order to select optimum transit or assault lanes without compromising operational security. Its clandestine operation would also be of value for reconnaissance in contested areas (where more-observable MCM assets would be at risk) or in support of achieving U.S. submarine "assured access" in potentially mineable locales. The LMRS's initial operational capability (IOC) is planned for 2003.

Planned Capabilities for LMRS. The nominal single-vehicle endurance is 40 to 62 hours with an associated vehicle sortie reach of 75 to 120 nautical miles, i.e., the maximum distance from the host submarine that the UUV can be expected to conduct mine reconnaissance operations and still be recovered. An LMRS system on a host submarine would include two UUVs plus two energy-source replacements for each vehicle that would allow at least six sorties, yielding a total system area coverage of up to 400 to 650 square nautical mines (after all sorties). Planned procurement includes up to twelve systems. Potential upgrades under consideration for LMRS include precision underwater mapping to improve ahead-looking sonar performance in high-clutter environments and to allow more precise mapping of bottom objects and bathymetry. Other potential upgrades include advanced renewable energy sources (replenished rather than replaced), synthetic aperture sonar for high-fidelity classification at significant ranges, and improved acoustic communications.

Technical Issues for LMRS. Meeting mission reliability goals for an autonomous ≥40-hour mission is one engineering challenge. Others include achieving reliable launch and recovery from the submarine torpedo tubes, meeting ambitious goals for reduced radiated noise to allow close operations near mines without causing detonation, certifying an advanced high-density primary battery for submarine use, and developing effective computer-aided detection/computer-aided classification (CAD/CAC)-type algorithms for the ahead-looking sonar (for managing the clutter and achieving a high rate of detecting actual versus possible mines).

Operational Issues for LMRS. LMRS is considered a contingency system that would be employed as needed; i.e., not all submarines operating with or in support of battle groups would be routinely equipped with LMRS. Two other primary operational issues are associated with LMRS:

1. Nets (e.g., fishing related) can pose a significant obstacle for UUVs and must be accounted for in LMRS mission planning and in any inherent obstacle-avoidance capabilities on the vehicle.
2. Lacking an identification capability, LMRS is intended to find gaps to exploit, high-clutter regions to avoid, or suspicious patterns of objects to avoid or investigate (possibly based on "change detection" approached by comparing LMRS contact information with previous maps of bottom objects for a given

locale). The ability to beneficially exploit pattern recognition or change detection techniques when interpreting LMRS reconnaissance information must be demonstrated.

Remote Mine-hunting System

A semisubmersible vehicle launched and recovered by a surface ship, a remote mine-hunting system (RMS) tows a mine reconnaissance sonar. RMS(V)4, designated the AN/WLD-1(V)1, is being developed for deployment on the DDG-51-class destroyers (beginning with the DDG-91). An RMS-like off-board mine reconnaissance capability may also be required for the DD-21. The key components for RMS include the following: a remotely controlled, semi-submersible diesel-powered UUV; a variable-depth sonar (VDS) based on the AN/AQS-20 system featuring ahead-looking search sonar, volume search sonar, side-looking classification sonar, and an electro-optical identification (EOID) sensor; a mission control and display integrated into the SQQ-89(V)15 undersea combat system on the DDG-51; a launch and recovery subsystem plus maintenance/stowage area; and a data link subsystem for both line-of-sight (LOS) and over-the-horizon (OTH) communications. RMS is a low-observable vehicle and is capable of semiautonomous operations. Much of the contact information from RMS would be communicated back to the host ship during the conduct of a mission. In this regard, LOS operations are preferred for RMS, but OTH operations can be accommodated as necessary.

RMS can be employed for any mine reconnaissance missions in ≥30-ft depths that do not require a high degree of covertness. These include fleet operating areas, naval surface fire support areas, theater ballistic missile defense (TBMD) patrol areas, Q-routes, straits, choke points, and approaches to various operating areas (e.g., an amphibious objective area). Because of its easily refueled diesel engines, RMS is potentially a workhorse system. With its inherent identification capability, RMS can be used to directly support mine clearance operations conducted with other assets such as the MH-60S helicopter with its airborne mine neutralization system. In addition, its reconnaissance information can be used to establish areas to avoid (due to the presence of one or more mines or the presence of numerous minelike objects) or to determine "safe" routes or operating areas (when no mines are found).

Technical Issues for RMS. Engineering challenges include achieving desired high duty cycles, demonstrating reliable launch and recovery (L&R) techniques even in high sea states, meeting signature reduction goals to allow safe operation in the presence of mines in water as shallow as 30 to 40 ft, and demonstrating the ability to convert own classified minelike contacts into rapid EOID reacquisitions under various turbidity conditions.

Operational Issues for RMS. Nets, cables, nonmilitary shipping and other obstacles, or even piracy of the unit can potentially cause premature mission abort (or even loss of the vehicle system) for RMS unless some combination of mission planning and reliable obstacle-avoidance capabilities on the vehicle itself can mitigate the risk. The reliability of OTH operations for RMS needs to be demonstrated for cases in which the host ship would prefer large standoff distances from the vehicle (either for its own safety in a potential mined area or due to other mission requirements). For large operating areas such as those associated with a CVBG where there may be far too many minelike objects to identify them all, then other techniques for exploiting RMS reconnaissance information (e.g., pattern recognition, change detection) must be demonstrated.

While the Navy's plans for incorporating RMS in various surface combatants addresses CVBG and standing naval force (i.e., the Middle East Task Force) organic MCM needs, the committee noted no Navy plans to incorporate RMS or organic airborne MCM in ARG forces.

MH-60S Airborne MCM Suite of Five Systems

The MH-60S is the Navy's designated organic airborne MCM platform and, as a system, represents the only end-to-end organic airborne MCM capability (mine detection through neutralization). The MH-60S platform, a derivative of the MH-60 series of helicopters which operates from ships, will host, one at a time, five separate airborne MCM systems (all currently at varying stages of development) within a common architecture. Airborne MCM is just one mission for the MH-60S, along with other intended missions of combat search and rescue, special warfare support, and vertical replenishment. The MH-60S will achieve IOC in 2001, and the various airborne MCM components will achieve IOC between 2003 to 2007, depending on the specific system. The five airborne MCM systems are as follows:

1. **AN/AQS-20X.** The AN/AQS-20 is a towed mine-hunting system that includes ahead-looking search, volume search, gap-filler, and side-looking classification sonars. It provides increased area coverage rates and better clutter management techniques compared to the existing AN/AQS-14A system on the MH-53E helicopter. The AN/AQS-20X variant of the system will be compatible with the MH-60S helicopter and will provide an identification capability; it is also the system planned to be adapted for use on RMS. The AQS-20X should achieve IOC in 2003.

Technical Issues for AN/AQS-20X. A key engineering challenge includes enhanced CAD/CAC algorithms to achieve reduced false contact rates without adversely affecting desired area coverage rates (and a high probability of detecting actual mines). Other challenges relate to both integrating an EOID capability into the towed body, as constrained for the MH-60S, and achieving rapid and reliable reacquisition with the EOID sensor. Also, some reliability issues have been identified for the AQS-20X that will have to be resolved.

2. **Airborne Mine Neutralization System (AMNS).** AMNS is an expendable, remotely operated, mine neutralization device compatible with both the MH-53E and MH-60S helicopters. It is designed to reacquire and neutralize (with a shaped charge warhead placed very near a previously identified mine to cause high-order detonation) both bottom and volume mines, excluding the mines found very near the surface. Relying on an adaptation of the German SEAFOX neutralization device, it is expected to achieve IOC in the 2004 to 2005 time frame. Either the AN/AQS-20X or the RMS could provide the initial mine classification and identification that cue the AMNS prosecution.

Technical Issues for AMNS. Deployment of AMNS from the MH-60S, including associated munitions certification tests, must be demonstrated. The underwater tracking system deployed by the helicopter to guide the mine neutralization device must be reliable and must result in rapid, achievable mine neutralization.

3. **Organic Airborne and Surface Influence Sweep (OASIS).** OASIS is intended to provide the only organic MCM influence sweep capability; it is compatible with the MH-60S helicopter and potentially with surface MCM units as well. OASIS should achieve IOC in about 2005 and the towed system should be capable of transport by and deployment from the MH-60S with only modest handling equipment (due to its reduced size and weight compared to other existing airborne MCM sweep equipment). OASIS includes a towed magnetic and acoustic source (in one towed body), a tow/power-delivery cable, a power-conditioning/control system, and an external power supply (from the helicopter). OASIS will be towed at appropriate depths to optimize sweep performance against various mines in shallow water environments.

Technical Issues for OASIS. Engineering challenges include achieving adequate magnetic output from the small towed body (using available electrical power from the MH-60S down the tow cable), ensuring the ability to survive shallow water detonations from various mines (e.g., by designing adequate hardness/shock-factor resistance into the system), and achieving appropriate tow depths and speeds to effectively sweep certain difficult shallow water bottom influence mines.

4. **Airborne Laser Mine Detection System (ALMDS).** ALMDS is an electro-optical-based mine reconnaissance system capable of rapid detection, localization, and classification of mines on or very near the sea surface, i.e., floating and drifting mines or moored mines (contact or influence) at the top of the water column. It relies on a downward-looking blue-green LIDAR (light

detecting and ranging) system, will be compatible with the MH-60S, and should achieve IOC by about 2005.

Technical Issues for ALMDS. Engineering challenges include achieving desired or acceptable false contact rates without adversely affecting desired area coverage rates (and a high probability of detecting actual mines), achieving adequate depth coverage under likely conditions of optical clarity, and relying on the effectiveness of pattern recognition contact sorting techniques during precursor reconnaissance operations over large operating areas (if, e.g., there is inadequate time to allow for separate investigation of all contacts detected and localized by ALMDS).

5. **Rapid Airborne Mine Clearance System (RAMICS).** RAMICS is a gun system designed to rapidly reacquire, target, and neutralize floating and near-surface moored mines found in the upper portion of the water column. The system will rely on a laser system for targeting and directing the fire of super-cavitating, water-penetrating projectiles that are intended to either deflagrate (which is preferable, to allow battle damage assessment) or sink mine targets. The gun/turret system needs to be demonstrated to be compatible with the MH-60S helicopter. RAMICS will often be responding to contacts generated as a result of ALMDS reconnaissance missions. RAMICS IOC is unlikely to occur before 2007; it is the least mature of the five airborne MCM systems in the MH-60S suite.

Technical Issues for RAMICS. Engineering challenges include establishing a gun and turret installation concept for the MH-60S that minimizes the impact on the aircraft in terms of loads, recoil, flight dynamics, and so on; achieving required overall system errors (including helicopter-induced errors); achieving deflagration at desired mine case depths and against mine types with large case thicknesses; and establishing safe helicopter standoff distances from floating or very-near-surface mines without a catastrophic reduction in performance (e.g., the need for excessive expenditures of rounds required to achieve desired damage against targets at associated standoff ranges).

Overall MH-60S Integration. Engineering challenges associated with integrating all five systems on the MH-60S helicopter include providing a common console and display that accomplish all the needed functionality for each of the systems, as well as simplifying installation and deployment by having all five systems rely on a common carriage stream and recovery system. Both of these integration issues will influence how rapidly reconfigurable the MH-60S is when switching from one airborne MCM mission to another and to other multimission roles. Target transition times were not identified for the committee. Given C4I considerations, integrating the MH-60S airborne MCM systems into the combat systems of several classes of ships, including amphibious ships, also must be the focus of a significant effort.

Operational and Technical Issues for the MH-60S. The MH-60S tow test results (in preparation for integration of the AQS-20X and OASIS) to date have been encouraging (acceptable tow tensions have been apparent) and ideally will result in approaches that maximize helicopter time on station and minimize long-term wear and tear on the aircraft.

The potential basing options for the MH-60S will greatly influence its ability to perform various airborne MCM tasks without excessive flight hours and sorties. An MH-60S capability to effectively "lily pad"/cross deck from small combatants (e.g., destroyers) would greatly reduce the helicopter's transit distances for certain operational settings, allowing the MH-60S to be more aggressively employed. The true degree to which lily-pad/cross-deck operations can be relied on needs to be firmly established. When operating from small combatants, it needs to be determined whether it is possible to rapidly reconfigure between airborne MCM missions or whether it is necessary to effectively swap aircraft (between the CVN primary host and the small combatant).

The MH-60S will have five of the seven signature systems that constitute the bulk of what represents the transition to organic MCM in the fleet. As the "long pole in the tent," it is important that MH-60S airborne MCM capabilities be as operationally flexible and adaptive as possible.

Recommendation: The Navy should give increased attention to the overall airborne MCM system capabilities of the MH-60S, with particular emphasis on ensuring both rapid reconfiguration from one MCM mission to another in a representative operational environment and reliable and flexible hosting (basing and support) alternatives within deployed forces. At a minimum, the MH-60S operations should be supportable (fuel, other expendables, data links, shipboard signal-processing and display consoles) by all DDG-51s, the DD-21, and all large-deck amphibious ships, including the new LPD-17 *San Antonio* class. The associated ship and/or helicopter engineering changes required to implement the intended operational concept need to be identified and funded.

SHORTFALLS AFFECTING CURRENT AND PLANNED OFFSHORE COUNTERMINE WARFARE SYSTEMS AND INITIATIVES

Based on the sum total of the briefings received by the committee on the various aforementioned systems and programs related to offshore countermine warfare, several apparent shortfalls were evident.

Lack of an Overarching Concept of Operations

An overarching concept of operations (CONOPS) for future countermine warfare forces in the era of mainstreaming mine warfare capabilities must be established. This CONOPS must reflect basing and logistics support limitations, as well as the potential for various missions to make conflicting demands on host platforms. The combined dedicated and organic MCM capabilities must be optimized with a systems view of how to best exploit the emerging organic MCM technologies in conjunction with the legacy MCM systems. For example, large-deck ships with their higher signatures would be expected to be held well away from suspected mine threat locales until the risk from mines was significantly reduced. As a "work-around," the MH-60S operated from smaller combatants (cross-deck or lily-pad operations) is a potentially significant force multiplier, but one that depends on the resolution of numerous operational and technical issues.

Four separate mine warfare CONOPS efforts were identified by the committee—a fleet mine warfare draft CONOPS largely addressing command and control issues (under review), a mine warfare-amphibious warfare draft CONOPS addressing MCM in support of amphibious assaults (currently under consideration in the fleet), a draft CONOPS document for the MH-60S (under review), and the standard CONOPS for current dedicated MCM forces (in place).

Based on the briefings received, several observations are in order:

- Potential paradigm shifts are expected in the use of mine reconnaissance information to reduce time lines, assuming adequate data collection and processing, including development of pattern recognition or "change detection" methods and associated tactical decision aids.
- Education of senior commanders, staffs and even political leaders is needed to enable them to recognize how mining and countermine warfare affect their planning and execution of operations, to ensure that appropriate and realizable ROE are adopted, and to reduce unrealistic expectations.
- The benefits and limitations of real-time mine detection and avoidance techniques used by individual warships have to be better understood.
- Maneuver guidelines and constraints for battle groups operating in mineable waters prior to completion of countermine warfare operations are needed, whether or not mines have actually been identified (found).
- Safe water depths for various warships facing bottom mines have to be better understood, based on realistic knowledge of threat actuation mechanisms and the warships' signatures.
- Procedures for selecting the best route based on knowledge of the bottom, the environment, ship signature, water depths, general shipping patterns, and other factors need to be promulgated to the fleet.
- The best command and control structure for countermine warfare in various operational settings needs to be established to ensure adequate planning and execution of countermine warfare operations.
- Consideration should be given to what portion of the overall MCM tasking in-theater would be reasonable for organic MCM (versus dedicated MCM) assets to address.

• CONOPS should be modified as experience with the new organic MCM systems is gained.

Organic MCM will have significant responsibilities for reducing the threat from mines in critical areas that may include strategic sea lines of communication (SLOCs) and ports, fleet operating areas, warship patrol areas, and during fleet/ warship transits. Dedicated MCM will have significant responsibilities for post-amphibious assault follow-on clearance and large area, post-conflict clearance ("cleanup") operations. For example, what balance of organic MCM versus dedicated MCM efforts are required for clearance of strategic ports (e.g., for high value maritime pre-positioned ships early in a contingency and for follow-on/ sustaining strategic sealift that comes later)? What organic MCM versus dedicated MCM balance is required for clearance and response to potential reseeding of crucial SLOCs? Will the CVBG commander and the CINC be on the same page if realistic CONOPS are not developed prior to potential conflicts? Overarching CONOPS should reflect appropriately high priority for national, theater, and tactical ISR and interdiction assets, the likely phasing of MCM assets into the theater, basing constraints, conflicting multimission obligations, and other key factors. The mine warfare-related CONOPS documentation reviewed by the committee left these fundamental issues largely unresolved.

Lack of an End-to-End, Overall Systems Approach for the New Organic Systems

Many individual systems were briefed to the committee, each with its own technical and operational challenges as described above. Before they can take on a significant share of the overall MCM tasking, these organic MCM systems must be demonstrated and the capabilities fielded in adequate numbers. However, even if all of the system-specific technical and operational issues can be overcome, the full benefits from these technology developments are not likely to be realized until corresponding developments occur in a number of key countermine warfare support areas:

• Manning and unit/force countermine warfare training concepts must be developed that are compatible with the host platforms—surface combatants, aircraft, and submarines. For example, integrating an RMS-type capability (operations, maintenance) on a DD-21 could prove very challenging, given the many other mission obligations of a crew of roughly 100. The committee saw little evidence that, in the limited planning to date for the fleet introduction of the new organic MCM systems, the likely future limitations on manning of afloat units has been seriously considered.

• The mine threat must be better understood, including future trends in stealth design, actuation mechanisms, and so on. It is crucial that MCM efforts not lag the emerging threat characteristics (albeit without becoming unaffordable from excessive mission and/or requirements "creep").

- The littoral environment where mines are expected must be better characterized and understood, to ensure the ability to exploit both previous environmental survey information and in situ measurements during actual contingencies in order to optimize countermine warfare operations.
- Mine warfare forces have to be better integrated into the joint maritime command information system (JMCIS). Progress has been slow in this area. C4I systems to allow near-real-time tactical planning and coordination of diverse MCM-capable elements (surface and airborne MCM, EOD, submarines, surface combatants) are currently not available. Effective C4I will also be critical to future mine warfare operations to ensure that a fused common operational picture can be developed from all source information (national and theater intelligence, surveillance, and reconnaissance data; environmental and bottom mapping data; and diverse tactical MCM sensor contacts) and that appropriate force protection measures can be taken. Future planned upgrades for connectivity and communications should realistically reflect multiwarfare and multiservice competition for bandwidth.
- The MCS-12 and surface MCM units (MCM-, MHC-class ships) should be upgraded to a Link-16 capability similar to that of other naval joint force elements. In addition, the emerging organic MCM systems must be designed to effectively leverage future JMCIS C4I developments.
- The commander in chief should be made aware long before a contingency occurs of the crucial role that joint forces can play in facilitating successful countermine warfare operations by providing timely access to national or theater ISR assets, offensive strikes against mine stockpiles and minelayers, interdiction of suspicious ships under way, and suppression or rollback of adversary sea-denial forces. The last two joint contributions would depend significantly on the rules of engagement.
- Inventories of expendable and nonexpendable MCM systems should be adequate, reflecting both intended rates of use for various contingencies and potential losses to mine and nonmine threats based on realistic assessments (red team) of vulnerability to these threats. An independent vulnerability assessment for key organic MCM systems (MH-60S, RMS, LMRS) appears warranted.[1] It would examine adversary countermeasures to these systems as well as other potential vulnerabilities, review signature goals for off-board vehicles' avoidance of mine detonations, and examine possible approaches to countering "cheap kills" (e.g., from nets and obstacles). The CNO should form a red team to conduct such

[1]The Navy-sponsored MCM Force-21 study that reinforced the need for the seven organic and dedicated MCM systems did not evaluate systems' vulnerability to mine or nonmine threats (including adversary defenses). This was a major gap that has not been addressed subsequently.

an assessment as a step toward ensuring that planned inventories for key organic and contingency MCM systems are adequate.

Absence of End-to-End, Overall MCM or Countermine Warfare Requirements

Nowhere in MCM-system level operational requirements documents (ORDs) briefed to the committee were overall MCM or countermine warfare force requirements stated that effectively rolled-up the individual "stove-pipe" system requirements. An MCM capstone requirements document (CRD) that attempts to quantify overall MCM force required capabilities (e.g., the area clearance required within a given CONOPS time line, with an acceptable level of residual risk) would address MCM requirements. CRDs have served other warfare communities well and are a key method to honestly establish "how good is good enough" and whether deficiencies still exist. Absent end-to-end, overall requirements, it is difficult to ascertain whether the collection of system ORDs will be sufficient to accomplish MCM tasking in various scenarios.

Equally important is the development of a set of threat-oriented design reference missions (DRMs) for MCM. The DRMs, which would define the problem set in terms of which the CRD thresholds and objectives could be evaluated, would characterize mine threats, littoral environments, flow of forces into theater, and other details needed to assess design and concept trade-offs for MCM. With DRMs approved and in place (and periodically updated), proposed MCM initiatives could be assessed for the value they add to this set of DRMs. What investment balance is required, for example, in increased force structure, improved training, enhanced C4ISR, improved basing, lift, and logistics, and advanced technology developments for mine hunting and clearance and for ship self-protection? If done well, DRMs could provide a needed analytical basis (along with CRDs) for the development of effective future MCM investment strategies and could help ensure that the Department of the Navy obtains an optional return on dollars spent for an enhanced countermine warfare capability.

The Department of the Navy has developed a draft capstone requirements document for the overall MCM forces that is undergoing review, and it is in the process of developing a set of design reference missions for MCM that will define the operational scenarios against which the CRD goals can be evaluated. It is also revising the airborne MCM ORD to better specify which naval platforms will need to host and/or support MH-60S airborne MCM operations in the future. This ORD will be under review both within and outside OPNAV during calendar year 2001.

Approved MCM force-level requirements and operational scenarios can help in establishing whether deficiencies exist from a total countermine warfare force perspective.

Recommendation: The Department of the Navy should finalize efforts to establish countermine warfare force required capability goals related to key naval planning scenarios, and to come to a definitive closure on future airborne MCM basing and support requirements. Broader countermine warfare requirements for ISR, indications and warning, interdiction, and post-interdiction intelligence collection should be addressed in these multiwarfare requirements definitions, treated similarly to the other key warfare areas.

Lack of an Overall System Architecture

Each of the systems briefed to the study group has clearly undergone a systems design process in which its impact on, and the impact of, the host platform have been considered. It is not as clear, however, that the new systems have been considered within the constraints implied by the other six new organic systems. Individual systems and programs appear to be addressing various technical issues related to communications and interoperability, environmental databases, navigation/position errors for sensor contacts, type of sensor information that would be stored/disseminated, CAD/CAC algorithms and associated thresholds for detection and classification, and so on. An overall MCM systems architecture is needed to ensure that common standards are adopted, or that different standards applied to various systems will not impede the interoperability of the overall MCM system of systems. The MCM architecture should ensure the utilization of common components and subsystems such as displays, data formats, commands, operating procedures, maintenance, storage, and spares. It should establish the formats, rates, quantity, and quality of data as well as the interfaces between various communication systems that transfer the data to established databases.

With the introduction of organic MCM into the fleet, seven new systems must be integrated into a diverse fleet of ships and sailors. The technical and social infrastructure of the fleet will be affected by the introduction of these new systems. The impact on fleet readiness should be as minimal as possible and should not recur with the introduction of each new system. It is imperative that these seven systems share a common MCM systems architecture that accounts realistically for differences between the new technology and the existing systems and procedures on board the various ships and facilitates their integration. Compatibility with MEDAL should be a given.

Addressing the Shortfalls

Recommendation. The U.S. Navy should improve the overall integration of its seven organic offshore mine countermeasures (MCM) systems that are currently in development. Improvements should include (a) developing and promulgating an integrated countermine warfare concept of operations and a total system architecture, (b) testing and evaluating the resulting integrated capabilities at sea, and (c) extending the application of the new systems to the amphibious force. Specifically,

- The CNO should develop and promulgate a countermine warfare concept of operations and a total system technical architecture that includes all the legacy dedicated MCM systems and the new organic MCM systems and subsystems and other upgrades that will be fielded. As part of this effort, the planned integration of organic MCM systems into the fleet should be extended to include amphibious ships as well as battle group combatants.
- The CNO should designate a single official to design a detailed program plan for integrating the seven MCM systems that are in development, and others that may follow, into battle groups and amphibious ready groups. The plan should include manpower and training, interaction with other combatant systems, logistics support plans, provision for accommodating MH-60S contingents on CVNs and aviation-capable amphibious ships as appropriate, and qualification of all combatants that will have a latent capability to operate the MH-60S to actually do so.

ADDITIONAL TECHNICAL IMPROVEMENTS TO FLEET OFFSHORE COUNTERMINE WARFARE CAPABILITIES

High-frequency Sonar Developments on Warships

Both submarines and surface combatants are equipped with hull-mounted mine detection sonars that can be used for real-time detection and avoidance of mines and minelike objects (in terms of sonar system thresholds). The AN/BQS-15 sonar on SSN-688-class submarines is being upgraded (engineering change 17, EC-17) with enhanced CAD algorithms and target-height-above-bottom measurements for the ahead-looking search sonar. The EC-18 variant of the AN/BQS-15A on SSN-688s and the AN/BQQ-10 Phase IV on improved SSN-688s (SSN-688I) will provide precision underwater mapping (PUMA) capability for the ahead-looking sonars, i.e., high-resolution bathymetry, MCM contact maps, precision ground reference navigation, and real-time map data merging and management. Most SSNs are scheduled to have this capability by around 2005. The NSSN (*Virginia* class) is scheduled to get both a sail array and a chin array with similar bottom-mapping and mine-detection/avoidance capabilities. The chin array is referred to as the advanced mine detection system (AMDS) and is intended to enhance mine detection performance in shallower waters (with a uniquely located, high-frequency, ahead-looking search sonar). All of these submarine sensor improvements are designed to produce MEDAL-compatible mine warfare data for entry into the MEDAL data system.

A system similar to AMDS may ultimately be installed on new-construction surface combatants (e.g., the DD-21) and would represent a marked improvement over existing "Kingfisher" systems (adaptation of SQS-56 and SQS-53 sonars for mine detection). The Kingfisher system has only limited detection capability against bottom mines.

Technical Issues for Future High-frequency Sonar Upgrades on Warships

Engineering challenges include first and foremost the development of CAD/CAC algorithms to reduce false contact rates to acceptable levels and to achieve reliable detection of actual mines (including low-target-strength mines in adverse/high-multipath environments). In addition, if PUMA-based ahead-looking search sonars are used for conducting surveys of bottom contacts in a region, it may prove technically challenging to fuse this information with data from side-looking classification sonar surveys in the same locale (due to differences in navigation errors and sonar resolution between these diverse sensors).

Operational Issues for Future High-frequency Sonar Upgrades on Warships

It is crucial that warship commanders know when (and how) to rely on hull sonars for real-time detection and avoidance of objects that may be mines. If a particular sonar cannot reliably detect and classify actual bottom mines (moored mines away from the bottom or surface are much easier to detect) at acceptable standoff ranges in a particular littoral environment, then reliance on extensive mine-detection/avoidance maneuvers may actually increase the risk to the ship. In other words, too much time may be spent maneuvering in the vicinity of mines that cannot be detected reliably or with adequate warning to allow execution of planned maneuvers. Maneuvering a warship correctly at slow speeds in the presence of strong currents can also prove challenging.

Ship Signature Reduction Developments on Warships

Developments in advanced degaussing and advanced acoustic quieting techniques deserve mention. Quieting techniques are routinely included in the design of U.S. naval warships. Signature reduction is intended to reduce the likelihood of mine actuation; however, any actuations that do occur may occur in closer proximity and thus with greater explosive impact to the ship. Advanced quieting techniques are expected to be included in the new DD-21, *Zumwalt* class of land attack destroyers. Initial analysis for DD-21 suggests that the benefits of reducing actuation from advanced acoustic silencing and advanced degaussing outweigh the increased lethal effect (of shorter ranges given an actuation).[2]

Advanced signature reduction and control techniques (magnetic, acoustic) have always been included in the design of U.S. submarines. The new SSN (*Virginia* class) will feature acoustic and magnetic signature reduction advances beyond those in the current SSN-688 (*Los Angeles* class), i.e., will incorporate stealth technologies similar to those of submarines in the *Seawolf* class.

Operational and Technical Issues for Ship Signature Reduction Developments on Warships

To maintain their designed signatures, warships (submarines and surface combatants) must be well maintained, and those with magnetic signatures must periodically pass through USN degaussing ranges (a half dozen are located at various continental United States bases plus Hawaii and Yokosuka, Japan). Two portable degaussing and acoustic ranges are located overseas (in Sasebo, Japan, and in Bahrain) for surface MCM units (MCM-, MHC-class ships). The availability of such ranges has suffered in recent years as needed O&M funds have been diverted to meet more urgent needs.

It is generally recommended that warships operating in mineable waters operate at low speeds (less than 5 to 10 knots) to reduce their acoustic and pressure signatures. Unfortunately, significant advancements in warship signature reduction against undersea threats, or hardening (to absorb hits with less damage), can usually be accomplished only for new-construction ships (i.e., only small to moderate signature reductions are possible as part of back-fit programs), and then usually at much expense, thus raising issues of affordability for new-ship designers.

Recommendation: The CNO and fleet commanders should ensure continuing attention to and maintenance of design acoustic, magnetic, and underwater electric potential signatures of all hulls. Updated data, charts, and decision aids showing operating conditions to protect against influence mines should also be available and understood on all naval platforms. This effort would require routine signature measurement and assessments of individual hulls as well as an understanding of signature expectations for ships of a class, and correction of signatures that noticeably increase the risk from mines.

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[2]Edlow, Sabrina R., and Rodger E. Poor. 1998. *SC-21 COEA Part II Results: Sea Battlespace Dominance/Mine Warfare* (U), CRM 97-45, Center for Naval Analyses, Alexandria, Va., January (classified).

Science and Technology Initiatives

The results from several crosscutting S&T programs—especially investigations focusing on synthetic aperture sonar and UUV technology—will have a positive impact on reducing the current gaps in capability for both the offshore and inshore regimes. The electrical resistivity techniques, mentioned in Chapter 5, when applied using UUVs, could well contribute to capabilities required in the offshore areas. Similarly, efforts to understand and duplicate the mine-hunting capabilities of dolphins and other biological creatures would have a broad impact.

Detection and Classification of Buried Sea Mines and Higher-Resolution Mine Detection

The detection of buried mines is currently accomplished effectively only by the marine mammal system, but at a rate far slower than what is desirable. The system also requires that mammals and people be placed in harms way. Eventual replacement of mammals with systems that can accomplish the detection of buried mines has been the goal of a number of research efforts over the years but, as yet, no such systems exist.

One of the new systems for addressing this issue is synthetic aperture sonar (SAS). By processing data to account for the motion of an acoustic array, it is possible to acquire very-high-resolution acoustic data from a relatively small array and thus increase the ability to detect and classify water column objects, bottom, or even buried objects. If such a system is integrated with a UUV, the quality of the data may be further increased (due to smaller motion-related errors) and could provide a significant increase in capability for detection of bottom objects. In fact, some experiments have been completed that suggest that SAS can be used to image buried minelike targets in sandy bottoms. The committee is aware of four SAS development efforts:

1. A DARPA program that will integrate a SAS system with the Lemming vehicle. The program is undergoing testing in the summer of 2001. Depending on the Lemming-SAS system experimental results, ONR may incorporate the approach into its surf zone reconnaissance project to evaluate performance in very shallow water and the surf zone.
2. A program is under way to integrate SAS with the Morpheus vehicle to evaluate system performance in the shallow water regime. Testing of this integrated system is scheduled for April 2002.
3. The intent of a new, cooperative program between the Program Executive Office for Mine and Undersea Warfare and its equivalent in the United Kingdom is to share information related to this evolving SAS technology. An additional goal is to integrate a long-range SAS on a UUV for test and evaluation.

4. An effort is under way to include SAS on the long-term mine reconnaissance system (LMRS).

These programs will provide valuable insight into the potential capability of SAS in future systems. More work must be done, but the initial results are promising.

Another system called the generic ocean array technology system (GOATS) seeks to use multiple UUVs to acquire multistatic acoustic data. A sonar source radiates acoustic energy toward bottom objects, and multiple UUVs then jointly acquire spatially and temporally referenced acoustic data reflected from the objects. This acquired data is then aggregated and processed to form a picture of the acoustic field reflected from the object. The characteristics of that field can then be analyzed to identify specific object types. The NATO-approved GOATS effort will continue for the near future.

Although such S&T efforts as the SAS and GOATS programs may not be ready for transition for a number of years, they are part of the required continuum of system development from basic research through transition to the fleet.

For decades researchers have been fascinated by the ability of biological creatures to develop high-resolution information about the environment in which they live. Videos showing dolphins seemingly standing on their nose while they use their sonars to detect fish buried in the sand beneath inspire the wish to duplicate such a capability in mine-hunting sonars. Understanding of these creatures' ability and the availability of processing hardware and software are now providing an opportunity to make significant advances in this S&T area. Among the several ONR programs focused on this capability, the program in broadband biomimetic sonar seeks to develop a dolphin-based sonar, form a biosonar integrated product team, fabricate a prototype digital broadband sonar to a defined set of requirements, and, once completed, test and evaluate biomimetic sonar for MCM in order to identify a system for future development (transition).[3] Positive results in this S&T program will have a significant effect on MCM.

Rapid In-Stride Mine Identification

Identification of bottom objects requires the acquisition of data of adequate resolution. Although video data allow ready identification of bottom objects, the ocean environment limits the range of video cameras and imaging systems due to backscatter of light in the water column. Two nonvideo programs are focused on rapid mine identification. An electro-optic laser line scan system in development is focused on the ability to reacquire and identify bottom mines. The optical system allows an increase in range of three times that of conventional optical

[3]Office of Naval Research. 2000. *Broadband Biomimetic Sonar Program Review* (CD-ROM; September 6-7, 2000, presentations), ONR, Arlington, Va.

systems and provides 0.25-in. resolution. A second system currently being developed, a streak-tube imaging LIDAR system, can be towed over the bottom at relatively high rates of speed while it acquires high-resolution optical data suitable for identification of bottom objects. It has been selected for inclusion in the AQS-20X system for high-speed airborne search, detection, and classification of bottom, close-tethered, and moored mines.

Supercavitating Rounds for Neutralization

The RAMICS is intended to provide standoff neutralization of near-surface mines from an MH-60S helicopter. This system has completed the advanced technology demonstration phase of development and is beginning the engineering and manufacturing development phase. Its potential is clear, but a number of substantial engineering issues must be addressed prior to integrating such a system into the fleet.

Small UUVs for Clandestine Reconnaissance

In the past few years it has become clear that small UUVs may well provide a significant capability for MCM tasks ranging from simple hydrographic surveys of littoral areas to detailed mine hunting and identification in areas of interest, especially in very shallow water. These vehicles can be launched from a submerged platform and transit to inshore areas autonomously. Once at a predefined location they can undertake preprogrammed tasks to acquire data and then return to a predetermined location to off-load data. Alternatively they can acoustically telemeter acquired data to a remote platform—a capability that, although not extensively demonstrated, does exist. A number of UUV systems are providing prototype platforms for various experiments with new technologies and operational strategies. These efforts are increasingly integrated through cooperative programs and evaluation testing such as the fleet battle experiments. Such fielding of new technology to operational users has produced and will continue to provide strong feedback for the S&T community. Current efforts to further evaluate UUV technology in the context of MCM operations promise increased capabilities in the near future.

Data Fusion for Development of a Coherent Tactical Picture for MCM

Current technology with its inherent small size and low energy demands is underpinning the implementation of a distributed system of data-gathering platforms that will significantly increase the amount of data acquired in operational areas. This wealth of data can be assessed to develop important information for MCM users. The transformation of data into information must be accomplished while taking into account many of the parameters associated with the data-gathering process. Data may be acquired at different times from different sensors with different characteristics. The value of the data may change with time depending on the dynamics of the physical process that generated the data. All of these factors and others must be accounted for in the data assessment process. Once this has been accomplished, the developed information can be stored in a database capable of generating a coherent tactical picture of the operational area. Although much talked about, this capability does not exist for MCM. Some S&T programs are focusing on these issues. Current efforts focus on resolving a number of these issues as well as identifying a process by which to make acquired information available to the fleet. This work has defined temporal and spatial scales of data and information required in the littorals.

High-resolution Bathymetry and Accurate Minelike Contact Mapping Initiatives

It is well understood that mine clearance rates would increase if it were possible to look for changes to known bottom maps rather than investigate all objects detected by sensors during ongoing operations. Such a capability implies that data sets exist that accurately describe and geodetically reference sea bottom features and the objects on that bottom. Once such data exists, in principle newly acquired data can be compared against existing data so that only new features or objects have to be examined. In this manner, clearance rates could increase dramatically. However, the data sets that would allow this much-desired scenario to become commonplace do not yet exist. As organic systems are introduced into the fleet, the potential for gathering needed data will be in place. The goal is then to field programs that can manage acquired data, accurately reference that data in time and space, and archive the information developed from that data for future use. A number of ongoing programs are addressing these issues, but most of the required data does not currently exist and is available only for a relatively small percentage of the areas of interest. Furthermore, detailed time-series observations are needed in the areas of greatest interest to establish the natural rates of change of bottom features due to shipping, storms, and seasonal and tidal bottom currents. Such information is needed to allow operational commanders to estimate the risk of reliance on "change detection," and to identify necessary remapping schedules.

Methods for Exploiting Microprocessor-based Mines

Mine exploitation provides critical support to operations and to mine development initiatives in several ways:

- Refines tactics and minesweeping effectiveness estimates,
- Focuses minesweeping development efforts,

- Refines ship vulnerability to various mine types within sensitivity setting ranges of the weapon, and
- Provides on-scene insight into the miner's plan, providing employed sensitivity settings, ship count settings, and so on.

With the infusion of microprocessor-controlled influence mines, exploitation by traditional means does not work. Hacking into these microprocessors to retrieve critical exploitation information, especially on-scene to support ongoing operations, is an area ripe for S&T initiatives and may be a logical companion to mine development initiatives recommended in Chapter 3. Currently only limited information is available and will become even more problematic with the growth in microprocessor-controlled influence mines.

Recommendation: Naval intelligence should give mine exploitation efforts greater priority to ensure support for operations and to provide insight to ensure fielding of adequate minesweeping capabilities. Emphasis should be placed on developing approaches for exploiting microprocessor-controlled influence mines, both in the laboratory and in the field.

It is clear that a number of S&T programs now under way will provide new technology in the future. This continuum of new ideas and system concepts is a critical component of MCM. It is important to the effectiveness and credibility of the Navy's overall mine warfare plans that such S&T developments lead to significant performance improvements in the fleet.

Recommendation: The Department of the Navy should ensure that S&T programs have valid transition paths to the fleet (i.e., more numerous and more timely transitions).

5

Inshore Countermine Warfare

INTRODUCTION AND BACKGROUND

The inshore area is measured from the very shallow water (VSW) zone, with a depth from 40 ft to 10 ft, through the surf zone (SZ) and the craft landing zone (CLZ), and onto the beach through the beach exit zone approximately 200 ft across the beach. This is the area that, for example, would have to be traversed by an amphibious landing force against opposition. Also, however, much of the material applicable to inshore mine countermeasures (MCM) applies to clearing port approaches for the U.S. Transportation Command (TRANSCOM), as discussed in Chapter 2.

Strategic Need

Amphibious landings against significant opposition are a rare event. Few such landings have been needed since the heavily opposed landings during World War II.[1] The Inchon landing in the Korean War was made without major oppo-

[1]Operation Overlord, the cross-channel invasion of June 6, 1944, was the largest opposed amphibious assault of the war, and by far the most difficult and costly MCM operation. In preparation for the cross-channel invasion, the Allies assembled 3 million men, 16 million tons of supplies, 5000 large ships, 4000 small ships and landing craft, and 11,000 aircraft. Elaborate deception was used to convince the Germans that the invasion would be over the 20-mile stretch from Dover to Calais instead of the actual route from the Isle of Wight to the Normandy beaches between Cherbourg and Le Havre—a distance of roughly 100 miles. Even so, extensive mine and obstacle clearance by over 300 MCM ships, swimmers, and extensive supporting forces was necessary during the few night hours before the landing on June 6.

sition, and in particular without having to overcome maritime mines. Plans for a landing at Wonsan in the enemy's rear during that war were delayed by extensive minefields. Eventually, plans for the Wonsan landing were canceled because the South Korean Army captured Wonsan as it moved north. Plans were made for landings in Soviet-threatened areas during the Cold War, and Soviet mining doctrine for protecting beaches is expected to inform future U.S. opponents along the littoral. The Soviet defensive mine doctrine, which was followed only in part by Iraq in defending against a possible coalition landing in 1991, called for a succession of mine barriers starting with a perimeter minefield about 25 nautical miles off the beach, extending through a main mine barrier with several lines of mines about 7 to 9 nautical miles offshore and a VSW barrier, and ending with a heavy deployment of mines and obstacles from the surf zone through the beach exit zone.

The last time a major amphibious landing against opposition was contemplated by the United States in wartime was during the Gulf War in 1991, but although landing forces were kept in place offshore to tie down Iraqi forces it was decided not to make a landing.[2,3] The mined approaches to the landing beaches were one, but not the only, factor in the decision. The only operational over-the-beach landing since that time was in Somalia in 1992, but the greeting force was mostly the U.S. media. Future such landings with relatively small forces might easily be thwarted by a combination of sea mines, beach mines, and obstacles even if no shoreside opposing force is present.

The declared U.S. policy continues to be to maintain a capability for opposed over-the-beach assaults, and much of the Marine Corps combat development and modernization planning envisions them. Amphibious landings remain a part of contingency planning for wartime expeditionary force operations along the littoral, and should the need for one occur, time and maneuver space can be critically limited.

Such landings might be needed, for example, on islands of modest size that have no easy landward approach for operations in a country that has only a short coastline, or where ports may not be available and over-the-beach approaches represent the only way to support follow-on logistics early in a campaign.

While amphibious landings of the scale of those seen in World War II are an anachronism when contemplated in terms of currently developing U.S. national and military strategies and operational concepts, a landing of the scale contemplated during the Gulf War could well be called for, into the indefinite future. For example, a Marine expeditionary brigade (MEB)-size landing to protect a major U.S. interest, carried out as a component of the "Operational Maneuver From the

[2]Gordon, Michael R., and General Bernard E. Trainor, USMC (Ret.). 1995. *The Generals' War: The Inside Story of the Conflict in the Gulf*, Little, Brown and Company, New York, pp. 192-194.

[3]Amphibious planning during the Gulf War is described in Appendix B.

Sea" and "Ship to Objective Maneuver" concepts,[4] could be needed. And "opposition" can come in many forms, from opposing forces massed behind a potential landing beach (which would be bypassed if at all possible under the new maneuver concepts) to waters and landing zones that are mined and that may or may not be overwatched by protective forces. Despite the natural preference to avoid hazardous opposed landings, such operations may be unavoidable.

Even in the reduced cases referred to above, the resources needed for an amphibious landing against opposition can be large. An amphibious landing of the size that can be contemplated today (described below) would be an extremely complex affair, fraught with risks and requiring extensive advanced planning. For the readers of this report who are not familiar with the intricacies of such operations as planned under the new operational concepts, Appendix A describes the process in some detail. If such landings were to be routine, the cost might be prohibitive. Given that they are rare but urgent when the need arises, planners are justified in calling for the development and availability in reserve of extraordinary, joint resources. However, even in that case, the statement of resources required to support a landing must be in keeping with the size landing that the planned amphibious resources will permit. This is not currently the case, as is indicated below.

State of Navy Responsibility and Attention to the Need

Although the Navy has moved smartly to increase capability for offshore countermine warfare in support of amphibious landings and subsequent logistic operations, the same cannot be said for inshore countermine warfare. Currently, the Navy has responsibility for mine clearance up to the high-water mark in support of Marine Corps amphibious landings, with the Marines being responsible for clearing the beach and the exit points. Responsibility for the beach zone is under discussion between the Navy and Marine Corps. However, there is no joint Navy/Marine concept of operations that involves Navy and Marine mine-clearing systems in a continuous operation. Attention to this joint operations area admittedly needs to be expanded and should be included in the current draft concept of operations for MCM in support of amphibious landings that is currently under consideration in the fleet.

Until very recently, the inshore region has not been a major focus of the Navy's mine warfare program planning. Consequently, the inshore capability at present is more "paper" than real. The major modernization programs as embodied in the organic MCM initiative, and the operational command structure as

[4] Headquarters, U.S. Marine Corps. 1996. "Operational Maneuver From the Sea," U.S. Government Printing Office, Washington, D.C., January 4. Available online at <http://www.192.156.75.102/omfts.htm>.; Van Riper, LtGen Paul K., USMC. 1997. "Ship to Objective Maneuver," Marine Corps Combat Development Command, Quantico, Va., July 25. Available online at <http://www.192.156.75.102/stom.htm>.

evidenced by the role of the Mine Warfare Command, focus on the countermine warfare challenges in deeper water. While there have been some general requirements for MCM support of over-the-shore logistics, specifics await the further development of the sea-basing aspects of the "Operational Maneuver From the Sea" concept.

State of Current Capability and Efforts vis-à-vis Marine Corps Requirements

Capability for inshore mine and obstacle clearance today is only slightly better, in effectiveness and speed, than it was in preparation for the Normandy landing during World War II. Essentially all of the nation's inshore/surf zone countermine warfare capability currently resides in the explosive ordnance disposal (EOD) teams, with their divers, mammals, and expectations for unmanned undersea vehicles (UUVs). The sizing and posturing of these units are not coupled with current operational plans for amphibious warfare in major regional contingencies. Mines are likely to be accompanied by obstacles to block movement of landing craft to the beach. Reliable clandestine ways to locate mines and obstacles in the surf zone are limited, although overhead observation as tides vary and water is disturbed by breaking surf can be of some help both for near-surface moored mines in VSW and obstacles in the SZ and CLZ. Thus, swimmers—humans or other mammals—are needed for these purposes, and they cannot remain unobserved if the opposition has night observation equipment. Sea mammal systems remain the only currently fielded way to find buried mines in the VSW zone. Mine and obstacle clearance in support of amphibious operations under these conditions will be time consuming and dangerous.

In contrast to these realities of current capability, the Marine Corps requirements for mine and obstacle clearance call for clearing six transit lanes, each 165 yd wide, from the line of departure to the surf zone. The completion threshold is 72 hours in the near term, shrinking to 24 hours in the mid and long term. This step is to be followed by mine and obstacle clearance from two 50-yd-wide assault lanes departing from each transit lane (to permit, e.g., two rifle companies to land in parallel), a total of 12 assault lanes, in 60 to 90 min. This requirement describes the quantitative implementation of "in-stride" mine clearance, a term variously defined but meaning that mine clearance should not delay a planned operational schedule that is driven by considerations other than mine clearance. For comparison, during the Gulf War, the plans for a landing by a force of two regimental landing teams, had one taken place, reduced the above 12 lanes to 3, since that was the only size landing the available amphibious lift could accommodate.[5] That situation has not changed.

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[5]MajGen Harry W. Jenkins, USMC (ret.), the landing force commander, private communication, January 2001.

Various means have been under consideration to meet the Marine Corps requirements. Transit lanes would be cleared by the organic MCM systems, in combination with the dedicated force if necessary; resource availability to perform the clearance in the required time would be a critical issue. The LMRS and RMS mine-hunting systems can penetrate only part-way into the VSW zone. The helicopter-based systems, ALMDS, RAMICS, AMNS, can do some of the task physically if they are not under shore fire, but the towed sonars for mine detection and the OASIS sweeping gear need some water depth for safe operation. And they cannot detect buried mines, nor can they operate clandestinely if that is required to avoid "telegraphing" where the landing will take place. Finally, as might be expected, the process using these assets would be slow.

To clear the SZ and CLZ, the Navy and Marine Corps have been developing the combined SABRE explosive line charge and the DET explosive net (discussed further below). However, both face technical and operational problems that include their inability to handle obstacles and the space they would occupy on scarce assault landing craft. The Army's armored plow-type machine for sweeping mines in the SZ and CLZ, and on the beach, has been discontinued. Navy MCM investment in the water regime from a 40-ft depth into the beach is limited to several long-term technology base efforts of ONR, described in Chapter 4 and (in a few cases) below in this chapter. As useful as some of these may prove to be, these technology base programs do not constitute a Navy plan to acquire the needed inshore countermine capability in a timely fashion.

The Physical Environment

Modern sensors and their projected improvements are becoming increasingly sensitive to environmental parameters. Foreknowledge of these parameters is, therefore, becoming more critical to the operational effectiveness of countermine warfare (CMW) systems. Nowhere is this more obvious than in the VSW, SZ, and CLZ, which encompass a high-energy, changeable, and complex environment ill suited to the effective performance of MCM systems and equipment.

The VSW region, submerged following the last Ice Age, still bears past erosional irregularities softened by more recent sedimentation, a condition leading to variability in bathymetry, patchiness in bottom-type distribution, and a wide range of distances between the 40-ft contour and the SZ (taken in this report to have an average slope of 1:300, or a distance of 9000 ft). Due to the shoaling bottom, wave heights tend to build, tidal currents become more pronounced, sound conditions are more complex, and bottom mines tend to bury more rapidly. And due to heavier pleasure, fishing, and commercial traffic, the density of nonmine, minelike bottom objects (NOMBOs) is here at its greatest.

The SZ also presents a wide range of distances between the offshore bar and the high-water mark (a nominal distance of 1750 ft is used here for purposes of calculation, although the distance is much less for many beaches). The offshore bar, its depth controlled by storm waves and seasonally variable incident wavelengths, causes waves to build and break, creating a deepening of the bottom in the plunge pool landward of the bar. Where waves strike the coast at an angle, swift alongshore currents are formed, and breaks in the offshore bar can cause dangerous riptide currents.

The slope of the beach, and therefore the distance from the high-water mark to the beach exit zone (BEZ) (a beach width of 300 ft is assumed in this report), are controlled by the beach's composition, which can range from rock to shingles to sand, and by tidal range, which may run from inches to many feet.

While the basic infrastructure is largely in place for receiving, managing, and presenting environmental data on the VSW, SZ, and CLZ, the collection of data during peacetime is difficult and lags far behind requirements. *A robust peacetime environmental data collection program is essential if MCM planning and systems performance are to function at their potential.*

AN INSHORE COUNTERMINE WARFARE SEQUENCE OF SYSTEMS

From the background presented it is possible to describe the countermine warfare systems, broadly defined, that are required to allow such operations to proceed along lines previously outlined. The emphasis is on dealing with the mine and obstacle threat in the VSW, SZ, and CLZ, a region extending from the 40-ft depth contour to that area immediately landward of the BEZ. The objective is to reduce the threat from mines and obstacles to an absolute minimum and to leverage scarce MCM systems whenever possible. Above all, the intent is to define a countermine warfare sequence of systems, and not an uncoordinated set of CMW assets.

The exemplar problem set for this section is the one described in Appendix A—clearance of six 165-yd-wide transit lanes from the 40- to 10-ft contour, and for each, the breaching of two 50-yd assault lanes through the SZ and CLZ, and the clearance of an 80 × 80 yd offloading zone on the beach, the initial craft landing zone (ICLZ) for each assault lane. Attention is also given to the need to broaden these lanes for the transit of heavy logistics and follow-on echelons immediately after the initial assault, and the larger potential task of satisfying joint logistics over the shore requirements. The problem is in keeping with the Marine Corps requirement to land a MEB against opposition.

Intelligence, Surveillance, and Reconnaissance for Inshore Countermine Warfare

The importance of intelligence, surveillance, and reconnaissance (ISR) for mine warfare is discussed and emphasized in Chapter 2. Clearly, ISR systems encompass all activity that might be related to mining and minefields, onshore and offshore. Nevertheless, several additional observations and details of ISR systems that are especially pertinent to inshore countermine warfare are given here. Details of the inshore physical environment are given above. The threat environment is outlined in Appendix A.

Intelligence

In a 1994 report,[6] and again in its 1997 report on undersea warfare,[7] the Naval Studies Board (NSB) recommended strongly that the Navy increase its mine warfare intelligence effort to a level comparable to that enjoyed by such areas as antisubmarine warfare (ASW) and antiair warfare (AAW) during the Cold War. As a result of extensive data gathering, and during its briefings from and discussions with Navy and Marine Corps leadership during this study, the committee saw no evidence that such priority has been assigned to mine warfare intelligence. Funding necessary to evaluate the hardware that has been obtained appears to be as scarce as ever, and the cadre of mine experts needed for such evaluations has dropped below a critical mass. Funding and priority for ISR must be increased, as is indicated in several parts of this report.

Surveillance

As discussed in Chapter 2, inshore MCM could begin with surveillance that indicates minefield building activity. Surveillance of mining activity could enable mines to be interdicted between bunker and minefield *if and when ROE permit.* If not, it allows mined areas to be avoided, given alternative routes. If both of these fail it still allows an efficient concentration of limited MCM assets.

In the past most mine-laying activities were conducted beyond the reach of then-available surveillance assets. Today, thanks largely to the Cold War buildup and the more recent developments in response to the requirements of the emerging electronic battlefield, no mine-laying activity is beyond the reach of available U.S. surveillance assets.

Relevant surveillance assets consist of imagery and signal intelligence from satellites and both manned and unmanned atmospheric vehicles,[8] submarine elec-

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[6]Naval Studies Board, National Research Council. 1993-1994. *Mine Countermeasures Technology Study* (U), 4 volumes, National Academy Press, Washington, D.C. (classified).

[7]Naval Studies Board, National Research Council. 1997. *Technology for the United States Navy and Marine Corps, 2000-2035, Volume 7, Undersea Warfare,* National Academy Press, Washington, D.C.

[8]Tilson, CAPT Paul Tilson, USN (ret.). 2000. "NRO Overview (U)," briefing to committee subgroup, National Reconnaissance Office, Washington, D.C., December 14; Buellner, Col George K., USAF, and LtCol George J. Cusimano, USAF. No date. "Developmental Flight Test in Combat" (Joint Stars at War), a white paper, Tactical Air Command, Langley AFB, Va., and Joint STARS Joint Test Force, Electronic Systems Division, Melbourne, Fla.

tronic support measures (ESMs) and passive acoustics, Special Forces, unmanned sensor networks, and human intelligence. Since mine surveillance should be utilized at the first indication that intervention might be required, all of these sources will not be available at the outset. The information flow from all-source surveillance will be required in order to monitor and track the movement of mines from bunker to minelayer to minefields.

As an example, the nominal mine defense lay-down used in the threat (Appendix A), if it were applied by a modern-day opponent, would require 2670 mines weighing up to 2000 lb each to be loaded on trucks or rail cars, transported to piers for offloading onto mine-laying platforms that would then be moved to three offshore locations, and then laid at precise intervals in relatively straight rows. While the pier to minefield transit might be masked by other traffic, the precise and repeated pattern of mine laying would be more easily distinguished. Similarly, the establishment of an SZ/CLZ defense extending for 3.5 nautical miles along the beach, and consisting of 13,700 antitank (AT)/antipersonnel (AP) mines and 600 obstacles, is a highly visible engineering task given the resolution of present sensors. Such massive and localized activity would be detected by surveillance sensors whether tasked or not, as was the case in Desert Storm. In the latter case it is not necessary to be able to distinguish individual mines and obstacles. Given the breaching techniques likely to be required, determining the existence of a beach defense with boundaries and existing gaps is all that is needed.

Since the NSB pointed out in its 1994 report that ISR should be the number-one MCM priority, some progress in mine surveillance has been made. The Hamlets Cove/Radiant Clear exercises, ONR's Littoral Remote Sensing program, and the Third Fleet's evaluation of the littoral surveillance system (see Appendix A) have all been positive steps that made limited use of national systems. There is little evidence, however, that all-source surveillance has been addressed as a unified program, that tasking priorities have been addressed, or that the required architecture for converting all-source data into an evolving tactical picture for commanders has been considered.

Joint Littoral Awareness Network (JLAN)/Deployable Autonomous Distributed System (DADS)/Advanced Deployable System (ADS). Even using the combined sensor sources noted above, the naval forces cannot count on a perfect surveillance picture of mine-laying activity throughout the area of interest. Temporal and spatial gaps due to satellite orbital times, day/night conditions, cloud cover, inclement weather, conflicting tasking, and a staggered arrival time of data from various sensors must be factored in. To assist in filling these potential gaps in surveillance coverage, one additional system should be considered.

In the 1990s, JLAN was a project of the Naval Command, Control, and Ocean Surveillance Center's RDT&E Division, with input from ONR's

Deployable Sensor project and DARPA's Internetted Unattended Ground Sensor program.[9] The system consisted of a land/sea network of small, air-deployed sensor packages, the data from which was to be relayed via radio frequency (RF)/acoustic transmission to a modem for low probability of intercept (LPI) uplink to either a satellite or aircraft to provide a common tactical picture to the commander, joint task force (CJTF) at sea in the joint maritime command information system/global command and control system (JMCIS/GCCS). The land packages consisted of acoustic, seismic, infrared (IR), and chemical sensors for detection of land vehicle traffic, defense preparations, and missile launches. The sea packages consisted of acoustic, seismic, electrical field, and magnetic sensors to detect ship and submarine traffic, and both the splash of mines entering the water (air or ship laid) and the thump on impact of an anchor or a mine with the bottom (air, surface, or submarine laid). JLAN sensors took advantage of an increase by a factor of 10 to 100 in acoustic, magnetic, and seismic sensitivity over the past decade, a power increase by a factor of 1000, and a volume decrease by a factor of 10 to 100. The number of sensors required to cover 2000 km^2 was estimated to be 165 for land and 665 for sea, approximately one sensor per square mile.

DADS and the Autonomous Off-Board Surveillance Sensor (AOSS) program, both under development by SPAWAR with ONR support, are evolutionary steps in the integrated underwater surveillance system aimed at providing an ASW/ISR capability in the littoral.[10] Deployed from aircraft or surface ships, individual sensors' components are packaged in an "A"-size sonobuoy-like container. Each package contains a 1.3-m-long battery and processor module, acoustic communication transducer, and float, and a 100-m-long array containing 14 hydrophones, 3 magnetometers, and 1 E-field sensor. With a life cycle of up to 90 days, the arrays are deployed in a barrier sensor field in water depths of 0 to 500 m, with 200 m nominal. Contact and tracking data are transmitted acoustically to a receiver buoy for RF uplink to aircraft or satellite. Although intended primarily for detection of quiet diesel electric submarines, the system is capable of detecting aircraft, surface ship, and submarine mine-laying activity by monitoring traffic sounds and patterns as well as the water entry and bottom impact of mines.

The committee was not briefed on ADS. However, it is understood that the system, designed to be deployed in the littoral and capable of detecting mine-laying activity and quiet diesel electric submarines, has successfully passed its milestone reviews and is set for procurement in FY05. ADS appears to be better

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[9]Evans, CAPT Kirk, USN, Comanding Officer, Naval Command, Control and Ocean Surveillance Center, Research Development Testing and Evaluation Division, Naval Research and Development Command, San Diego, Calif., "Joint Littoral Awareness Network Advanced Technology Demonstration (JLAN-ACTD)," briefing to the Technology for Future Naval Forces committee, July 30, 1996.

[10]Space and Naval Warfare Systems Command. 2001. "Deployable Autonomous Distributed System (DADS)," briefing to a subgroup of the committee on January 5, 2001.

suited than DADS to fill the mine-laying surveillance gap in both the offshore and inshore areas.

To more completely satisfy the OMFTS/STOM mine surveillance requirements, a land extension of JLAN/DADS/ADS technology is required in order to detect the erection of engineering beach barriers, shore defenses, and minefields directly landward of the BEZ. JLAN was a good start in filling this surveillance requirement.

Thus, it appears that existing surveillance assets, while capable of providing excellent surveillance of land and sea mine-laying and beach defense activity, may not provide perfect coverage. Critical gaps may occur in monitoring such activity.

To avoid this, the CNO and the CMC should ensure that the DADS or ADS technology is capable of monitoring surface, air, and submarine mine-laying activity in the inshore and offshore areas and should reevaluate the JLAN technology as a possible land extension of that capability.

Reconnaissance

Surveillance can detect the existence of mine laying and the rough boundaries of the resulting minefield, but reconnaissance is needed to provide ground truth and to begin filling in the details of inshore minefield boundaries[11] and mine and minelike object density, and ultimately to focus detection and classification efforts on likely mine locations. Fortunately, the effort to achieve a minefield reconnaissance capability has been more aggressively pursued over the past 10 years than has the effort to fully utilize surveillance assets. Those efforts have included the Marine Corps coastal battlefield reconnaissance and analysis (COBRA) sensor payload for an unmanned aerial vehicle (UAV) using multispectral imaging for SZ and CLZ reconnaissance, the Army's airborne standoff minefield detection system (ASTAMIDS) UAV using IR sensors for the detection of land mine fields (important to the Marines), and the submarine-launched long-term mine and reconnaissance system (LMRS) and surface-ship-launched remote mine-hunting system (RMS) for reconnaissance in the littoral. Too, there has been an aggressive and ongoing effort to develop a range of UUVs for limited littoral minefield reconnaissance and follow-on mine hunting, plus environmental surveys (SAHRV, CETUS).

The committee believes that COBRA has sufficient potential for reconnaissance in the SZ and CLZ to warrant completion of the program, and ASTAMIDS, because of its night reconnaissance capability and importance to the Marine Corps, warrants Navy encouragement. For the purposes of this section of the report, however, it is understood that LMRS has a 40-ft cut-off, and RMS is likely to have a similar depth restriction. It is assumed that this restriction is due to the signature of the two vehicles, the effect of a shoaling bottom on maneuver-

[11] The inshore minefields may well be extensions of those offshore.

ability, and, in the case of RMS, the likelihood of snagging the towed sonar. In any event, both systems may have limited utility in the VSW. Recommendations in Chapter 4 on R&D for improving LMRS and RMS (e.g., SAS for LMRS) may eventually increase the capability of these systems in the VSW. However, for now, it is assumed that both systems may have limited utility in the VSW.

With respect to UUVs in general, the committee judges that unmanned autonomous or remotely controlled underwater vehicles and robotic devices represent a natural evolutionary trend in MCM, including minefield reconnaissance. There is now a groundswell of interest in removing (except for mine recovery for intelligence purposes) both swimmers and marine mammals from the job of minefield reconnaissance, mine marking, and mine neutralization. That step is probably inevitable at some point in the future. However, the same groundswell has been evident, at intervals, since the 1960s. Therefore, although the committee supports the ongoing R&D effort in UUVs, it cautions against any attempt to replace swimmers and marine mammals until UUVs have proved to be a more cost-effective solution, the naval community has learned to place equal confidence in them, they have demonstrated the ability to overcome countermeasures such as fishing nets (including mist nets, which can be strung in lengths of up to 40 miles), and they can successfully replicate the mammals' unique ability to detect buried mines.

Clandestine Mine Reconnaissance and Countermeasures System (CMR/CS). The VSW (40 to 10 ft) is the area where mines are most likely to bury due to bottom impact, wave scour, and traveling sand ridges, and where the density of NOMBOs is likely to be the greatest. Therefore, an effective minefield reconnaissance system for this area should be capable of detecting, classifying, and identifying moored, bottom, and buried mines. A proposed system capable of accomplishing this difficult task has been on the table for much of the past decade.

The CMR/CS is a small small-waterplane area twin hull (SWATH) platform with displacement in the range of 15 to 20 tons that utilizes suitably adapted *Sea Shadow* technology to reduce radar cross section and acoustic quieting, and is equipped to transport, launch, operate, and recover two mammal systems. Except for the stealth modification, the SWATH platform can be similar in size and function to the MHS-1-like baseline discussed below in the section "The Mine Clearance Task," or even the same vehicle for both purposes. A variant of the MHS-1 hull design has the ability to ballast down such that the SWATH superstructure is near water level.[12] This variant, combined with *Sea Shadow* technology, may be preferred for the CMR/CS application owing to a further reduction

[12]Gaul, Roy D. 2000. *Evaluation of Host-and-Drones Concept,* BSC Report No. 20880-1, Blue Sea Corporation, Houston, Tex., April (see also Porter, Richard T. No date. *SLICE—A Stable Reconfigurable Platform,* update of 1997 white paper, Lockheed Martin Government Electronic Systems, Sunnyvale, Calif.).

in profile and a better mammal-handling capability. The craft can then de-ballast for its own MCM operation in shallow water.

The baseline SWATH (MHS-1) is 40 ft long and 18 ft wide. It draws 4.5 ft and has a top speed of 18 knots and a range of 750 miles at an efficient cruise speed of 7 knots. It is operational in sea state 4. Therefore, the platform is capable of being launched from over the horizon, and operating in to the SZ, defense permitting. Thus it is capable of covering the three main mine belts described in the committee's threat lay-down.

All future mine threats will not necessarily follow the integrated anti-amphibious assault (IA3) doctrine described in Appendix A. However, using the nominal threat lay-down described in Appendix A, and assuming that surveillance and reconnaissance have confirmed the location and boundaries of the perimeter, main, and VSW mine barriers, transit speeds between mine barriers could be at a level governed only by the platform and the need for covertness. This places the mine-hunting phase within the endurance of the mammal system.

The original proposal called for the SWATH platform to be unmanned and remotely controlled by either RF or fiber-optic link.[13] It was believed that the mammal systems could be trained to operate without a handler. However, the committee believes that the first-generation CMR/CS should operate with a three-man crew—a boat handler and two mammal handlers.

It should be pointed out that the platform being suggested for CMR/CS can also be adapted for use by the VSW detachment. It would provide a long-range delivery and support platform with enough payload capacity to carry needed personnel, equipment, and neutralization charges.

Thus far, CMR/CS, with marine mammals trained to detect and classify moored, bottom, and buried mines, offers a minefield reconnaissance capability not equaled by any system now fielded. The CMR/CS platform evaluation issue is discussed further in connection with the description of the MHS-1 as an inshore mine-hunting craft below.

Recommendation: The Navy should fund an experimental prototype test series with the MHS-1 vessel to determine its potential as a CMR/CS platform, a delivery and support platform for the VSW detachment, and/or a delivery platform for an influence minesweeping system ahead of assault vehicles. The Navy should evaluate any other potential MCM missions and roles as a future surface MCM vessel prototype, inshore or offshore.

Buried Mine Detection by Electrical Resistivity. The VSW detachment and, later, UUVs need an ability to detect buried mines; this is especially important in

[13]Maritime Technology Sector, "Clandestine Mine Reconnaissance and Countermeasures System," briefing to the Panel on Undersea Warfare, Technology for Future Naval Forces, on February 12, 1997, Science Applications International Corporation, McLean, Va.

the inshore region, where surf and tidal flows are likely to bury mines. Since the introduction of the bottom influence mine in World War II, the burial of mines due to natural causes has been a sleeper threat to which we have given lip service, provided for only sporadic and incomplete research (e.g., magnetic acoustic detection of mines), and otherwise attempted to ignore. Today, although research on biosensor and SAS technology (see Chapter 4) appears promising, the marine mammal is the only means of detecting buried mines. And that problem becomes more difficult as the mines become smaller approaching the SZ.

Since the VSW is the area in which bottom influence mines are most likely to bury due to natural causes (and we still have not come to grips with the possibility of a self-burying bottom mine), if U.S. mine reconnaissance and clearance efforts in the VSW are expected to be fully successful, we can no longer ignore the problem of buried mines.

During the Desert Shield (the buildup to Desert Storm) phase of the Gulf War the JASONS[14] proposed a buried-mine detection technique for use by swimmers based on electrical resistivity[15]—a technique long used in such applications as mineral exploration, and even for the detection of plastic bags of hashish in the belly of camels.[16] The JASON suggestion featured two active electrodes spaced one ahead of the other a distance depending on the desired vertical dimensions of the electrical field generated between the two. The vertical dimension of the electrical field is several times that of the spacing between the active electrodes. The space between the active electrodes is filled with many small nonactive electrodes used to monitor the field with the aid of a small computer. The top surface of the rectangular device can be insulated to prevent interference from surface wave effects, and it is "flown" over the bottom a distance allowing the electrical field to penetrate to the desired depth (say, 12 in.). Given sufficient distance above the bottom, the device can detect the anchor and cable of moored mines, bottom mines, and buried mines. And since the field responds to both conducting and nonconducting anomalies, both metallic and nonmetallic mines can be detected.

Since the JASON recommendation, considerable research on interdigital dielectrometry magnetometry[17] has produced systems requiring much less power,

[14]JASON is a rotating group of the nation's foremost scientists who have, since the late 1950s, devoted extensive time and energy to problems of national security.

[15]Muller, R., D. Eardley, R. Garwin, S. Koonin, and R. Perkins. 1992. *Mines in the Surf Zone,* JSR-92-180, draft, JASON, MITRE Corporation, McLean, Va., December 9.

[16]Personal communications between Lee M. Hunt and Dr. Ralph Stuart Mackay (inventor), University of California at Berkeley, 1965.

[17]Goldfine, Neil J., Darrell E. Schlicker, Andrew P. Washabaugh, David Clark, and Markus Zahn. 1999. "New Quasistatic Magnetic and Electric Field Imaging Arrays and Algorithms for Object Detection, Identification, and Discrimination," *Proceedings of SPIE, International Society for Optical Engineers, Detection and Remediation Technologies for Mines and Minelike Target IV,*

reduced electrode cross section, and the ability to distinguish the small amount of metal in a nonmetallic mine. Dielectrometry and magnetometry sensors measure changes in circuit impedance at electrical terminals as a function of frequency to determine changes in terminal capacitance, inductance, and resistance due to the presence of buried objects such as mines. Such measurements can greatly improve sensor discrimination to significantly reduce the false-alarm rate.

Recommendation: The Navy (ONR) should investigate the utility of electrical resistivity, with particular emphasis on interdigital dielectrometry and magnetometry, for improved mine (including buried mine) detection, classification, and identification with decreased false-alarm rate.

Global Positioning System (GPS). The GPS provides highly accurate position, velocity, and time information to users anywhere in the world. Characterized as the most important MCM development since World War II, GPS adds the ability of all relevant platforms to navigate much narrower cleared channels, and the ability to better reacquire mine contacts. It is critical to the objective of this report—approaching the mine threat with maximum efficiency and asset leverage—that all MCM and assault platforms be equipped with GPS. Further, the GPS system should include a display that shows a cleared channel's coordinates, or the coordinates of a channel that is to be cleared. All MCM and assault/logistics platforms should be able to navigate these channels on GPS-connected autopilot. The objective, in addition to that noted above, is to eliminate the burdensome task of lane marking by systems that may be obscured at critical times during an assault.[18]

The Mine Clearance Task

The section "Amphibious Operations" in Appendix A stipulates that the VSW detachment, aided by CMR/CS, would use the 48 hours of D-2 to D-Day to

3730:(1):89-100, AeroSense 1999 Symposium, held at Orlando, Fla., April 5-9; Goldfine, Neil J., Andrew P. Washabaugh, and Darrell E. Schlicker. 2000. "High Resolution Inductive Array Imaging of Buried Objects," *Proceedings of SPIE, International Society for Optical Engineers, Detection and Remediation Technologies for Mines and Minelike Target IV,* 4038(1):56-65, AeroSense 2000 Symposium, held at Orlando, Fla., April 24-28.

[18]The low power of the satellite signal broadcast makes GPS particularly susceptible to jamming, and pulse, continuous wave, broadcast noise, and spoofers can disrupt precision navigation operations that rely on GPS. Sophisticated antijamming techniques under development for GPS offer significant improvements in jam-to-signal (J/S) ratio over the existing fielded equipment. Improved antenna design and digital filtering and signal processing techniques that take advantage of advances in electronics can provide cost-effective solutions for next-generation military GPS receivers. Potentially, antijam receivers that can operate with J/S up to 120 dB could be developed within the next few years. With a 120-dB J/S margin, operations could be sustained with relatively high-power jammers (e.g., 1 kilowatt) to within 100 meters of the jammer.

reacquire, identify, and place command-detonated neutralization charges on mines in at least the six transit lanes. However, to provide backup for that effort, immediately begin broadening all transit lanes, and clear additional logistics lanes following the initial penetration, a substantial increase in MCM assets is required. The organic airborne MCM assets, owing to reduced vulnerability to coastal defenses following the penetration, can supply a part of this increased requirement. However, the dedicated force will have to provide most of it.

The Navy recognized the need for MCM assets that could deploy with the fleet in the early 1960s. It also recognized, through long experience, that neither minesweeping nor mine hunting required a large platform to operate in the littoral. Experiments were conducted with two MCM support ships, the USS *Catskill* (MCS-1) and the USS *Ozark* (MCS-2), carrying 20 minesweeping launches (MSLs) and 3 airborne MCM helicopters. The MSL, a 36-ft open launch (patterned after the Boston whaler), was capable of mine hunting with a strap-on AN/SQQ-16 sonar, mine neutralization by lowering a charge from a Z-boat using the sonar for guidance, and minesweeping using lightweight airborne MCM gear. The helicopters were the forerunners of the present airborne MCM capability.

It was found that the MSL became a very wet boat at sea state 2 and that it was unable to operate in sea state 3. Also, it was found that when both the MSLs and the airborne MCM helicopters were loaded at the main deck level, the support ships became unstable in certain maneuvers and wave directions. However, with the eventual introduction of large well-deck/flight-deck amphibious ships, the perfection of airborne MCM, and demonstration of the stability characteristics of the SWATH hull form, all of the flaws in the original idea can be remedied.

Such a dedicated MCM support ship with both well deck and flight deck capable of deploying with the battle groups and amphibious ready groups, and carrying enough airborne MCM and surface MCM assets, could be able to handle the littoral mine threat.[19] An MHS-1-like craft to supplant the MSL would be able to perform the functions originally intended for the MSL, in addition to the swimmer and mammal support tasks described above.

The MHS-1, procured through the Office of Special Technology and built for Mine Search Squadron One (later assigned to the Explosive Ordnance Disposal Mobile Unit (EODMU)-Seven upon termination of the Mine Search Squad-

[19]This concept, described in more detail in the main text immediately below, emerged with the highest score among five that were analyzed in Office of the Chief of Naval Operations (N725) and Program Executive Office, Mine and Undersea Warfare (PMS 490), 2000, *MCM(X) Mission Area Analysis (MAA) Final Report* (U), *Appendix I: Concepts Assignment*, Department of the Navy, Washington, D.C., October 30 (classified).

Box 5.1 MHS-1 Characteristics

• Length	44 ft
• Beam	18 ft
• Draft	4.5 ft
• Weight	24.0 long tons full, 21.4 long tons light
• Speed	18 knots
• Range	750 nautical miles at cruise (7 knots)
• Endurance	107 hours
• Propulsion	Two Caterpillar marine diesels (Mod. 3116 DITA 255 hp)

Box 5.2 MHS-1 Equipment Package

- Sidescan Sonar—Kline 5000
- Obstacle Avoidance Sonar—Kongsbert Simrad SM-2000, Version 2.2, 240 kHz
- Global Positioning Receiver—Raytheon RAYSTAR 108GPS
- Digital Gyro—Raytheon Anschutgz Gyro Compass (STANDARD 20)
- Navigation Set—Raytheon NAV398, and AN/PSN-11 Position Locating OPS
- Heading Sensor—Raytheon "Heading Sensor"
- Autopilot—ComNav 2001
- Radar—Raytheon R40xx with color display
- Chart System—Raytheon RAYCHART 600xx
- Remotely Operated Vehicle—Deep Ocean HD2+2 with video camera and imaging sonar (Mesotech 971)
- Acoustic Data Processor—Triton-Elics ISIS Version 4.0
- Survey System—HyPack Version 8.1A

ron), would serve as an excellent baseline from which to design the surface MCM component.[20]

The MHS-1, now based in Coronado, California, with EODMU-Seven, has the characteristics shown in Box 5.1 and carries the equipment shown in Box 5.2.

Due to twin submerged hulls, the MHS-1 can operate in sea state 4 and survive in sea states 5 and 6. With its excellent seakeeping characteristics the

[20]McCoy, CAPT James M., USNR, and LCDR Wayne Neely, USNR (TAR). 2000. "The SWATH Mine Hunter: An Enabling Technology That Works," *Proceedings of the Fourth International Symposium on Technology and the Mine Problem,* Naval Postgraduate School, Monterey, Calif., March 12-16, pp. 11-13 (see also Explosive Ordnance Disposal Mobile Unit 7. 2000. *MHS-1 Concept of Operations,* San Diego, Calif, January 5; Navy Office of Special Technology. 2000. *MHS-1 Integration Plan,* San Diego, Calif.).

boat has a vertical acceleration of 0.04 *g* (RMS) in sea state 4 and a motion sickness index of 1 percent (RMS). The threshold of malaise for motion sickness is at approximately 0.1 to 0.2 *g*'s, and the intolerable conditions occur at 0.2 to 0.5 *g*'s.

The MHS-1 is designed to rest on its twin hulls without a cradle. Thus it can be transported aboard virtually any ship with adequate main-deck or well-deck space. It is C-5 qualified (by removing the cabin) and can be transported aboard a flatbed truck. Its cost, fully equipped, is in the $2 million range.[21]

Due to its low acoustic and magnetic signature, the MHS-1 has been tested successfully against the versatile exercise mine system (VEMS) without actuation. Therefore, with its shallow draft and obstacle-avoidance sonar, it can operate with reasonable safety in moored contact/bottom influence minefields set for deeper-draft ships.

The present Kline 5000 cannot detect objects directly beneath the towed body. Therefore, the 50-yd search path is cut in half by having to overlap along the return path. Efforts to correct this feature are under way.

To date, the MHS-1 has participated in three major exercises: Seahawk 98 (Seattle, Washington), Kernel Blitz 99 (off Camp Pendleton, California), and Foal Eagle 99 (Korea). In Seahawk 98 and Foal Eagle 99 the MHS-1 was transported on the main deck of a landing ship, dock (well deck devoted to other craft), and joined Kernel Blitz 99 under its own power from Coronado. In these exercises the MHS-1 performed above expectations, operated for 48 continuous hours with only crew changes, continued operation when other MCM craft had to return to port due to heavy weather, accurately identified 10 out of 11 contacts, duplicated the performance of MH-15 helicopters equipped with the AN/AQS-14 sonar, and demonstrated the ability to return to a mine contact four times in four tries.[22]

When a small SWATH mine hunter/neutralizer is designed with the MHS-1 as the baseline, the mine avoidance sonar should be upgraded to mine-hunting status and should be equipped with an expendable mine neutralization vehicle. To this end, plans to make AMNS common to both airborne and surface MCM platforms should be continued. The objective cycle time from launch to mine detonation should be no more than 10 min (the Norwegian MINE SNIPER cycle time is only 6 min).[23] The Kline 5000 or 5500 should be retained for bathymetric

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[21]Informal communication between Lee M. Hunt and CAPT James M. McCoy, USNR, July, 2000.

[22]McCoy, CAPT James M., USNR, and LCDR Wayne Neely, USNR (TAR). 2000. "The SWATH Mine Hunter: An Enabling Technology That Works," *Proceedings of the Fourth International Symposium on Technology and the Mine Problem,* Naval Postgraduate School, Monterey, Calif., March 12-16, pp. 11-13 (see also Explosive Ordnance Disposal Mobile Unit 7. 2000. *MHS-1 Concept of Operations,* San Diego, Calif, January 5; Navy Office of Special Technology. 2000. *MHS-1 Integration Plan,* San Diego, Calif.).

[23]Spalding, G., Douglas Todoroff, and Kenneth Lobb. 1993. *MCM Technology in Norway, Finland, and Sweden,* ONR Visit Report, Office of Naval Research, Arlington, Va., September.

and minefield survey work, and the design should be capable of towing lightweight influence sweep gear for proofing cleared lanes. Additionally, a masthead lidar should be included for detection and avoidance of floating mines since the small SWATH will be expected to operate during night hours.

The ideal support ship should have a flight deck and a well deck and be able to transport, at fleet speeds, the number of the small SWATH MCM platforms tailored to clearing the necessary number of lanes in a specified time (perhaps up to 10, if space is available in the well deck), and a similar number of MH-60S (or more capable follow-on) airborne MCM helicopters. Additionally, serious consideration should be given to providing space to carry the VSW detachment and mammal systems, along with UUVs when they become available.

The MHS-1 has demonstrated its ability to do the work, in the littoral environment, of the MCM-1, MHC-51, and MH-53. A support ship designed or modified with the above capacity would transport, deploy, support, and recover the MCM equivalent of roughly the combined MCM capability of the coalition forces of Desert Storm (26 surface MCM hunter/neutralizers and 6 airborne MCM helicopters). The committee understands that the MCM(X) study,[24] now under way, is considering a design along these lines, and it strongly endorses that option.

In conclusion, there is a clear need for a dedicated/organic mine control ship (MCS) with well deck and flight deck, capable of deploying with the fleet, and equipped with surface MCM and airborne MCM platforms capable of operating in both the offshore and inshore areas.

As noted in Chapter 2, planning and programming for replacing the USS *Inchon* (MCS-12) in the near term, and for the next-generation MCS, must consider the addition of a well deck along with a flight deck in order to fully address the mine reconnaissance and mine clearance problem in both the offshore and inshore areas. Existing and developing designs should be evaluated for this purpose.

Recommendation: As a baseline for future design, the Navy should fully evaluate the MHS-1 for inshore reconnaissance, as a VSW detachment delivery platform, as a UUV delivery platform, and for mine hunting and neutralization as well as minesweeping (with lightweight gear).

NEUTRALIZING INSHORE MINES AND BREACHING INSHORE MINE AND OBSTACLE BARRIERS

The U.S. Navy does not now have a mine neutralization charge suited to inshore mine clearance as defined by the requirements discussed in this report.

[24]Office of the Chief of Naval Operations (N752) and Program Executive Office, Mine and Undersea Warfare (PMS 490). 2000. *MCM(X) Mission Area Analysis (MAA), Final Report* (U), Department of the Navy, Washington, D.C., October 30 (classified).

Swimmers now use a neutralization charge attached to the mine by a bungee cord and detonated by a timed fuse (up to 72-hour delay) attached to a float. Needed is a command-detonated (by coded acoustic pulse) cavity charge to allow more flexibility in detonation time and to reduce the logistic burden.

Delivery of a neutralization charge to a mine has long been a problem. Remote delivery systems have to use a bulk charge and settle for an instrument kill due to the inability to place the charge in contact with the explosive section of the mine. This leaves a minelike object to confuse subsequent minehunting sonars, an explosive charge in the environment, and a doubt as to whether the mine has actually been killed. Since mammals have not been trained and equipped to precisely place a charge against a mine, swimmers are now the only means of precisely placing a neutralization charge in contact with the explosive section of a mine as required by a small charge capable of ensuring a high-order detonation.

Attachment of a neutralization charge to a mine such that it remains in place under current conditions is a problem yet to be solved. The bungee cord works with moored mines and with proud mines but is less applicable with partially and completely buried mines. And it takes time to attach. Magnets do not work with nonmetallic material mines, and glues and bonding by vulcanization do not work because of marine fouling. The committee suggests a command-detonated neutralization charge for bottom and buried mines that can be placed in contact with the mine, but affixed to the bottom, rather than the mine, by a small embedded anchor pin. Since the time between setting the charge and detonating it is, in the case under discussion, measured in hours, the possibility of the mine moving due to storm-induced wave action is minimal. For moored mines, a small buoyancy ring, similar to those worked on by the Coastal Systems Station, Panama City, Florida, clipped around the mooring cable should be sufficient to hold the charge in contact with the mine case.

Recommendation: The Navy (ONR) should undertake a development program aimed at producing a small mine neutralization charge capable of achieving the high-order detonation of a mine, and easily and quickly emplaced by a swimmer, perhaps a marine mammal, and ultimately by an unmanned undersea vehicle (UUV). The charge should be capable of both timed and command detonation.

Pulsed Power

Pulsed power has been vigorously studied over the years and has been developed to serve many commercial applications. Versions have been developed for use in crushing kidney and bilial stones, in forming metal, and in crushing rock. Over the past decade, DARPA has funded research on the possible use of pulsed power to produce an instrument kill of mines, and to reduce obstacles to rubble.

Research over the past 3 to 5 years focused on the use of an electrothermochemical transducer with multiple firing ports (the proposed Water Hammer) that could be remotely floated into the VSW and sunk to rest on the bottom. Using a mixture of aluminum powder and water ($2\ Al + 3\ H_2O \rightarrow Al_2O_3 + 3\ H_2 + 797$ kJ) for energy production, the research aimed to produce overpressure of 2000 psi over 0.5 msec at a range of 20 to 50 yd with a repetition rate of 5 to 15 sec. Earlier pulsed power testing proved that the desired lethality for mines at these ranges could be achieved. However, DARPA support for Water Hammer testing terminated at sublethal pulse levels based on the potential logistics footprint and employability issues associated with the Water Hammer device.

In operation, the Water Hammer proposal called for three transducer devices to be placed on the bottom in the VSW in a diamond formation, the purpose of the two transducers at the base of the formation being to broaden the swept path and to brush aside crushed mines and "rubbleized" obstacles. Advancement of the transducers, in unison, was to be achieved by venting some of the explosive energy both fore and aft of the transducer. The interaction of the shock waves with the bottom would lift the transducer clear of the bottom, at which time the energy vented aft would move the transducer forward.[25]

Although an instrument kill (sympathetic detonation is unlikely) against mines in deeper water appears feasible, the committee has concern about the application of pulsed power, as configured, in the SZ and CLZ. Besides the problem of maintaining the diamond formation, there is the problem of energy loss through surface venting as the water becomes shallower than the shock wave pattern, particularly as the transducers have to climb up over the offshore bar and down into the plunge pool. And creating and projecting a wave onto the beach through which the energy is focused appears problematic.

The committee understands that a research effort is ongoing to produce a small mine neutralization charge using aluminum powder and water. This effort appears to have merit and should be continued.

Massive Breaching of the SZ and CLZ

It is necessary to understand the magnitude of the breaching task. In considering how to breach the SZ and the CLZ to the desired dimensions of the ICLZ, the widths of the SZ (10 to 0 ft) and the ICLZ (high-water mark to beach exit zone) are critical. The Marine Corps requirement mentioned earlier in this chapter assume an SZ with a slope of 1:300 and a beach width of 100 yd. This section accepts the 100-yd width for the ICLZ. Published beach data[26] show that 50

[25]Meth, Sheldon Z., and Theo Kooij, "DARPA/ATO Water Hammer Mine Neutralization Program" briefing to the committee on September 6, 2000, Defense Advanced Research Projects Agency, Advanced Technology Office, Arlington, Va.

[26]Coastal Systems Station. 1998. *Defense Planning Guide Beach Data,* Naval Surface Warfare Center, Dahlgren Division (NSWC/DD), Panama City, Fla., March 20; Coastal Systems Station. 1998. Revision of "Navy Standard Surf Model (NSSM): Defense Planning Guide," NSWC/DD, Panama City, Fla.

percent of the beaches surveyed have a gradient not exceeding 93, giving a maximum SZ width of 536 ft; 75 percent have a gradient of 208 or less, giving a maximum SZ width of 1200 ft; and 83 percent of the beaches have a gradient not exceeding 300, for a maximum width of 1750 ft. The discussions that follow use the 1750-ft width as the more stressing case.

For calculation purposes, the committee stipulates that instead of focusing on the two 80 × 80 yd areas (the ICLZ) at the end of each 50-yd assault lane, clearance will focus on the 65 × 100 yd area between the two assault lanes projecting through the SZ and CLZ from each 165-yd transit lane. The purpose of the two ICLZs is for incoming landing craft, air-cushioned (LCAC) to sit down, unload, and then exit the same assault lane. If, instead, the beach area between the two assault lanes is cleared, LCACs can enter one lane, unload in the space between, and exit via the second lane. The committee also stipulates that if ISR indicates that no minefield or obstacles exist immediately landward of the BEZ, then that area will be used for LCAC unloading, thus avoiding the need to clear either the two ICLZs or the area in between the two assault lanes. The latter possibility, according to present plans, would save a critical hour of breaching time, remove the necessity of housing, transporting, and offloading mechanical clearance equipment at each of six locations, and save the clearance of a total of 960 × 960 yd (ICLZs) or 390 × 600 yd (area between assault lanes) for the six transit lanes.

Over the past decade, through numerous studies, workshops, and brainstorming sessions participated in by some of the best minds in the country, several ideas for breaching the SZ and CLZ within the desired time and area constraints have been put forward. Virtually all of these ideas have been rejected on sound technical, operational, or logistics grounds. Those that have been retained for further examination fall into four categories—kinetic energy, explosives, foam, and mechanical equipment.

Kinetic Energy

Of the several kinetic energy approaches, all employ multiple high-velocity darts, impactors, or continuous rod warheads (CRWs) delivered by air-launched missiles or shipboard 5-in. or 155-mm guns. Darts are intended to neutralize AP/AT mines in the SZ and the ICLZ area, and impactors and CRWs are intended to reduce obstacles only in the ICLZ area.

Hydra-7, now in the R&D program, uses an FA-18 aircraft to deliver a wind-corrected tactical munitions dispenser (WC-TMD) housing five SUU 66/B munitions missiles, each carrying 926 high-temperature incendiary darts (2000 fps) or 14 explosively driven impactors for a total of 4630 and 70 penerators per WC-TMD, respectively. The expected kill radius for each munitions missile is approximately 25 ft.

An alternate approach is the mine/obstacle defeat system (MODS), which uses a JDAM tail kit and Diamond Back folding wing (JDAM-ER) on either of two dispensers. One is the aerodynamic form of an Mk-84 2000-lb bomb to deliver, with circular error probable (CEP) of less than 3 m, 6320 (50 *g*) penetrators with a kill diameter of 60 ft. The other consists of two 650-lb CRWs with a kill diameter of approximately 78 ft. The former is intended to neutralize mines in the SZ and ICLZ, and the latter to reduce obstacles in the ICLZ area only. JDAM-ER has a standoff range of 30 nm.

A third approach under consideration is the use of two dispenser warheads fired from 5 in. or 155 mm naval guns. Again, chemical and reactive darts are used against mines (SZ and ICLZ), and CRW warheads are used against obstacles in the ICLZ, with a kill diameter of approximately 20 and 30 ft, respectively. The standoff range is 15 nautical miles.[27]

The committee considered the number of missile dispensers and the number of 5-in.-/155-mm rounds required to clear the SZ and ICLZ area for six transit lanes (12 assault lanes) and found them to be large within the time and assets available.[28]

Explosive Breaching

SABRE and DET. The breaching approaches nearest to completion are shallow water assault breaching (SABRE) and distributed explosive technology (DET), although the status of both programs is now uncertain. SABRE is a 400-ft discontinuous line charge emplaced from an LCAC using an Mk-22 Mod-4 rocket, and DET is a 180 × 180 ft primer cord net (nominally 150 × 150 ft actual coverage) launched into place by two rockets. Neither is effective against heavy obstacles.

Due to wind effects and rocket inaccuracies, as well as its horizontal cleared path, 15 SABRE line charges are required to clear each 400-ft increment of an assault lane in the SZ. The LCAC moves in to the beginning of the SZ, backs off 200 ft for the desired standoff, and launches successive charges by moving sideways for each shot. If the obstacles begin at the offshore bar, then SABRE is restricted to the first 400 ft of the assault lane, leaving the remaining 1300 ft unreachable. DET is similarly affected. The now canceled ATD program for SABRE/DET called for a rocket capable of significantly greater range. If these

[27]Yunker, Chris, "MCM in Millennium Dragon: Seaward Maneuver and MCM in Support of STOM—Complementary CONOPS," briefing to the committee, February 7, 2001, Applied Physics Laboratory, Johns Hopkins University, Laurel, Md.

[28]To provide some comparison with past breaching experience, during the beach bombardment preceding H Hour in the invasion of Okinawa (April 1, 1945), the fleet fired 44,825 rounds of 5- to 16-in. shells, 33,000 rockets, and 22,500 mortar shells. This does not include the 3-in., 40-mm, 20-mm, and 50-caliber rounds that may have equaled the combined total of all other ordnance. And the invasion beach was not even defended. (Leckie, Robert. 1995. *Okinawa: The Last Battle of World War II,* Penguin Books USA, Inc., Viking Press, New York, pp. 70-71.)

two systems are to be continued, consideration should be given to reviving the requirement for a longer-range rocket.

The SABRE/DET systems, although on hold, are near completion. They are the only breaching systems that might be available in the near term. There may be contingencies in which mines but not obstacles will be used in the SZ and CLZ, and where obstacles are also used they may be confined to the tidal range area of the SZ, thus significantly shortening the SZ breaching distance at high tide.

Harvest Hammer. In both its 1994 MCM study[29] and its 1997 TFNF study,[30] the Naval Studies Board concluded that air-delivered bombs used to create a line charge analogue were the only effective means of clearing both mines and obstacles from the assault lanes through the SZ and ICLZ within the time limit desired by the Marine Corps. In reaching that conclusion, after evaluating several different ideas, the NSB drew on a wealth of cratering and buried line charge analogue experiments conducted during World War II, during the Plowshare program, and during years of experimentation by the Army Corps of Engineers. Independent calculations drawing on this prior experience estimated that bombs carrying explosive charges equivalent to 10,000 lb of TNT, buried on impact to a minimum of 21 ft at 23-yd intervals, would excavate most mines and obstacles from a channel approximately 64 yd wide where the water depth was 3 ft and greater, and from a somewhat narrower dry beach. The result would be a smooth channel some 10 to 15 ft deeper than the original sediment surface. Both NSB studies recommended a scaled test of this concept to characterize the phenomena and to enable the adjustments necessary to a full-scale test and possible operational use.

The cited experience, results of the independent calculations, and discussions leading to the NSB's 1994 recommendation are reproduced in this report as Appendix C.[31]

Subsequent to the 1994 recommendation, the Indian Head Division of the Naval Surface Warfare Division did its own calculations (including several for this study), conducted scaled tests of buried charges (of up to about 250 lb of TNT) and surface-detonated bombs, and sponsored centrifuge experiments at the University of Maryland. Additionally, Lawrence Livermore National Laboratory has done calculations of the effects of a double line of smaller bombs. All of this work, while adding new knowledge and understanding, has confirmed the basic

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[29]Naval Studies Board, National Research Council. 1993-1994. *Mine Countermeasures Technology Study* (U), 4 volumes, National Academy Press, Washington, D.C. (classified).

[30]Naval Studies Board, National Research Council. 1997. *Technology for the United States Navy and Marine Corps, 2000-2035, Vol. 7, Undersea Warfare,* National Academy Press, Washington, D.C.

[31]Naval Studies Board, National Research Council. 1994. *Mine Countermeasures Technology, Volume II: Task Group Report,* (U), National Academy Press, Washington, D.C. (classified).

findings of the NSB. For instance, in scale tests, Indian Head found, in confirmation of earlier Plowshare work, that buried charges simultaneously detonated leave a berm on either side of the long axis of the resulting channel, but not at either end of the channel—a phenomenon yet to be explained but one helpful to the transit of LCAC and advanced amphibious assault vehicles (AAAVs) into and out of the channel. Also, Indian Head found that surface-detonated bombs "sweep" both mines and obstacles some distance away from the blast site.

Unfortunately, the Indian Head effort has been only a part of a larger research task, and progress has, therefore, been slow; the scaled experiments have had to be performed in the United Kingdom and in Australia. Many of the questions posed by the 1994 report have yet to be addressed.

This committee endorses the earlier findings and recommendation of the NSB study group (see Appendix C). After reviewing the many ideas proposed over the past decade for clearing assault lanes through the SZ and CLZ within the desired time limits and ICLZ dimensions, the committee believes that the Harvest Hammer approach holds the greatest promise. However, additional research, scaled tests, and demonstration are required to prove the concept. The Navy should include, inter alia, the following:

- *Air Force demonstrations.* The ability to deliver a string of bombs in a straight line (within GPS tolerances) and at the required interval is critical to the success of the Harvest Hammer approach to breaching the 50-yd assault lanes through the SZ and CLZ. During the course of this study, Air Force representatives expressed interest in demonstrating that a B-2 can meet these requirements. Since the Air Force has aircraft with the required payload capacity, and their use for the delivery job would free up naval aircraft for other missions, the committee recommends that the demonstration be conducted at the earliest opportunity.
- *Scale tests.* The scale, centrifuge, and modeling work at Indian Head should be accelerated, extended to determine what explosive size, spacing, burial depth, and timing are required to form a channel of sufficient width, measured at depths allowing safe passage of vehicles over any mines or obstacles that may not have been removed, or that may have been thrown in from other channels. Recommended to be addressed are (1) the dispersion of mines and obstacles, including partially buried posts, ejected from the explosion channel; (2) the probable condition of tilt rod, pressure, and magnetic AP/AT mines so ejected; (3) the slope of the lip at the terminal end of the channel; (4) the relationship between longitudinal berm formation and wash back following detonation of a line charge analogue; (5) the effects of longitudinal wash back on the slope of the terminal lip; (6) the probability of mines being moved back into the channel by wash back; and (7) the shape of the channel's cross section following berm formation and wash back.
- *Bomb size.* The calculations for the 1994 report were based on a 10,000-lb penetrating bomb containing around 5000 lb of explosive with yield equivalent

to 10,000 lb of TNT. Using modern explosives at three times TNT would reduce the charge weight for a 10,000-lb TNT equivalent to around 3300 lb, with a corresponding reduction in case weight. If, in the far term, a five times TNT explosive compound with acceptable sensitivity is achieved, then the charge weight could be reduced to around 2000 lb. Future calculations should obviously be based on the use of modern and anticipated explosives. Additionally, modern technology and materials should be brought to bear on reducing case weight while maintaining the penetration requirements. This work should be coordinated with the Air Force effort to develop penetrating bombs following Desert Storm.

- *Alternate delivery.* Harvest Hammer is intended for use only in cases where both mines and obstacles are present, where there is no alternative to breaching, and where breaching time is critical. In such cases, IA3 could include antiaircraft guns and missiles. If the naval fire support has not been able to neutralize these defenses, a standoff delivery of bombs using JDAM delivery should be considered in the R&D effort.
- *Delivery accuracy.* GPS guidance of bombs will be required to ensure impact precision under varying operational and atmospheric conditions. See footnote 18 in this chapter for a discussion of possible GPS jamming and means to overcome it.
- *Simultaneous detonation.* In the 1994 NSB study[32] it was estimated that to obtain the best results, bombs in a given channel should detonate within a time window of 0.01 sec, which was considered feasible using timed fuzes. The research program should evaluate timed detonation mechanisms, including trailing wire antennas for command detonation.
- *Dud rate.* For this application, attention should be devoted to reducing the dud rate experienced in stockpile bombs.
- *Bomb requirements.* The original NSB calculations in the 1994 report assumed bombs with 10,000 lb of TNT and spaced at 60-ft intervals. This number will obviously change when the results of the recommended research program become available.

Foam

Sandia National Laboratories has conducted extensive experimentation with a binary foaming agent—polymeric methylene diphenylene di-isoyante (PMDI) and a polyol resin.[33] The foaming agent, mixed at the nozzle, has a 20:1 expan-

[32]Naval Studies Board, National Research Council. 1994. *Mine Countermeasures Technology, Volume II: Task Group Report,* (U), National Academy Press, Washington, D.C. (classified).

[33]Woodfin, Ronald L., D.L. Faucett, B.G. Hance. A.E. Latham, and C.O. Schmidt. 1999. *Rigid Polyurethane FOAM (RPF) for Countermines (Sea) Program, Phase II,* Report SAND98-2778, Sandia National Laboratories, Albuquerque, N.M., October.

sion ratio and sets in about 5 to 8 min. Additional layers can be added after allowing 8 min for the previous layer to cure. The foam will set up and cure in water as well as on dry land. The result is a tough surface, buoyant in water, capable of supporting the weight of tanks and other armored vehicles without undue wear (55 tank transits result in a rut 1 ft deep). Also, foam stands up well under projectile impact and explosive attack, is fire resistant, and when damaged can be easily and quickly repaired with additional foam.

The advantage of foam is that it can be used to cover both mines and obstacles—at least to the extent of allowing exposure of only the maximum 10 in. tolerable for LCACs and Marine Corps assault vehicles. A free-floating foam causeway in the SZ could, under the pressure of traffic, activate tilt rod mines. However, where the causeway rests on the bottom or beach, tilt rods would be enclosed by and immobilized by the foam. Due to the distribution of weight, pressure mines, particularly those requiring a rolling pressure signature, would not likely be set off. Magnetic mines likely would be set off. However, the foam layer provides both standoff and cushioning of the blast. Experiments have indicated that an AP mine will not vent through a foam layer of only 30 in. in thickness.

A simple calculation from the expansion ratio shows that a 4-ft-thick causeway wide enough to accept a tank, say 20 ft, and extending through the SZ and ICLZ ($20 \times 4 \times 2025$ divided by 20) would require 8100 cubic ft of chemicals, or 16,200 cubic ft for two assault lanes.

In addition to the possible breaching application, the Marines and the Army might find foam useful inland for bridging AT and AP minefields, swampy areas, and small rivers. In the latter application the "sock" technique could be used to form the pontoon bridges before floating them.

In summary, experiments with binary foaming chemicals (PMDI with polyol resin) have demonstrated the ability to rapidly form roadways and causeways capable of bearing and withstanding heavy traffic, immobilizing or providing blast mitigation of mines, and reducing the exposure of obstacles. Further, such foams have application to bridging inland minefields, swampy areas, and small rivers.

Part of the ONR's efforts would utilize the data from experiments on foaming agents to evaluate the logistics footprint, delivery and time of installation, and cost of using foaming agents both in the SZ and ICLZ area and inland. If the results are positive for foaming agents, the CNO could then initiate action for the Navy to acquire the capability.

Mechanical Clearance of the ICLZ Area

Present plans call for the Navy to assume responsibility for all breaching operations from the SZ to the BEZ by 2008. However, the committee believes that the Navy should continue its responsibility for clearing the assault lanes for each transit lane up to the high-water mark to inland on the beach and the Marine Corps should retain the responsibility for clearing the ICLZ areas. This approach is in keeping with the need to clear land mines in maneuver areas that the Marine Corps will face in any case.

When two 50-yd assault lanes have been breached through the SZ and CLZ, and the first wave of AAAVs has passed, the MCM forces have 60 min (90-min threshold) to clear an 80 × 80 yd ICLZ area at the end of each assault lane for LCAC set-down and unloading. However, discussions with Marine Corps representatives indicated that clearing the 300 × 195 ft section on the beach between the two 50-yd assault lanes will suffice. Present plans call for landing mechanical equipment to perform this task. With the cancellation of Grizzly, the Marines retain a track-wide mine plow with magnetic rollers mounted on an M-1 tank (12 in each tank battalion) and the line charge system, which is a 300-ft rocket-propelled line charge (1750 lb of C-4).

Utilizing the nominal threat lay-down, and given the stated spacing between mines (18 to 24 ft) on the beach, approximately 22 AP mines and 11 AT mines will have to be cleared from the 300 × 195 ft area between the assault lanes. Stipulated are two 4 × 4 × 4 concrete blocks at the waterline spaced 50 ft apart, two steel tetrahedrons with equal spacing higher on the beach, and behind that a triple roll of concertina wire.

Inland AT minefields are usually sown with AP mines to prevent combat engineers from simply walking into the field and placing neutralization charges on the AT mines. To broaden the acquisition radius of the AP mines, and for concealment, AP mines with deployed trip wires are commonly used. The Army has a technique for clearing a tank lane through such fields in as little as 15 min. A small grapnel hook attached to a line is fired across the field and reeled in by hand—thus setting off all of the AP mines by snagging the trip wires in its path. Combat engineers then walk that line placing neutralization charges on the AT mines over the width of a tank lane. A variant of that technique would seem to have application to the ICLZ task outlined above.

Based on a suggestion made by the JASONs during Desert Shield/Storm for sweeping beach mines aside, a suitable vehicle could be equipped with a self-priming pump, a trainable nozzle, and a trailing intake hose for using seawater as the feed. Assuming that Harvest Hammer has been used to clear the assault lanes, the water cannon would be used to rearrange the slope of the terminal lip (if required) to cut the longitudinal berm on the interior side of the channel,[34] and to

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[34]During the 1973 war between Egypt and Israel, the Egyptians used high-pressure water jets to breach the Bar-Lev Line. The Bar-Lev Line, on the east side of the Suez Canal, was designed to give the Israelis a 24-hour warning of an Egyptian attack, that being the time estimated to bridge the canal. Forward of other obstacles, the Israelis created a huge sand ridge. Calculations of the time required to breach the sand barrier were based on the need to cut a hole 6.8 m wide to pass a tank through, necessitating the removal of 55 cubic meters of sand. It was estimated that 60 such breaches would be required to accommodate the Egyptian tank force, and that using either bulldozers or

sweep AP mines to a central location—possibly against the upper border of the beach. AT mines would be more difficult to move, and, using the Army technique, it is not necessary that they be moved anyway. It should also be pointed out that due to wind, wave, and tidal action, many mines, both AT and AP mines, may be buried. The water cannon can be used to expose buried mines.

Once the 22 AP mines have been swept to a known location, combat engineers can place neutralization charges on the 11 AT mines, and on the two concrete blocks and two tetrahedrons. Since the triple roll of concertina wire will already have been cut by the two assault channels, this vehicle could simply drag the rolls inland for disposal.

An alternative to using explosive charges to reduce obstacles might be the abrasive water saw. Such saws are now in use for a broad spectrum of applications, including EOD work.[35] Abrasive water saws applicable to reducing obstacles use a nozzle size of 0.8 mm, a water pressure of 350 bar, and a flow rate of 8 liters per minute. The abrasive is 80-mesh (150 to 300 microns) garnet mixed with water at approximately 12 percent by weight. Although higher pressures are possible, an abrasive water saw with these specifications is capable of cutting 100 mm per min in 10-mm-thick mild steel, or roughly the leg of a tetrahedron in 30 sec. A hand-held version of the abrasive water saw for combat engineers could be used to quickly reduce tetrahedrons and hedgehogs, cut holes in concrete blocks for the insertion of explosive charges, and cut the tilt rod from AT mines.

An alternate approach would be to use cannon fire to destroy the mines as they are exposed by the water cannon, as well as the obstacles (except for the concertina wire). The AAAV is equipped with a 30-mm Bushmaster Mk 44 cannon and a 7.62-mm machine gun with a total of 600 and 2400 rounds, respectively, and its armor can withstand shrapnel from the nearby explosion of antipersonnel and antitank mines.

The combination of a water cannon, the AAAV's 30-mm cannon, and a hand-held water saw offer the possibility of clearing the ICLZ of mines and obstacles in less than the time now allowed for this activity.

Wattenberg Antisnag Plow. Again as part of Desert Shield/Storm, the JASONs recommended a helicopter-towed mine plow invented by Dr. Willard H. Wattenberg.[36] The plow consists of a strong-back, the bottom side of which

explosives would require between 10 and 12 hours. Using water jets taken from their fire fighting equipment, the Egyptians were able to accomplish the task in 5 to 6 hours, thus accounting for their early successes in that war. (Summers, David A. 1989. "Development of Waterjet Technology," paper presented at the Waterjet Cutting West conference, held at the Sheraton Plaza La Reira, Los Angeles, Calif., on November 14-15 by the Society of Manufacturing Engineers, pp. 7-8.)

[35]Written communication between Lee M. Hunt and DISARMCO, Limited, Bucks, United Kingdom, regarding the DIADIS 300 remote mine neutralization water saw, March 8, 2001.

[36]Muller, R., D. Eardley, R. Garwin, S. Koonin, and R. Perkins. 1992. *Mines in the Surf Zone,* JSR-92-180, draft, JASON, The MITRE Corporation, McLean, Va., December 9.

contains a series of cutting knives spaced 4 in. apart and capable of penetrating 10 in. into the soil surface. The antisnag label comes from the fact that the knives are capable of articulating in order to pass over immovable objects. Behind, and towed by the strong-back, is a chain "blanket" used to hold the strong-back on the ground under tow and to sift disturbed earth through the blanket while leaving buried mines proud of the ground. Disturbed earth and mines flow over the strong-back in a kind of standing wave. With the addition of a wire basket mounted on the chain blanket, mines can be accumulated for more efficient disposal.

A scale version of the Wattenberg antisnag plow has been tested at 20 knots in very tough terrain (lava boulders) without breaking the digging knives. And it has been demonstrated that an AT mine exploding under the blanket reduces the blanket by only 10 percent, and that repairs are rapidly and cheaply made by simply snapping in new chain segments.

The Wattenberg plow has two major disadvantages: The towing helicopter cannot be used until AA defenses have been neutralized, and it cannot be used efficiently for clearing beaches heavily populated by obstacles. However, for rapidly clearing those beaches where mines but not obstacles are used and where opposing fire has been neutralized, including the SZ, the Wattenberg plow, due to its clearance speed and its ability to clear buried AP/AT mines, would seem to have a unique role to play. Further, after the covering fire has been neutralized, the plow has a role to play in the broadening of inland minefields. As demonstrated by Desert Storm, the most time-consuming MCM job, both at sea and on land, comes after the initial assault.

Under benign operating conditions, the Wattenberg antisnag plow offers unique characteristics of clearance speed, modest initial and repair costs, and applicability in the SZ/CLZ (in the absence of obstacles) and on land.

The Navy (ONR) should evaluate the Wattenberg antisnag plow for application in the SZ and CLZ and on land.

Marking Systems

The Navy and Marine Corps need a cleared-lane electronic marking system suitable to safely guide assault and logistics vehicles through narrow lanes and variable headings. An interim marking system consisting of a fresnel lens beacon on the beach now provides navigation guidance for assault and logistics vehicles approaching the beach. It must be placed on a presumably mined beach prior to the assault. It allows only for a straight-in approach and does not accommodate track segments with different headings.

There is no autopilot capability on assault or logistics vehicles which would allow them to conform to an electronically marked transit (165 yd) or assault (50 yd) lane. In situ visual lane markers could be used as an interim technique, but they essentially "paint" the lanes to be used, making them equally visible to the enemy.

Acoustic pingers could be placed by clandestine clearance forces (divers, mammals, UUVs). The pingers would be energized by an acoustic modem on lead assault vehicles and serve as a backup for electronically marked lanes in a common tactical picture display in assault and logistics vehicles.

The key issue is that a satisfactory lane-marking and assault vehicle navigation system is needed to safely guide assault and logistics vehicles along relatively narrow transit and assault lanes under varying conditions of visibility. A system that does not depend on pre-emplaced navigational aids would appear to be the preferred methodology, such as one that relies on the GPS coordinates in conjunction with autopilot controls on the AAAV and LCAC, should be developed for this purpose.

CONCLUDING COMMENTS AND RECOMMENDATIONS

This discussion of inshore countermine warfare identifies many systems and techniques for clearing mines and obstacles from the VSW, SZ, and CLZ. The committee recognizes that funding for such systems and techniques will continue to be tight in the current defense budget environment and that choices will have to be made as to which ones to emphasize early. The committee believes that to solve the inshore MCM problem satisfactorily in the near term, the following systems and techniques deserve early attention and funding: JLAN/DADS/ADS; UUVs for mine hunting; Harvest Hammer; GPS on landing craft and all MCM craft; lane-marking systems; and continuing experiments with the MHS-1. The remainder of the systems and techniques mentioned merit continuing R&D at some useful level within the affordability constraints, consistent with designating mine warfare as a major naval warfare area.

Recommendation: The U.S. Navy and U.S. Marine Corps countermine warfare capabilities for the inshore region should be improved and harmonized, and responsibilities among the Services should be clarified. In general, efforts are needed to (a) improve the utilization of inshore intelligence, surveillance, and reconnaissance (ISR) information in order to better assemble a common operational picture so that maneuver units can avoid mined and obstructed areas, thereby limiting the need to conduct breaching operations; (b) improve U.S. capabilities for rapid breaching operations (when they are needed); (c) expand the focus of inshore countermine warfare to more fully reflect the need to provide assured, timely access for logistics support; and (d) agree that responsibility for countering land mines above the high-water mark should be retained by the U.S. Marine Corps. Specifically,

- The Marine Corps Combat Development Command for the Marine Corps and the Navy Warfare Development Command for the Navy, under CNO and

CMC direction, should jointly define and approve preferred concepts of operation (CONOPS) for opposed amphibious operations, the size and operational character of which should form the basis for future landing force size and equipage requirements (including MCM requirements). The CONOPS should be consistent with the available amphibious lift and fire support resources, approved threat scenarios, and the requirements for logistics flows to and across the shore.

• The CNO and the CMC should agree on, and the CNO should ensure that the Navy funds, the programs needed to fulfill the Navy's responsibility to clear minefields from the VSW zone through the SZ that the Marines may have to traverse to make amphibious landings of up to two Marine expeditionary brigades in size against levels of opposition and on the time lines that have been jointly determined and agreed to be reasonable. These programs should include:

—Expansion of the MCM capability supported by the dedicated MCM support ship(s) to include inshore waters;

—Harmonization and funding of the automated navigation systems for Navy and Marine Corps landing craft as needed to minimize the width of the lanes that have to be cleared of mines;

—A joint research, development, testing, and evaluation (RDT&E) program with the U.S. Air Force to develop and refine the Harvest Hammer approach to clearing channels through the SZ, perhaps as a variant of the JDAM weapon system, including expansion of the existing memorandum of understanding with the Air Force to reflect how the technique will be designed and proved, and how the service will be provided when needed; and

—An aggressive program to reevaluate SABRE/DET and other line charge systems concepts.

In addition, the Marine Corps should retain responsibility for clearing the beach above the high-water mark of land mines and obstacles and should aggressively pursue a program to evaluate innovative techniques (such as water cannon) for use in fulfilling this responsibility.

• The CNO should work with the Commander in Chief, Transportation Command to more clearly define the likely requirements for joint countermine warfare activities in support of the planned early arrival in the combat theater of maritime prepositioning ships and others that plan to put unit equipment and logistics supplies ashore, either through ports or over the beach—both of which are subject to inshore mining.

Appendixes

Appendix A

Details of Amphibious and Logistics Over-the-Shore Operations

THE THREAT ENVIRONMENT

Should U.S. forces be called on to execute the present and evolving naval strategy ("Forward . . . From the Sea," "Operational Maneuver From the Sea," and "Ship to Objective Maneuver" (STOM)) in full, the Navy, with Marine Corps assistance, must be able to place the Marines ashore with speed, surprise, flexibility, and acceptable casualties. The Navy must also be able to sustain the Marines ashore with firepower and logistics—and, in prolonged operations, the Army and Air Force as well.

In any future power projection mission U.S. naval forces must be prepared to meet or circumvent an integrated antiamphibious assault (IA3) defense similar to that developed by the former Soviet Union, since many potential U.S. antagonists still use former Soviet military doctrine—a defense consisting of perimeter, main, and very shallow water (VSW) mine barriers in the beach approaches, and tough obstacles interspersed with antitank (AT) and antipersonnel (AP) mines in the surf zone (SZ) and the craft landing zone (CLZ).

To gauge the current U.S. capability to deal with an IA3 defense, and to help fill any gaps in that capability, the committee used the Joint Countermine Advanced Concept Technical Demonstration (JCM ACTD) nominal threat lay-down employed in JTFEX 97-3 held at Onslow Bay in September 1997 (see Box A.1).

MINE COUNTERMEASURES IN SUPPORT OF SHIP TO OBJECTIVE MANEUVER

Expeditionary maneuver warfare is the overarching concept that encompasses four integrated supporting operational concepts that characterize how the

Box A.1 JCM ACTD Nominal Threat Lay-Down

The JTFEX 97-3 threat lay-down deviates from classic IA3 doctrine by adding a very shallow water (VSW) mine barrier. The following detailed description of the threat is for a nominal threat lay-down, not a high-end lay-down.

Perimeter Minefield

The seaward mine barrier is placed approximately 50 nautical miles from shore, and in 40 to 200 ft of water. The distance from shore may vary depending on bathymetry and the range of covering fire. The perimeter minefield is 25 nautical miles in length and 0.5 nautical miles deep. It consists of one row of 500 MKB moored contact mines and two rows of 200 KMD II-1000 bottom influence mines with spacing of 150 to 200 yd spacing between mines to prevent countermining, i.e., one mine detonation causing adjacent mines to detonate.

Main Minefield

The intermediate mine barrier consists of five mine belts placed 7 to 9 nautical miles from shore, and, again, in 40 to 200 ft of water. Each belt is 5 nautical miles long and 1 nautical mile deep. The first two mine belts consist of two rows totaling 150 MKB moored contact mines spaced 125 yd apart, and one row of 50 KMD II 500 bottom influence mines spaced 150 to 200 yd apart. Two other mine belts consist of a total of 80 MYAM moored contact mines in two rows, and one row of 40 KMD II 500 bottom influence mines, all spaced 250 yd apart. The fifth belt consists of 250 MKB moored contact mines in three rows with mines spaced at 120-yd intervals.

Very Shallow Water Minefield

Added to the classic IA3 mine defense is a mine barrier located 0.5 nautical miles from the surf zone (SZ). The barrier is 12 nautical miles in length and 0.3 nautical miles deep, and consists of a total of 1000 Al Muthena-35 and PDM-3ya moored contact mines in two rows with mines spaced at 40 and 20 yd intervals, respectively, and one row of 200 Manta bottom influence mines spaced 110 yd apart.

Marine Corps will fulfill its national security role, as well as project power and influence in the 21st century. These concepts are (1) peacetime forward presence, (2) crises prevention and deterrence, (3) expeditionary operations from a sea base, and (4) sustained operations ashore. The Navy will continue to play a key role with support at varying levels in all four of these concepts. Its ability to carry out mine countermeasures (MCM) in support of STOM missions from a sea base will be critical for success and will demand new thinking on how to accomplish that requirement.

STOM will be executed by Marine air-ground task forces (MAGTFs) at Marine expeditionary unit (Special Operations Capable) (MEU (SOC)), Marine

Engineer and Beach Barrier

The final barrier covers the SZ (10 to 0 ft) and the craft landing zone (CLZ) (high-water mark (HWM) to the beach exit zone (BEZ)). According to the Defense Planning Guide[1] the SZ is 571.58 ft for a gradient of 1:99, and 1743.60 ft for a gradient of 1:300. The CLZ is taken as the 300 ft from the HWM to the BEZ.

The SZ barrier is approximately 3.5 nautical miles long, and consists of three clusters of mine belts, each 1000 to 2000 yd long. In water depths of 10 to 3 ft the belts are made up of 1000 PDM-1 tilt rod mines spaced at 6-yd intervals, and 750 PDM-1 tilt rod mines spaced at 8-yd intervals. Near the HWM 3000 TM-36/TM-57 (or equivalent) antitank (AT) mines and PMN/POMZ (or equivalent) antipersonnel (AP) mines are spaced at 6-yd intervals.

The mine barrier in the CLZ consists of one row of 6000 PMN/POMZ AP mines, and two rows of 3000 AP/AT mines (TM-46/TM-57 and PMN/POMZ) spaced at 6-yd intervals.

There are 600 obstacles beginning with the SZ and covering the CLZ. The first row begins with hardwood logs, telephone poles, or railroad rails driven into the offshore bar and angled seaward. The second row, in the shallower part of the SZ, consists of 4 × 4 × 4 ft cubes of 3000 psi concrete. The CLZ obstacle defense consists of one row of steel hedgehogs made of 4 × 4 × 5/8 in. angle iron, each leg 4 ft long and welded together, and one row of tetrahedrons made of 4 × 4 × 5/6 in. angle iron, each leg 5 ft long and welded. Between these rows is a single roll of concertina wire behind which is a triple row. The obstacles, of course, are superimposed on the SZ and CLZ minefields.

The characteristics of the mines used in the nominal threat lay-down are well known. Not included are mines whose existence and characteristics are only speculative. Such mines might include acoustic anti-invasion mines, self-burying mines, advanced stealth mines, anti-MCM mines, pure pressure mines, distributed sensor mines, and mines with computers for control of multiple sensitivity, ship count, and counter-countermeasure settings.

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[1]Coastal Systems Station. 1998. *Defense Planning Guide Beach Data,* Naval Surface Warfare Center, Dahlgren Division (NSWC/DD), Panama City, Fla., March 20; Coastal Systems Station. 1998. Revision of "Navy Standard Surf Model (NSSM): Defense Planning Guide," NSWC/DD, Panama City, Fla.

expeditionary brigade (MEB), and Marine expeditionary force (MEF) levels depending on the threat from theater ballistic missiles (TBMs), cruise missiles, and mines, along with available assets to deal with them. STOM employs the principles of maneuver warfare on land to maneuver on the sea in littoral regions in order to project combined arms MAGTFs directly against objectives well inland from the sea base. Specifically, STOM will allow for tactical movement by air and surface means from over the horizon directly toward assigned objectives inland without the need for stopping to seize and build up beachheads before moving on. It means that the unit will have the ability to avoid opposition strengths in coastal areas, while finding weaknesses or "gaps" in enemy defenses that can be exploited through maneuver. This also means finding mine-free areas in the shallow water (SW) and VSW—or gaps in existing minefields that seaborne forces can maneuver through. The MV-22, the advanced amphibious assault vehicle (AAAV), and the landing craft, air-cushioned (LCAC) will give the commander the flexibility of speed of maneuver from over the horizon, across the beach, and inland that has not been possible in the past.

STOM is a distinct change from the way amphibious operations, including the planned amphibious landing at Ash Shuaybah in Kuwait, have been conducted over time. Amphibious operations have always called for the establishment of a beachhead, the buildup of supplies, and then the attack inland toward assigned objectives. There was little flexibility in this approach, and it was difficult to avoid enemy strengths due, in part, to the limitations of intelligence, lack of maneuver space, and the limited capabilities of the platforms utilized in ship-to-shore movement.

The fundamental requirement for STOM to succeed in the future is accurate and responsive intelligence available to commanders in common tactical pictures supported by appropriate databases. There must be a coherent and coordinated intelligence, surveillance, and reconnaissance (ISR) plan that is built around surveillance, clandestine reconnaissance, and lane search that extends from offshore assembly areas through the beach exit zone (BEZ) and into the area just landward of the BEZ. The ISR operations in accordance with the plan must remain covert from initial tasking (C-Day to a notional C + 50[2]) to the commencement of seaborne maneuver by the MAGTF. The tasked assets in the ISR plan should be able to detect the transportation of mines and obstacle materials from depots to coastal areas, develop accurate environmental data and bottom mapping, determine both mined and unmined areas from the SW zone to the beach, and detect mining and obstacle construction on and behind the beaches in potential landing areas. This effort involves tasking national, theater, and tactical surveillance and reconnaissance assets by the joint task force (JTF) (see Figure 2.5 in Chapter 2), and it must be prioritized at the highest levels in order to get the necessary information. This is the only way that commanders can develop the tactical situation and appropriate maneuver plans for STOM missions in littoral regions where there is the potential threat of enemy mines.

New geographical definitions and coordination measures for STOM, not utilized in conventional amphibious operations in the past, are being developed as a means for determining the best areas for exploitation. The ISR plan should provide the commander with the necessary information for selecting the best geographical area with the least risk. These geographical areas are described in Box A.2.

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[2]Marine Corps Combat Development Command. 2000. *Ship-to-Objective Maneuver Concept of Operations* (draft), Warfighting Requirements Division, Quantico, Va., August.

Box A.2
Littoral Penetration and STOM

The littoral penetration area (LPA) is a geographical area designated by the joint task force (JTF) commander delegated overall responsibility for the forthcoming operation in conjunction with the supported and supporting commanders (see Figure A.1). This area must be of sufficient size to permit unrestricted control of sea, air, and land operations. Normally one LPA is associated with each objective area, and there may be more than one LPA under consideration early in the planning process. The distances involved in narrowing down the selected areas under consideration may stress the available Navy surveillance and reconnaissance assets in the beginning, and other national and joint surveillance assets will have to be utilized to gather the required intelligence.

Littoral penetration zones (LPZs) can be divided into smaller geographical zones to enhance command and control or facilitate coordination of maneuver or fire power. There could be several LPZs under consideration within the LPA that has been selected by the JTF commander for the operation. Each LPZ may contain several alternate axes for use by airborne or surface maneuver forces. The size of the LPZ should be sufficient to support the maneuver of the ground combat

continued

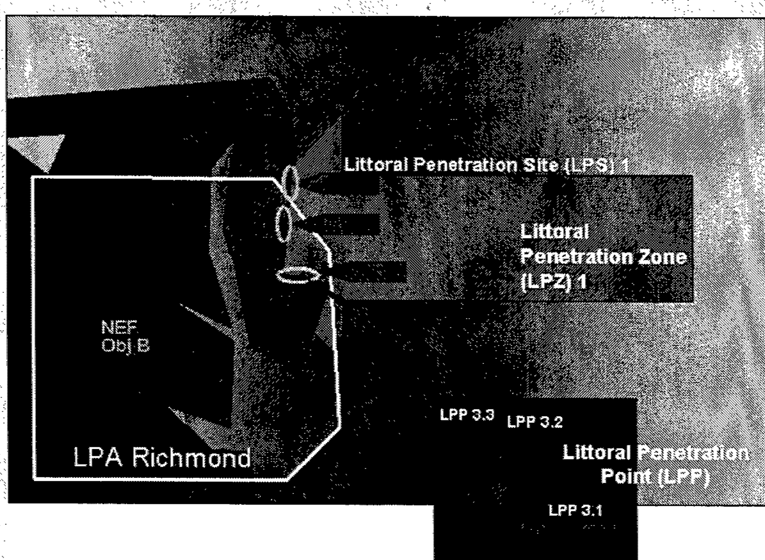

FIGURE A.1 Littoral control measures, littoral penetration area (LPA). SOURCE: Marine Corps Combat Development Command. 2000. *Ship to Objective Maneuver Concept of Operations* (draft), Warfighting Requirements Division, Quantico, Va., August 8, p. 7.

Box A.2 Continued

element of a Marine expeditionary brigade (see Figure A.2). Surveillance assets continue to be utilized while clandestine reconnaissance systems are brought into play that are cued by surveillance information. Reconnaissance assets should include, but are not limited to, nuclear-powered submarines (SSNs) and sea-air-land teams (SEALs) utilizing the advanced SEAL delivery system and unmanned undersea vehicles, the remote mine-hunting system, unmanned aerial vehicles (Global Hawk, Predator), and the joint surveillance and target attack radar system (JSTARS) in a standoff mode.

The littoral penetration site (LPS) is a continuous segment of coastline within an LPZ through which maneuver forces cross by airborne or surface means. The LPS must be of sufficient size to support a battalion landing team (BLT) (see Figure A.2). Surveillance assets continue to provide coverage while clandestine reconnaissance assets conduct detailed mine reconnaissance to determine lanes

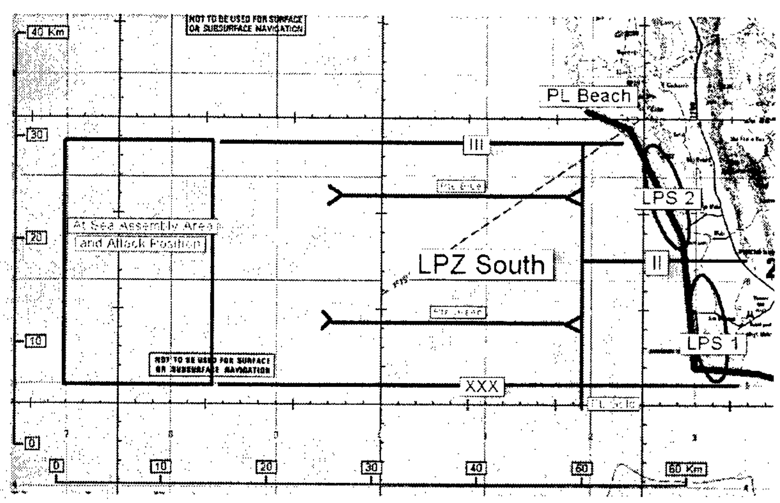

FIGURE A.2 Littoral control measures, littoral penetration zone and littoral penetration site (LPA and LPS). SOURCE: Marine Corps Combat Development Command. 2000. *Ship to Objective Maneuver Concept of Operations* (draft), Warfighting Requirements Division, Quantico, Va., August 8, p. 30.

either through or around identified mined areas in the water and on the beach. There could be three or more LPSs in one LPZ.

The littoral penetration point (LPP) is a point in an LPS where the actual transition from waterborne to landborne movement occurs. For planning purposes, an LPP can be up to 250 m wide and will be designed to support a mounted infantry company team, supported by landing craft, air-cushioned (LCAC). Each company team will normally have multiple LPPs in its zone of action (see Figure A.3). Surveillance assets should continue to be used to watch the beach areas and potential routes off the beach and inland toward assigned objectives. Clandestine reconnaissance units, the very shallow water detachment, and other assets continue to hunt for mines and prepare them for demolition in designated lanes prior to H-Hour on D-Day. Potential obstacles and mines in the surf zone and on the beach, if detected around LPPs, will have to be dealt with by organic or joint breaching systems as the surface maneuver forces move along designated lanes onto the beach.

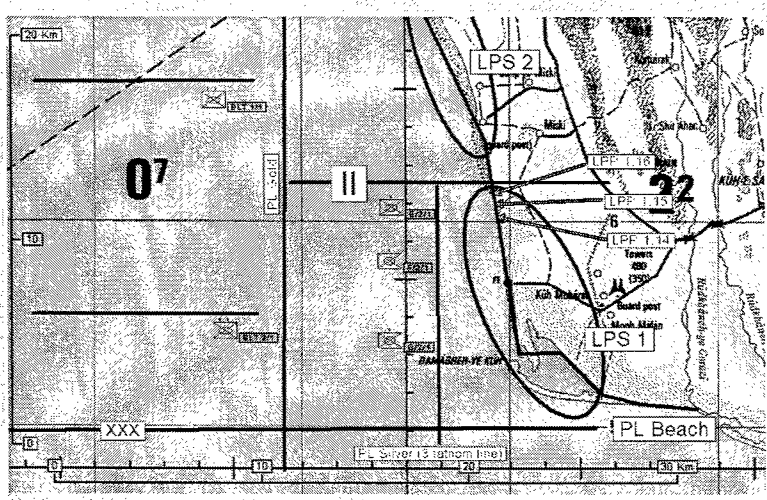

FIGURE A.3 Company maneuver control near shore, littoral penetration points (LPPs). SOURCE: Marine Corps Combat Development Command. 2000. *Ship to Objective Maneuver Concept of Operations* (draft), Warfighting Requirements Division, Quantico, Va., August 8, p. 31.

The Office of Naval Research (ONR) is supporting an assessment of the concept of MCM in support of STOM. This assessment is being carried on in coordination with OPNAV (N75), the Marine Corps Combat Development Command (MCCDC) at Quantico, and the Marine Corps Warfighting Laboratory (MCWL). Funding to support a myriad of activities to include the annual wargaming plan, assessment of emerging concepts of operations (CONOPS) associated with the aforementioned STOM control features, and the continued development and demonstration of small unmanned undersea vehicles (UUVs) and other sensors is maintained through the MCM future naval capability (FNC). It is clear that this effort is making progress in solving clandestine reconnaissance requirements from the SW to the CLZ in support of STOM. UUVs that are affordable, clandestine, and include a variety of capabilities will occupy an important role in the future of mine countermeasures. The Navy must acquire a family of UUVs and appropriate sensors if it is to operate effectively in shallow water in support of amphibious power projection missions in the future.

The committee concluded that ONR's assessment of the concept of MCM in support of STOM, in cooperation with OPNAV (N75), MCCDC, and MCWL, is headed in the right direction and should be continued.

The Navy's organic MCM CONOPS, currently under consideration in the fleet, is indirectly supportive of the concept of MCM in support of STOM initiative; however, none of the five developing MCM systems associated with the MH-60S helicopter are covert. With this organic MCM capability in the battle groups in the future, it is reasonable to assume that they would support the carrier battle groups (CVBGs) and amphibious ready groups (ARGs) as they approach the designated LPA (see Box A.2) prior to a STOM operation. The surveillance and clandestine reconnaissance systems would already be gathering the necessary information to support the STOM commander within the LPA. The necessity for retaining tactical surprise and lowering the potential risk to the MH-60S in daylight would preclude its employment until the rapid follow-on clearance phase begins after the STOM operation has been executed. This organic capability will play a major role in clearing at-sea assembly areas necessary to support maritime prepositioning force (MPF) (future) shipping if instream offloading is required for the sustainment of MEB- or MEF-size elements ashore (see Figure A.4).

An examination of both national and theater surveillance systems (see Figure 2.5 in Chapter 2) showed that those needed for use in gathering critical information are already in place. The majority of the clandestine reconnaissance systems, as well as those required for detailed lane search, are either in place or in varying stages of development. The emerging STOM CONOPS at Quantico and the MCM in support of the STOM CONOPS should bring all of this together into a coherent plan that can be utilized if it is needed in the future. Gathering the necessary information to support these CONOPS is not and should not be under the sole purview of the unit intelligence officers. *It must be the responsibility of the commanders to know what they need and drive the requirement for both*

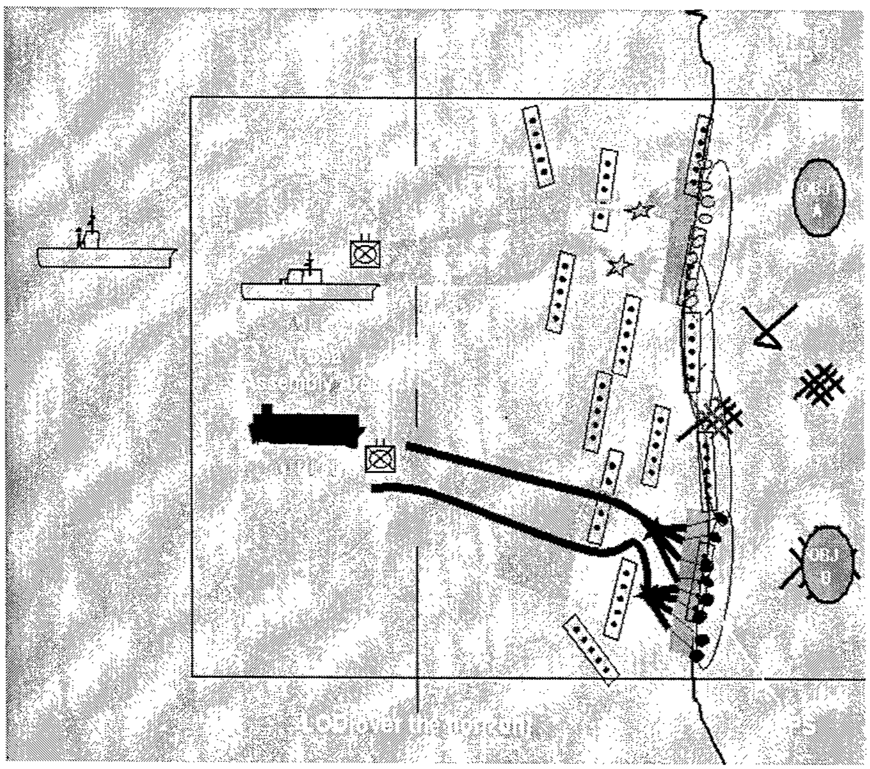

FIGURE A.4 Maneuver in a mined environment from the at-sea assembly area. SOURCE: Marine Corps Combat Development Command. 2000. *Ship to Objective Maneuver Concept of Operations* (draft), Warfighting Requirements Division, Quantico, Va., August 8, p. 32.

surveillance and reconnaissance assets at the right level of priority. The committee believes that there is a serious lack of knowledge in this area and that the Services need to address it in the appropriate schools. A robust and well-integrated ISR capability is absolutely vital to the success of the STOM concept.

INTELINK CONTINGENCY PLANNING TOOL

One of the biggest impediments to rapid planning is gaining access to the information and intelligence necessary to validate potential courses of action. The amount of available information on INTELINK is overwhelming, yet there is no equivalent of a card catalog or Dewey Decimal System to facilitate a search.

As a result, there is a reliance on search engines that are inefficient, incomplete, and time consuming.

A Marine Corps project aimed at reducing the time it takes to get critical infrastructure data to support the planning effort involves two separate initiatives. The first, development of an enterprise portal for operational intelligence, is nearly ready for worldwide distribution. The second phase involves gathering the baseline infrastructure data currently residing in open source material and hundreds of intelligence databases. This effort, called prepositioning intelligence, is a three-step process that will assign priorities or collection priorities in each of the three MEFs and in areas of responsibility (AORs), assign responsibilities, and train analysts to find information via INTELINK and the Internet and send it to Marine Corps Intelligence Activity (MCIA), Quantico, Virginia. MCIA, the designated production agency for VSW intelligence information for the Services, will then make the information more generally available by appropriate means.

By prepositioning intelligence months in advance during peacetime, staffs can reduce the time necessary to research this same information in crisis, thereby increasing the time available to provide situational awareness and predictive analysis (critically short commodities). There is no reason why Navy and Marine Corps planners will not be able to access this available information via the INTELINK in preparation for power projection operations in the littorals in the future. Information on mine stockpiles, mining activities, and early bottom mapping in regions of potential contingencies, as well as data on gradients, tides, and other environmental parameters that could be available through MEDAL, should also be made accessible through this developing planning tool. Access to INTELINK is through the SIPRNET or the joint world intelligence collection system.

Despite numerous efforts to develop a common tactical picture to support commanders in the field and at sea, they still suffer from the effects of architectures that contain "stovepiped" systems. Getting timely and accurate intelligence is critical if the STOM CONOPS or the MCM in support of the STOM CONOPS is to succeed. The committee is aware of the continuing evaluations ongoing in the Third Fleet with the littoral surveillance system (LSS). Similar to the Army's tactical exploitation system (TES) in terms of capability, but with 85 to 90 percent less footprint, LSS promises to bring fused information to the commanders at sea or ashore. This system will interface with numerous satellites and tactical aircraft sensors and will process and exploit their data, imagery, and information. It will combine all former tactical exploitation of national capabilities (TENCAP) functionality into a single, integrated, scalable system and will have the capability to serve as an interface between national systems and in-theater tactical forces. Most of the surveillance and wide-area reconnaissance systems listed in the suggested aforementioned ISR plan should be able to link to the LSS in the future (2005 and beyond).

REQUIREMENTS FOR AMPHIBIOUS LANE AND COUNTERMINE AND COUNTEROBSTACLE CLEARANCE

Before listing Marine Corps countermine and counterobstacle (CMCO) requirements, the committee notes that the Commandant of the Marine Corps reinstated the MEBs in the fleet Marine force after publication of the Marine Corps CMCO requirements document. This committee believes that it is imperative that the Navy develop a CMCO capability in the near term to far term that will support the power projection requirements for a minimum of two MEBs (amphibious or MPF) simultaneously. This capability is realistic and will also support the transition to the emerging concept of MPF (future).

While the organic MCM CONOPS currently under assessment in the fleet will assist the battle groups and amphibious ready groups as they approach the designated LPAs, it will not be a substitute for surveillance and clandestine reconnaissance systems required to support amphibious power projection missions from the SW zone to across designated LPPs. Application of rigorous intelligence, surveillance, and reconnaissance methods in a timely manner is the key to allowing unencumbered maneuver and sustainment for the MEBs.

The Marine Corps requirements for mine and obstacle clearance in the VSW, SZ, and CLZ are promulgated in a March 25, 1999, memorandum from the Commanding General, Marine Corps Combat Development Command (MCCDC), entitled "Amphibious Counter-Mine and Counter-Obstacle (CMCO) Requirements in Support of Operational Maneuver From the Sea (OMFTS)." This document is scheduled to be examined for revision in order to address issues that have changed regarding CMCO requirements.

CMCO requirements for the near, mid, and far term are defined as follows:

- *Near term.* From FY00 to FY08, the period leading up to the initial operational capability (IOC) of the MV-22 and advanced amphibious assault vehicle (AAAV).
- *Mid term.* From FY09 to FY14, that period of time when OMFTS and STOM mobility capabilities are being fielded, undergoing refinement of their tactics, techniques, and procedures, and leading to OMFTS and STOM full operational capability (FOC) in FY14. The fielding of an instride mine clearance and obstacle reduction capability from the deep water through the initial craft landing zone (ICLZ) will be essential for unencumbered maneuver and sustainment.
- *Far term.* From FY15 and beyond, that period when OMFTS and STOM mobility is fully fielded. Complete fielding of mobility assets, improved CMCO C4ISR systems, and in-stride breaching and neutralization capability will enable true unencumbered maneuver and sustainment.

The requirements document expresses four concerns of specific interest to this study:

1. Organic MCM assets will be useful in providing detection and limited clearance in the sea lanes of communication for both the carrier battle group (CVBG) and amphibious task force (ATF). However, they will be of limited assistance in amphibious operations in the littoral against a determined threat.

2. The current Navy organic MCM plan reflects the transition of CMCO capabilities to ATFs. This proposal must weigh any advantage an organic system offers against its potential displacement of landing force assets.

3. The LCAC mission to deliver CMCO systems, in accordance with the Navy Mine Certification Plan, is projected within the future year defense plan. It is imperative that the requirement for all LCAC missions as well as the quantity of craft and crews be determined. This analysis must ensure that additional missions will not have an adverse effect on the LCAC's original purpose of delivering assault and assault follow-on echelon forces ashore.

4. As the assault CMCO capabilities mature, concurrent work must begin immediately on defining and resolving the follow-on clearance requirements of the naval Services. For every transit lane across a littoral penetration point, even with the seabasing of major logistics support and services, three additional follow-on echelon lanes are required to support fuel, ammunition, and sustainment. Currently, the responsibility for follow-on LCAC landing zone clearance is undetermined.

Before listing Marine Corps lane-clearance requirements it should be noted that while intelligence, surveillance, and reconnaissance, rigorously applied in a timely manner, may permit mines and obstacles to be interdicted or avoided to allow unencumbered maneuver in some scenarios, there will be others in which there is no alternative but to clear and breach the mine and obstacle defenses. For instance, North Korea, Iraq, Iran, Cuba, and the former Yugoslavia and Syria have limited landing sites and have or are refining an IA3 doctrine, and such choke points as the Straits of Hormuz and Malacca may present a similar problem.

Near-Term CMCO Required Capabilities

Transit Lane Neutralization and Clearance

Transit lanes begin at the line of departure (LOD) and extend to the 40-ft contour, a distance of up to 25 nautical miles. Required are six 165-yd lanes cleared to tolerance within 48 hours, with a 72-hour threshold.

Very Shallow Water Neutralization

Using a slope of 1:300, the six 165-yd transit lanes will be extended to the 10-ft contour (SZ) within 48 hours, 72-hour threshold. The requirement envisions VSW clearance by the VSW MCM detachment.

Surf Zone Breach

The SZ breach will be conducted by the first assault wave. Required are two 50-yd assault lanes for each transit lane. The objective is to clear all ATF littoral penetration points (LPPs), up to 12, within 10 min, 20-min threshold, from the launch of the first munitions, using a gradient of 1:300.

Landward Breach

To allow uninterrupted landward transition of AAVs/AAAVs, the Marines will extend the 50-yd assault lanes through to the BEZ (100 yd) at a breaching speed of 10 min, 20-min threshold.

Assault Clearance

Upon completion of the landward breach, the Marines, using mechanical equipment, will immediately begin clearing an 80 × 80 yd initial craft landing zone (ICLZ) to receive LCAC-delivered waves. The objective clearance speed will be 60 min, 90-min threshold.

Marking

Due to deficiencies in the ability to navigate through gaps and cleared/breached lanes, a marking system must be employed to provide optical or electronic guidance for all AAAVs, LCACs, and other landing craft in all manageable sea states, and under conditions of reduced visibility.

Mid-Term CMCO Required Capabilities

Other than providing a CMCO capability in sea states up to and including sea state 3, there are no radical changes between near- and mid-term requirements.

Transit Lane Neutralization and Clearance

With the introduction of the AAAV the LOD will move seaward to a distance of 25 nautical miles or greater. Required is the clearance of up to six 165-yd lanes within 24 hours, 48-hour threshold.

Very Shallow Water Neutralization

It is anticipated that unmanned systems will begin to replace reliance on human divers and mammals. No other changes are required.

Initial Craft Landing Zone Standoff Clearance

The Navy must field an ICLZ standoff clearance and obstacle reduction capability that will neutralize mines and reduce obstacles to a uniform height of less than 10 in. just prior to the SZ breaching. The objective clearance rate is within 10 min of the first munitions launch, using no more than 10 percent of ATF organic fixed-wing air tasking order (ATO) D-Day sortie rate, 20-min threshold, with no more than 20 percent of the ATO D-Day sortie rate. Although the ICLZ is a defined and located area, ICLZ clearance systems may be needed to clear other inshore CLZs in support of follow-on waves to prevent delays in logistical throughput. This additional application of ICLZ clearance systems for CLZ clearance must be addressed in follow-on analysis of clearance alternatives.

Surf Zone Breach

After employment of the ICLZ clearance system, assault breaching systems (ABS) will be brought into the assault lane and will explosively breach 50-yd connections to the ICLZ through the SZ. Using a 1:300 gradient, the ABS must be capable of breaching without entering the SZ, and within parameters consistent with the near-term requirements (10 min, 20-min threshold).

Marking

Until all landing craft, to include assault follow-on echelon craft, have inherent C4ISR detection, reception, and navigational systems to avoid mines or navigate through electronically marked lanes, physical marking systems will remain a requirement.

Far-Term CMCO Required Capabilities

With full implementation of OMFTS and STOM mobility assets (MV-22, AAAV, LCAC), the vision of unencumbered mobility must become a reality. This includes the ability to detect and avoid mines, with a limited ability to conduct in-stride breaching at locations and times of choosing.

Detect, Classify, Mark

Using national assets augmented by theater intelligence, surveillance, and reconnaissance (ISR) systems, detection will continue prior to and during the ATF's movement to a theater and assembly at sea. Upon entry into the theater, covert systems will confirm surveillance and reconnaissance findings, classify mines and obstacles, and mark them with a digital tagging system for immediate dissemination.

Dissemination

With due attention paid to jamming vulnerability, dissemination of mine and obstacle locations, as they are uncovered, must continue throughout the planning and initial execution phase of the assault as input to constructing a tactical operational picture in near real time.

Precision Navigation

Navigation capabilities will increase to a level such that all landing craft and vehicles will have the ability to safely maneuver within the CMCO environment based on continually updated mine and obstacle locations.

Current CMCO Capability

Table A.1 summarizes current and developing U.S. CMCO capability, and Figure A.5 indicates the likely number of mines and obstacles to be encountered for each transit lane using the nominal threat lay-down as outlined in Box A.1.

TABLE A.1 Preassault Inshore Countermine Warfare Current Capability

Status	Surveillance	Reconnaissance	VSW/CMW	SZ/CMW	ICLZ/CMW
Fielded	0	VSW detachment (MMS)	VSW detachment (MMS)	0	M-1 plow LDC
Joint Countermine ACTD	LRS	COBRA ASTAMIDS (T)	0	EN/ATD	Power blade (T) EN/ATD
R&D program	LRS ADS/ DADS	UUVs (Remus/SAHRV/ CETUS/Morpheus) AROSS COBRA	Biosensor/ SAS	SABRE/ DET Hydra-7 MODS 5-in./ 155-mm projectiles	SABRE/ DET Hydra-7 MODS 5-in./ 155-mm projectiles
Gaps in capability to fully execute preassault CMW	0	0	0	0	0

NOTE: See Appendix F for definitions of acronyms used. T = program terminated.

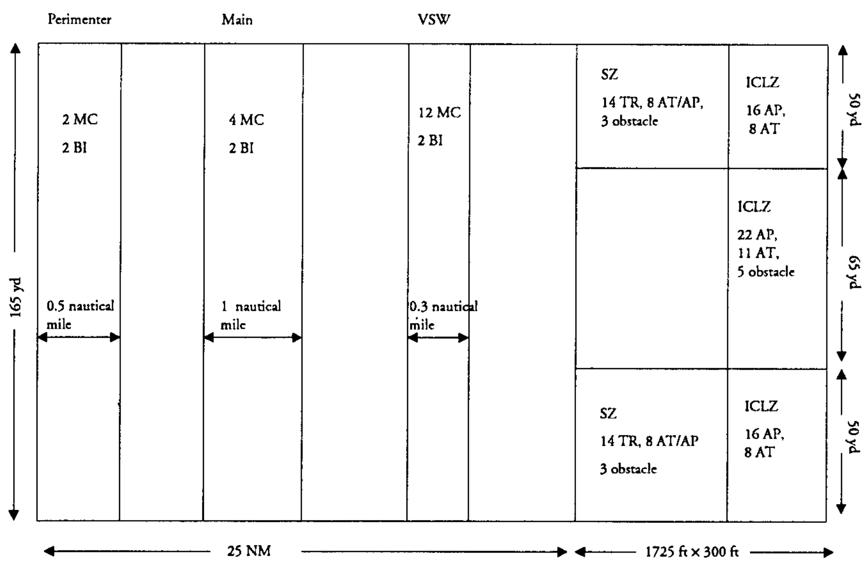

FIGURE A.5 Mine and obstacle density per transit/assault lane. MC = moored contact; BI = bottom influence; AP = antipersonnel mine; AT = antitank mine.

The technical discussions in Chapter 5 of this report describe the systems listed in Table A.1.

Penetration of the minefields and obstacles in the transit lanes to the beach depends on a complex interaction of systems used in various time phases of the operation. The next section, "Amphibious Operations," describes the operational sequence of events in penetrating to the beach, and the timing of the sequence, as well as how the various mine-hunting and neutralization force elements and systems are brought into play during these events.

AMPHIBIOUS OPERATIONS

To serve as a baseline for its assessment of inshore mine countermeasures, the committee formulated a sequence of events leading to power projection (amphibious operations) in a theater contingency. The sequence was constructed from available documentation and extensive briefings by mine warfare community leadership. The time windows may be altered by the scenario and by competing warfare demands, including competition for national surveillance assets. *The key to meeting or improving on the stated time lines is the continuum of intelligence, surveillance, and reconnaissance conducted in a window as narrow as 10 to 20 days prior to D-Day.*

As discussed later in this section, a Marine expeditionary brigade (MEB) may be the most likely amphibious power projection force of the future.

To assist in visualizing the sequence of operations, the committee summarizes material presented above (Box A.2): A landing penetration area is of sufficient size to accommodate an MEF-level landing, which could consist of two MEBs (one amphibious and one MPF). A landing penetration zone is an area of sufficient size, within an LPA, to accommodate a regimental landing team (RLT)-level landing. A landing penetration site is an area, within each LPZ, of sufficient size to accommodate an MEB-level landing.

It is assumed that a nominal 30-day period is available for amphibious operations preparation leading to a D-Day on day C + 30. Whether an MEF-level force can be assembled and prepared for assault in 30 days may be debatable. In all likelihood assembling such a force might take approximately 60 to 70 days. Even assembly of an MEB may take up to 45 days. However, the 30-day assumption is probably the minimum feasible for assembly and preparation and represents the most stressing time line for MCM support of an MEF.

Sequence of Events Necessary to Allow Planning and Execution of MCM Support

D-30 (C-Day)

Prior indications and warning (I&W) information has led to tasking of the theater commander in chief (CINC) to prepare for expeditionary operations, including amphibious operations. The theater CINC issues a tasking order to the commander, joint task force (CJTF) on C-Day to prepare for amphibious operations on C + 30 (D-Day), along with other concurrent expeditionary operations.

The theater CINC tasks national and theater surveillance assets to conduct initial or continuing surveillance of enemy force disposition and defensive preparations, including beach defenses. Surveillance data is processed into intelligence over the next 3 days.

Surveillance assets employed in support of upcoming amphibious operations are assumed to be either clandestine or wide enough in area coverage to conceal landing site intentions.

D-30 to D-27

The CJTF reviews available historical intelligence of enemy capabilities, including sea mines and coastal beach defenses.

The CJTF initiates a rapid planning process designating the joint operating area (JOA). He tasks subordinate commanders, including the commander, amphibious task force (CATF), with providing alternative courses of action and a recommended course of action for operations in the JOA, including the amphibious operation.

The CJTF and CATF review prior and ongoing surveillance results, along with historical intelligence. The CATF is assisted by the commander, landing force (CLF) and the CATF's mine warfare commander (MIWC). They collectively identify alternative LPAs within the JOA, each LPA of sufficient size to land six BLTs each.

The CJTF and CATF refine surveillance tasking to support further determination of LPZs, each of sufficient size to land two BLTs within each candidate LPA.

The CATF responds to CJTF tasking with alternative courses of action and a recommended course of action with associated, preferred LPA.

D-27 to D-20

The CJTF selects a course of action, including amphibious operations and LPA. He provides a JOA concept of operations and commander's intent as further guidance to the CATF and all other subordinate commanders. Supported and supporting commanders are identified for various phases of operation in the JOA. Presumably, but not necessarily, the CATF is the supported commander shortly before D-Day, and the CLF becomes the supported commander at the appropriate point in the amphibious operation, and for some time following D-Day.

The CATF requests/tasks surveillance assets to further refine the common operational picture relative to amphibious operations within the selected LPA. This action would engage a wide spectrum of national and theater surveillance assets as well as tactical intelligence assets. This effort is directed primarily toward selection of three landing penetration zones in the LPA with the intent of landing two BLTs in each LPZ.

The CATF, CLF, and MIWC begin an evaluation of potential LPZs and potential LPSs within each LPZ. Nominally, two LPSs within each LPZ will need to be selected for the two BLTs landing in each LPZ. The evaluation also considers the efficacy of:

- Potential at-sea assembly areas for amphibious and logistics shipping;
- Enemy disposition/threat;
- Beach trafficability and availability of egress to inland objectives;
- Level of beach defenses; and
- Relative difficulty/viability of mine and obstacle clearance/reduction in various portions of each LPZ.

At this point evaluation of items 1, 3, and 5 depends both on surveillance and historical environmental data. As indicated elsewhere in this report, *a robust* *peacetime environmental data collection effort is essential in order to effectively support all naval forces, especially the CATF, MIWC, and CLF, in amphibious operations.*

As surveillance continues and results are processed and disseminated during this period, the selection of LPZs becomes clearer to the CATF, CLF, and MIWC. Refinement of the operational picture with additional surveillance missions adds further clarity.

Near the end of this period, one or two MEBs may have assembled in-theater, and MPF (future) and amphibious shipping are assembling in an area protected from enemy defenses, including sea mines, for integration of all MEB elements.

D-20 to D-10

Early in this period the CATF, CLF, and MIWC have agreed upon and established the three preferred LPZs, each for landing two BLTs.

Additional surveillance results continue to add clarity to candidate LPSs within each selected LPZ. The surveillance information is related primarily to SZ and CLZ defenses and enemy threat ashore. Deployed surveillance systems may also have noted mine-laying activity seaward of the SZ provided they were deployed early enough in the contingency.

To further define the selection of two LPSs in each LPZ, the CATF tasks MCM clandestine reconnaissance missions to conduct wide-area reconnaissance of the LPZs. A typical clandestine reconnaissance capability is the submarine-delivered long-term mine reconnaissance system (LMRS). The surface ship equivalent, the remote mine-hunting system (RMS), may also be used. Both of these systems are limited to 40 ft of water and deeper.

The wide-area reconnaissance builds an operational picture of minelike contact density in each LPZ. Fusion of this processed data with information in the historical environmental database begins to focus on likely LPSs within each LPZ. Additionally, definition of at-sea assembly area(s) and transit lanes landward through the LPSs becomes clearer.

As early as possible in this time period, at-sea assembly areas for amphibious and logistics shipping in each LPZ are identified, and sea mine clearance has begun. All available and appropriate MCM assets may be used since the assembly areas are at a distance of 25 to 50 miles from shore defenses. Where feasible, assembly areas should be located in water depths greater than 200 ft (300 ft preferred for nonmilitary shipping) in order to avoid damage from nonmobile bottom influence mines. A moored mine threat in these depths, with the possible exception of rising moored mines, is much easier to deal with in the absence of bottom influence mines.

At this stage of planning, definition of assault follow-on lanes for sea-based logistics flow should have begun. Present estimates (as opposed to defined requirements) indicate three additional lanes for each assault lane through the SZ and up the beach (two assault lanes per BLT, for a total of 12 assault lanes) will be required, giving a total of 48 logistics lanes through the SZ and up the beach.

If the additional lanes are immediately adjacent to assault lanes, then MCM clearance is basically a widening of assault lanes. However, due to the potential for fratricide, standoff breaching will not be possible once the assault has begun, thus adding to clearance time lines and requiring additional technologies. If logistics lanes are sufficiently separated from assault lanes to allow standoff breaching, this significantly increases the CMCO requirement since additional transit lanes will be required from the assembly area, each with its assault lanes, to and through the SZ and up the beach.

Near the end of this period the MEB and associated shipping may be nearly assembled. Continued interaction between the CATF, CLF and MIWC, tempered by continuing surveillance results and MCM wide-area reconnaissance, should allow selection of six LPSs and associated candidate landing penetration points from some greater number of candidates under prior consideration.

Clearance of the at-sea assembly areas will require roughly 5 to 10 days from commencement. In water less deep than desired, more time will be required due to the possibility of bottom influence mines, adverse bottom conditions, and so on. However, the likelihood of less than desired water depths 25 to 50 miles from shore is minimal in many areas of interest. Exceptions are the Arabian Gulf and the Straits of Taiwan, as well as the Yellow Sea, where 63 percent of the water is less than 180 ft deep.

D-10 to D-2

At the beginning of the period, the LPA, three LPZs, and six LPSs have been selected. The associated at-sea assembly areas have been selected with mine clearance in progress.

Definition of final LPP selection is continuing with due consideration of CMCO requirements and enemy defenses ashore. Concurrently, definition of logistics lanes to support the MEB ashore is continuing.

Surveillance is continuing throughout the period to detect any changes in enemy threat disposition that might influence the final selection of the 12 required LPPs at H-48.

MCM wide-area reconnaissance must transition to the mine-hunting function of detection and classification by the beginning of this period. This is necessary to complete the definition of minelike contacts in the long transit lanes from the assembly area(s) to all candidate LPPs. This definition is necessarily completed by H-48 to allow sufficient time for mine reacquisition, identification, and clearance between H-48 and H-1.

It is also possible that the necessity for having more than 12 candidate LPPs from which to select 12 finally may require detection and classification in seven or eight LPS transit lanes in the three LPZs. Currently, MCCDC informally indicates a preference for four candidate LPPs per BLT from which two will be selected just prior to assault (possibly as late as H-2).

Clandestine MCM requirements up to H-1 largely drive the selection of mine-hunting assets, and the number of transit and logistics lanes dictates a sizable inventory of those chosen. In addition, these assets will have to concurrently collect environmental data. Depending on the clandestine assets utilized, some mine identification may have already taken place. However, the majority of minelike objects will require reacquisition, identification, and the placement of neutralization charges. Ideally, mine neutralization charges will be remotely detonated through an acoustic modem between H-1 and H-Hour to maintain the element of surprise as long as possible.

The time requirement for mine clearance (reacquisition, identification, and placement of neutralization charges) is between H-48 and H-1. Attempting to do detection, classification and identification, and placement of neutralization charges in this time window is not considered feasible at the present time.

The requirement for clearance of mines in transit lanes between H-48 and H-1 allows the CATF, CLF, and MIWC to delay selection of the final six (possibly more) transit lanes until as late as H-48. As mentioned above, selection of LPPs occurs shortly before H-Hour (approximately the latest time that allows tasking and preparation of air sorties and other methods of delivering standoff SZ and ICLZ breaching systems).

Final assembly of the MEB has taken place at the end of this phase.

D-2 to D-Day (H-Hour)

Amphibious and logistics shipping move to the at-sea assembly area(s) in preparation for the operation. Remaining deception operations are ongoing.

Surveillance continues to monitor the enemy threat ashore, enabling final LPP selection as late as possible.

Upon final selection of LPPs, tasking of standoff assault breaching systems for the SZ and ICLZ occurs. Note that Marine Corps CMCO systems will clear the ICLZ following the SZ breach by Navy systems from now through 2008. Thereafter, Navy standoff systems will breach the ICLZ just before breaching the SZ. These Navy systems will have to be fielded in time to support the full operational capability (FOC) of Marine Corps mobility systems (AAAV, M-22, LCAC) in roughly 2014.

As time allows, feedback from reacquisition, identification, and charge placement activities during this period is used to make final adjustments of transit lanes. Marking of cleared lanes occurs by placement of in situ indicators and/or identifying Global Positioning System tracks for landing vehicle control systems.

Remotely controlled minesweeping assets, capable of immediately preceding assault waves at assault speeds, are prepared for final clearance level improvement and proofing of cleared lanes.

H-1 to H-Hour

Neutralization charges in transit and logistic lanes are remotely activated.

Assault lanes are breached and the ICLZ cleared by the Navy standoff systems (after the near term). The time requirement is 10 min, 20-min threshold.

The SZ is breached shortly before landing at LPPs. The time requirement is 10 min, 20-min threshold.

Assault waves are en route to the LPPs, preceded by minesweeping assets. Assault vehicles conform to marked transit lanes unless tactically required to deviate at the risk of entering an uncleared area. This may be possible at little risk if surveillance and reconnaissance assets have been able to accurately mark the positions and boundaries of mine belts.

H-Hour Plus

All Navy MCM assets begin broadening all transit and assault lanes to land follow-on echelons and sustainment logistics. If the Army and the Air Force are to participate, then the number and width of cleared lanes must be further increased, or harbors cleared if available.

The VSW Transit Lane Challenge

From the operational sequence of events presented above, it is possible to derive a requirement for six transit lanes, each 165 yd wide from the at-sea assembly area(s) to and through the LPSs. There exists a potential requirement for additional 165-yd transit lanes to provide last-minute alternative routes to and across the beach, and to accommodate sustainment logistics. Therefore the committee assumed an additional transit lane for each LPS. This separate set of transit lanes for logistic purposes prevents the fratricide of incoming assault traffic as assault logistics lanes are opened. These six additional transit lanes may need to be cleared in the same time window (preassault) as the six required transit lanes so as not to unduly delay the flow of logistics to forces ashore. This imposes an additional stress on forces available for the MCM task.

This requirement can be used to define the VSW clearance force structure consisting of diver teams, marine mammal and handler teams, and UUV teams. Although diver and mammal teams may eventually be replaced by UUV teams, there will be a transition phase in which a combination of both capabilities will be needed to meet requirements.

In the future a decision may also be made to retain some diver and mammal teams even after the advent of large numbers of UUVs. For example, detection of buried mines is currently dependent on mammal systems, and may remain so for an extended period. Also, diver teams will probably still be needed for recovery and exploitation of enemy mines. And until technology provides a means for UUVs to effectively place neutralization packages on or near mines, divers and/or mammals will still be needed.

Wide-area reconnaissance between D-20 and D-10 will provide a relatively gross contact density picture in each LPZ from which to narrow the selection of two LPSs in each LPZ. It is imperative to commence detection and classification functions in each LPS in the vicinity of the "best estimate" transit lanes no later than about D-10 to D-15. This will allow refinement of the "best estimate" transit lanes, and, more importantly, define the specific locations of the minelike contacts to be dealt with later. Without this early detection and classification effort the capability to reacquire, identify, and place neutralization charges in all transit lanes between H-48 and H-1 will probably not be feasible.

Although it is not the intent of this report to determine VSW force structure, it was considered worthwhile to estimate the capability of the currently constituted VSW detachment for clearing a single transit lane for landing a BLT. In doing so, existing area coverage rates and schemes of employment were used. Additionally, the following assumptions were made:

1. The remote mine-hunting system (RMS) will be used for detection and classification as close to the shore as its low observable characteristics permit. The assumption here is that it can operate in to 10 nautical miles off the shore without enemy detection.

2. The at-sea assembly area(s) are 30 miles from shore, and are cleared by other means (organic and/or dedicated MCM assets).

3. Detection and classification provide some limited identification, but this function must be accomplished largely after reacquisition in the H-48 to H-1 time window. However, RMS missions will have identified mines from minelike contacts in to the 10-nautical-miles mark.

4. Diver and mammal teams have very low observability. It is further assumed that they will operate only at night, as is their present tactic to achieve clandestine operations.

5. Minelike contact densities from wide-area MCM reconnaissance are approximately 8 per square nautical miles in 70 percent of the area of operation, and approximately 15 per square nautical mile in 30 percent of the area of operation. It is further assumed that the higher minelike contact density will be in the shallowest area of operation. Actual contact densities may vary in real-world contingencies. Again, *an accurate environmental database developed in peacetime will pay significant dividends in minimizing the required level of effort.*

6. Traditional explosive ordnance disposal (EOD) MCM detachment support will be required to augment the VSW detachment in the reacquisition, identification, and placement of neutralization charges. This will be done at distances

offshore that are undetectable during daylight (EOD MCM detachments are daylight-only capable).

7. The Navy will develop neutralization charges that can be placed on or near mines and can be remotely detonated on command.

In summary, the available VSW force structure must do detection and classification of mines and nonmine minelike bottom objects (NOMBOs) in a transit lane extending from 10 nautical miles offshore to the SZ between D-10 and D-2. It must further reacquire, identify, and place neutralization charges on identified mines in a transit lane from 30 nautical miles offshore landward to the SZ, less the augmentation available from EOD MCM detachments. The SZ boundary extends approximately 1725 yd seaward from the high-water mark on the beach. Since transit lane segments will probably vary from a simple straight line (in order to avoid mine belts in some cases), the committee assumed a 15 percent increase in the track segment lengths to account for other than straight line approaches. This results in a total of 32 miles for a transit lane length.

An approximation points to a VSW detachment capability to perform the necessary MCM functions in one transit lane over approximately 15 nights. This would imply that a VSW detachment as currently constituted might be able to support a BLT-level assault given the above assumptions. However, if an alternate assault transit lane or an additional logistic transit lane is needed, clearance by a single VSW detachment could not be done without roughly doubling the time required to complete the preassault clearance for the BLT.

First-generation UUVs may provide area coverage as much as twice, and mission times on the order of four or five times, that of divers and mammals. This increase in capability will still require a robust force structure and logistics footprint for the UUVs required for an MEB-level amphibious operation.

Clandestine Operations

There is legitimate concern about telegraphing intended landing sites. Most of the surveillance systems capable of monitoring mine-laying activity have a footprint large enough to obscure that intent. It is with the operation of minefield reconnaissance systems that the problem of clandestine operations begins to be a matter of concern.

Because some level of broad-area surveillance is available to any country, the arrival of U.S. forces in assembly or patrol areas off an enemy coast will be known, and monitored to some degree. The enemy also knows, or will be prepared for the eventuality, that small units launched from these assembly areas will be probing their defenses over the 25 nautical miles or so separating the assembly areas and their coast, and will be trying to detect them for indications of intent.

Imposing a clandestine requirement on U.S. reconnaissance platforms is a severe penalty in both design and operation that translates into cost and time. It would seem, then, that some compromise between the level of detectability and alternative measures might be called for. Deception, for instance, is a well-established military tactic. The United States successfully convinced the Germans that Operation Overlord would occur across the Straits of Dover rather than along the much longer southern route, and it created the illusion of an amphibious assault on the Kuwaiti beaches that never took place. Such measures, of which there are many, should be used to reduce the burden imposed by the clandestine requirement. If the enemy detects a probe in one area only, that is intent. If he detects probes in 10 areas, that is confusion as to intent.

Similarly, there is a reluctance to neutralize mines by high-order detonation in the more distant perimeter and main mine belts more than a few hours before assault for fear of giving away intended transit lanes. Explosives are cheap; why not set off charges in many locations while the mines are being detonated? Without belaboring the point, the committee suggests that the issue of clandestine operations be reconsidered in the light of alternative means of obscuring and confusing intent.

The requirement for clandestine reconnaissance, particularly in the inshore area, imposes both cost and time on the performance of that mission. The Navy will have to determine and incorporate tactics, including diversion, disinformation, and obscuration, aimed at reducing the level of covertness now required of VSW reconnaissance vehicles.

JOINT LOGISTICS OVER THE SHORE

Postassault mine clearance to support the heavy logistics flow required by the Army and the Air Force, as well as the Marine Corps, places an additional, and in some cases much greater, demand on MCM assets. A review of available references by the Military Sealift Command staff did not indicate the existence of a set of requirements for anchorage area and logistics lanes needed to determine MCM and obstacle clearance requirements for Army and Air Force logistics.

Additionally, Marine Corps requirements statements are currently limited to an estimate of approximately three logistics lanes through the SZ and ICLZ for each transit lane. The operational requirements document (ORD) for clearance of offshore areas for assault follow-on echelon (AFOE) and MPF shipping is now under review. In its present version, required clearance is not viable within the desired time lines. If sea-based logistics shipping can provide the necessary logistics flow from the at-sea assembly area, a simple expansion of the existing requirement for amphibious shipping anchorage area(s) may suffice.

If joint logistics over the shore (JLOTS) clearance requirements are similar to the existing ORD for AFOE and MPF shipping, or even greater, then a significant shortfall of MCM and obstacle clearance capability probably exists, and may exist indefinitely considering planned and programmed MCM forces. If the Army adopts a lighter footprint in the future and adequate time lines for clearance, the necessary clearance might become feasible. Another aspect of this challenge is that the JLOTS area(s) may be significantly separated from previously cleared sea-based logistics areas. However, if JLOTS areas are in a benign area, then dedicated MCM force assets can be used in water depths greater than 40 ft.

The Navy, Marine Corps, Army, and Air Force together need to identify the requirements for logistics shipping and associated areas and lanes to be cleared of mines and obstacles in order that MCM asset requirements can be defined and resources furnished for the near-, mid-, and far-term support of forces ashore.

APPENDIX B

Amphibious Planning in the Gulf War

The most recent encounter with enemy minefields was during Desert Storm. The proposed amphibious assault at Ash Shuaybah, Kuwait, during Operation Desert Storm in February 1991 called for the landing of two regimental landing teams abreast under the control of the 4th Marine Brigade. Although the mine threat was just one of several reasons that the landing at Ash Shuaybah was not carried out, the lessons learned at the time were illustrative of some of the weaknesses in the Navy's approach to inshore mine countermeasures (MCM) that are still with us today.

Traditional thinking at the time assumed a variety of mines from deep water off the coast through the surf zone (SZ) and across the beach. This proved not to be the case and thus represented a major intelligence failure on the part of the Navy and the U.S. Central Command. The minefields that were laid by the Iraqis were in effect placed in an arc that was some 50 miles east of the beaches around Ash Shuaybah. As it turned out there was clear water from these mine belts all the way to the SZ in the landing area. In the craft landing zone and on the assault beaches there were barbed wire obstacles and antitank (AT) and antipersonnel (AP) mines in the sand up to and behind the high-water line. In specific areas the Iraqis had dug trenches for the troops, while fortifying certain high-rise buildings for crew-served weapons behind the beaches. Much of this information came from the Kuwaiti resistance movement and imagery from national sources. This combination of Iraqi mines and beach defenses had little depth and was not comparable to the heavy beach defenses last encountered in World War II.

There were two primary reasons for the U.S. intelligence failure. First, the Commander, Navy Central Command (COMNAVCENT) knew that the Iraqis were laying mines in the Northern Gulf at night but did not know exactly where.

Although this was a clear violation of international law, COMNAVCENT was prevented by the commander in chief (CINC), U.S. Central Command from tracking and attacking the minelayers north of the seaborne extension of the Saudi border for fear of starting the war early. The second reason was that the Navy lacked any effective intelligence, surveillance, and reconnaissance (ISR) platforms and sensors with which to conduct covert reconnaissance from the deep water around the Durra Oilfield west to the SZ in the designated landing area. COMNAVCENT did request support from national assets, but U.S. Central Command assigned a low priority to maritime requests early on. Navy sea-air-land (SEAL) teams assigned to the Joint Special Operations Task Force did do some mine reconnaissance well south of the Ash Shuaybah area, but they did not find any mines. This was unknown to COMNAVCENT because these units did not report to him.

At the time the conventional MCM assets belonging to COMNAVCENT were in the process of getting organized and were not available for deployment north even if the CINC had given COMNAVCENT permission to use them. The airborne MCM helicopters were sitting on the pier in Abu Dhabi waiting for a ship, and the surface MCM platforms were just arriving in the Gulf. Lacking any clear intelligence picture, command estimates of the amount of time required to search and clear the sea echelon and gunfire support areas off the landing beaches varied between extremes. The commander, amphibious task force (CATF) estimated that it would take at least 13 days to clear both the sea echelon and fire support areas, and other estimates went as high as 24 days—and all estimates were based on faulty intelligence.

Since the end of the Gulf War, the Navy has carried out numerous initiatives to create a mine warfare force that can operate effectively if ever confronted with such a threat again. The United States now has a well-trained and motivated force, part of which is forward deployed in potential trouble spots in Southwest Asia and the Western Pacific. Efforts are under way to bring organic mine warfare capabilities to the battle groups, and there is developmental work ongoing in a variety of areas to field systems consistent with today's funding constraints. At the same time the Marine Corps is developing concepts that are more in line with world realities involving amphibious power projection in scenarios that do not call for the traditional assaults so prevalent in World War II. The piece that is still missing in this positive picture is the integrated intelligence collection and dissemination capability that will give future commanders what they will need to operate effectively in potential inshore mined areas in the littorals. This is not just a Navy or Marine Corps issue; it is a joint issue. The Navy cannot solve this problem alone without relying on joint assets to collect the necessary information, and it is the responsibility of the Navy through its component commanders to keep the CINCs informed about what is required.

APPENDIX C

Breaching by Line Charge Analogue

This appendix is a reprint of cleared material excerpted from a 1994 Naval Studies Board classified report, *Mine Countermeasures Technology.*[1]

Bold Approach Alternative

"Overwhelming force" may be the only alternative if the operational imperatives require rapid breaching, with surprise or in emergency, of a sophisticated, robust, highly effective combination of mines and barriers in the very shallow water and surf zone. The task group has assumed that existing and planned MCM technologies will assist the safe transport of troops and equipment to the water depths at the deep-water end of the 2,000-yd approach lane. In the operational scenarios assumed, this 2,000-yd path must be 165 yd wide from the deep-water end to about 10-ft depth and 50 yd wide from about 10-ft depth onto and over the mined areas of the beach. The total length of the 50-yd wide section through the surf zone and on the beach is estimated as about 250 yd, of which 100 yd are underwater.

Surf and Beach Zone

For the surf and beach section of the assault lane, from 10 ft of water and onto the beach, where a high density of mines and obstacles is likely, the task group proposes that aircraft deliver a row of large, bottom-penetrating bombs that explode below ground level under the water bottom, and under the beach, to eject many of the mines and obstacles, and to form a channel deep enough that an LCAC could ride on water over the remaining

[1]Naval Studies Board, National Research Council. 1994. *Mine Countermeasures Technology, Volume II: Task Group Report* (U), National Academy Press, Washington, D.C., pp. 163-170 (classified).

mines and obstacles, without contact, to beyond the mine zone on the beach. The task group proposes that this wave of overwhelming force be followed with guinea pig barges as a second layer of mine countermeasures. The barges would be sunk or, if floating, stopped at the end of the channel to form a causeway for the landing force. The two tactics should result in a more robust system and increase confidence in the effectiveness of this bold approach.

To effectively excavate a channel of sufficient width and depth, the bombs have to be big enough to have a large crater radius and to penetrate sufficient depth. There is much more information on cratering on land than underwater. However, tests, e.g., by Davis and Rooke (1968)[2] and analyzed by O'Keeffe and Young (1984)[3] indicate that burial of a conventional explosive under a sand or mud bottom in shallow water can significantly increase the crater diameter compared to that from an explosion on the bottom. O'Keeffe and Young indicate that an explosive of W pounds (equivalent of TNT) should be buried to a depth of about $W^{0.33}$ ft below the bottom for maximum cratering, which for 10,000 lb of TNT equivalent explosive would be 21 ft. Young and O'Keeffe's data plots and other work on cratering,[4] done on land, indicate that the crater radius near the maximum may not be very sensitive to the exact depth of burial. Also, the crater diameter appears to be weakly dependent on the seabed material (except for rocky bottom) and on water depths, for this size of explosive, in a range between 10 and about 3 ft. O'Keeffe and Young suggest that the radius (R_c) of the crater at optimum depth of explosive burial in a soft bottom (about $W^{0.33}$, in this case 21 ft) would be given by $R_c = 4.4\ W^{0.33}$. Thus, a 10,000-lb explosive would produce a crater 95 ft in radius or 64 yd wide in the section of the lane from 10 ft to perhaps 3 ft of water. For lesser water depths and up to the (assumed sand) beach edge, the cratering phenomenology changes, leading to a gradual decrease of crater radius for a 10,000-lb TNT-equivalent explosive to about 65 ft on a wet sand beach, with a corresponding optimum explosive burial depth of about 40 ft, and to about 55 ft in completely dry sand for about the same depth of burial. The crater depths are greater up the beach than underwater.[5]

Work done at the Army's Waterways Experiment Station and the Atomic Energy Commission's project PLOWSHARE included use of row charges, buried in the bottom underwater, ranging from pounds to tons TNT equivalent, and detonated nearly simultaneously to approximate a line charge, to excavate boat channels.[6] Thus, PLOWSHARE's subproject TUGBOAT[7] excavated a boat channel and harbor in a coral bottom at

[2]Davis, L.K., and A.D. Rooke. 1968. "High-Explosive Cratering Experiments in Shallow Water," Miscellaneous Paper No. 1-946, U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Miss.

[3]O'Keeffe, David J., and George A. Young. 1984. *Handbook on the Environmental Effects of Underwater Explosions,* NSWC TR83-240, Naval Surface Weapons Center, Dahlgren, Va. and Silver Spring, Md., September 13.

[4]Vortman, Luke J. 1969. "Ten Years of High Explosive Cratering Research at Sandia National Laboratory," presented at the Special Session on Nuclear Excavation, Washington, D.C., November 10-15, 1968, *Nuclear Applications and Technology,* Vol. 7, No. 3, September, pp. 269-304.

[5]Footnote 4 gives a discussion and formulas for different depths of water table.

[6]The work cited in Footnote 3 discusses excavation of a boat channel in a lake using a row of explosives on the bottom underwater.

[7]Day, Walter C. 1992. "Project TUGBOAT, Explosive Excavation of a Harbor in Coral," Technical Report E72-23, U.S. Army Waterways Experimental Station, Explosive Excavation Research Laboratory, Livermore, February; LaFrenz, R.L. 1980. "Coral Cratering Phenomenology," DNA Report 5813T, Defense Nuclear Agency, Washington, D.C., October 31.

Kawaihae, Hawaii, by detonation of a row of large charges buried beneath the bottom. Using 10-ton charges (of explosives of yields slightly greater than TNT) simultaneously detonated and buried about 34 ft below the bottom, the channel was 250 ft wide at maximum (not all the explosives went off) with a relatively flat bottom about 12 ft below the original depth. While based on data not including coral explosions, for 10 tons TNT equivalent, O'Keeffe and Young's formula, above, gives a 239-ft width for a burial depth of 27 ft below the bottom.

Project PLOWSHARE's work on row charges on land also indicated than an excavated channel with fairly uniform, smooth sides can be achieved if the explosive spacing is about 30 percent greater than the individual crater radius.[8] However, the TUGBOAT charges were spaced more closely, about one crater radius apart. The task group also used a spacing equal to the estimated crater radius and estimated that the row charges would have to be detonated to within about 0.01 s simultaneity to act effectively like a single-line charge.

In uniform media, the number of row explosives required per unit length (N/L) and acting as an equivalent line charge increases approximately as the square of the excavation radius desired, R. However, the excavated medium changes with water depth and up the beach require the analogue of a tapered line charge. In 10 ft of water, the excavation radius of an optimally buried 10,000 lb of TNT is estimated as about 95 ft, and, in wet sand the radius is about 65 ft. Therefore, to achieve a 75-ft radius up to the beach, the number of bombs per unit length must be gradually increased to the beach edge and up the beach. Three such bombs, accurately placed, should be sufficient for a 50 × 100 yd channel up to the beach edge. For practical reasons, however, it may be desirable to space the bombs evenly. Thus, it was conservatively estimated that four accurately placed penetrator bombs, spaced about 60 ft apart beginning about 60 ft from the waterline, each containing 10,000-lb TNT equivalent, could excavate a 50-yd-wide channel through a 100-yd surf zone to the beach zone. Three penetrator bombs containing 20,000-lb TNT equivalent could also be sufficient. If it is desired to continue the excavated channel up the gradually drier beach, because the crater radius in sand decreases to about 55 ft, for a 150-yd-long channel, about six to eight additional 10,000-lb explosives would be required.[9]

The explosives could remove many mines and obstacles from the excavated channel. Most mines that are used in the surf zone are activated by magnetic fields, local pressure, or tilt rods. The shockwave and movement associated with the explosion are expected to inactivate or trigger many of these mines. Those that are not triggered and removed from the channel may be buried under displaced sediment, which may complicate later removal. Also, the washback of the water may return some of the mines and obstacles into the assault lane. However, these would be at a greater depth than they originally were in the surf zone, and deeper in the channel up the beach, so that the guinea pig and LCAC could ride over them on the water level extending to the end of the channel without contact with tilt-rod or pressure mines. Mines may be neutralized by the shock wave, or actuated by their motion or the magnetic fields due to the water motion. Tests will have to be conducted to determine the probability of exploding or deactivating the mines that are moved, the distribution of mines and obstacles after the explosion, and the residual threat of these mines to the invasion force.

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[8]Vortman (1969).

[9]While the radius of the excavated channel up the beach would be 75 ft, the width at the water level on which the ACV rides may be less, depending on the beach slope.

The end of the cratered trench is not expected to have as much ejecta as the sides if previous work with row charges is applicable to the surf and beach zone.[10] Further, part of the return flow of water should wash up the channel, smoothing the slope of the end crater.[11] If excavation is mainly in the surf zone, the crater's edge should be close to the level of the original beach. Before smoothing, the average end-crater slope at the end of the channel up the beach zone is estimated as about 20°. It may be necessary to use smaller explosions or a high-volume water jet to get a small enough slope of the end crater for the LCAC or invasion vehicles. The guinea pig causeway may also offer a partial solution to this problem.

The explosives could be placed with seabed penetrator weapons that contain 2,000 or 10,000 lb of high explosives. These large conventional explosives can be transported to the target area by B-52 aircraft, C-130s. A-6s, if these are still available, could carry five 2,000-lb, low-drag (so each A-6 can drop all of them simultaneously) bombs, that would be filled with modern explosives that have twice the explosive power per pound of TNT. To act as one 10,000-lb explosive in the surf zone, these 2,000-lb bombs would have to be dropped in a cluster with terminal positions within about 30 ft of each other, use mine-type fuzes adjusted for simultaneous detonation and configured to penetrate to approximately the optimum depth for a 10,000-lb bomb. The centers of the adjacent clusters, if they are equally spaced, would also be about 60 ft apart in the surf zone and up on the beach. Because of the timing feature, each A-6 could deliver its bombs independently but to a preset location. . . .

Status of Supporting Technology

The "Tallboy" and "Grand Slam" penetrator bombs . . . , which weighed 12,000 lb and 22,000 lb with 5,000 lb and 9,400 lb of TNT, respectively, were build by the British and used in World War II.[12] The U.S. Air Force (USAF) also built about 100 GPT-10s of the 12,000-lb variety toward the end of World War II and modified B-29s and B17s to carry them, but none were actually used. In Desert Storm, there was renewed interest in these weapons to attack deep, hard targets. None were extant in the United States but the USAF found that several bomb cases in Britain could have been made available. Subsequently, the USAF (Eglin Air Force Base) has funded a study of penetrators for future hard target-related contingencies, including the 5- and 10-ton variety.[13] Bombs of this size and construction can be filled with modern explosives to approximately double the equivalent TNT load. In tests in World War II, the 12,000-lb bomb could penetrate 47 ft of sand if dropped from 30,000 ft. The 2,000-lb bombs, if configured to penetrate 20 ft

[10]Teller, Edward, Wilson K. Talley, Gary H. Higgins, and Gerald W. Johnson. 1968. *The Constructive Uses of Nuclear Explosives,* McGraw-Hill Book Company, New York, pp. 147-148.

[11]Private communication between Dr. Sidney G. Reed, Jr., and L.K. Davis, U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, 1992.

[12]About 655 Tallboys were dropped by the British 617 Lancaster Squadron, including those required to sink the battleship *Tirpitz*. The British also tried to drop Tallboys in geometric patterns, with mine fuzes to detonate simultaneously, to generate stronger shock waves, but did not achieve sufficient accuracy. Yengst, William C., and Charles C. Deel II. 1993. *Hard Targets That Could Not Be Destroyed by Conventional Weapons,* Technical Report SAIC 93/1060, Science Applications International Corporation, San Diego, Calif., March.

[13]Private commmunication between Dr. Sidney G. Reed, Jr., and William C. Yengst, Science Applications International Corporation, San Diego, Calif., 1993.

into the sea bottom under 10 ft of water, may also be able to penetrate to 40-ft depth in sand on the beach.

Terminal guidance for locating the explosives within about 30 ft of the desired point must be added. Differential GPS guidance that should be adequate is under development. It will be necessary to accurately establish the location of the water's edge in GPS coordinates. To avoid misplaced explosions throwing mines and obstacles back on the lane to be cleared, it may be desirable to have a GPS-controlled "permissive-action link" negating detonation except in proper GPS coordinates. Also, dynamic controls to ensure the stability and flight dynamics of such a large weapon as the GP-T10, which may also be attractive for other applications, will require substantial development. However, the performance of the GP-T10 supports the feasibility of part of the concept.

A recent Lockheed study[14] discusses bomblets dispersed from available dispensers to explode surface or slightly buried mines on the beach, assuming a kill radius equal to crater radius. For a 100- by 50-yd area with a 50-ft CEP (50 percent criterion), Lockheed estimates that about 50 SUU54 dispensers would be required. The explosive weight required to clear the beach area appears to be similar to that required for the penetrator weapon.

Other System Considerations

The geology of the target area in the beach and surf zones will determine the penetration of the 10,000-lb bombs and the radius of kill. No investigation was made of how severe this limitation will be for the beaches of potential interest. A system study should make that determination. Such a study should also look into ways to ensure near-optimum depths of penetration of the bombs.

A systems and cost trade-off between platforms and guided and unguided munitions for the VSW approach lane region must be conducted to find an optimum approach. The relative amounts of explosive required and the difficulties of achieving a uniform distribution in area bombing indicate that a high premium may exist for very accurate delivery.

Guinea-Pig Causeways

Finally, the risk management is considerably improved by the addition of guinea-pig barges that lead the landing force through the assault zone to the beach after the overwhelming force option has cleared the lane of all obstacles and excavated and exploded many, if not all, of the mines. The barges could be crafts of opportunity, hardened for this mission, using modern damage-mitigation technology, and fitted with external and hardened propulsion systems, adapted with fore and aft platforms for easy transit of the amphibious force, and provided with a means to sink them if necessary when they reach the beach, where they become causeways to provide a predictable landing platform. However, all of this modification may justify the development and deployment of special-purpose guinea-pig causeways for the MCM application. A system-level cost-benefit trade study is needed to decide on the requirement for a special-purpose causeway. Without the overwhelming force as a first wave, the guinea-pig causeways would be vulnerable to the obstacles and could block the landing force. Without the guinea-pig causeways,

[14] Lockheed Corporation. 1992. "Conventional Munition Concepts in Support of Shallow Water Mine Countermeasures (CM-SWMCM)," Sunnyvale, Calif., unpublished.

the effectiveness of overwhelming force could not be verified in the 2 hours allotted for the landing. The synergism between the two techniques seems compelling.

In summary, it is suggested that an approach using a row of deeply penetrating, large, simultaneously detonated explosive weapons delivered in a line-charge analog could quickly clear a channel through the surf zone and mined beach areas with surprise or in an emergency using aircraft. Uncertainties are the crater performance for different types of bottoms and beaches, the final location and state (exploded or unexploded) of the affected mines and of the obstacles, the degree of difficulty the amphibious landing force would have at the end of the channel, the means and accuracy of delivery, and the penetrator design and performance. The addition of guinea-pig causeways to follow the overwhelming force and lead the landing force to the beach provides a complementary MCM to proof test the channel, verify the MCM effectiveness, and build the confidence of the forces. An extension of the line-charge analog approach might clear bottom, buried, and moored mines up to about 40-ft depth and a massive countermining strike might be able to clear the remaining deeper section of the approach lane.

Recommendations

- Support the exploration of the explosive excavation of a channel through the surf zone up the beach and in VSW by tests, calculations, and simulations[15] on cratering by deeply buried rows of charges of different sizes and depths.
- Conduct tests of the mobility of tracked vehicles out of the end crater on the beach and of the ability of small explosives and of water-cannon apparatus to reduce the end crater slope.
- Determine the feasibility and accuracy of B-52 delivery of large, terminally-guided penetrator weapons, and the possibility of A-6 delivery of clusters of 2,000-lb bombs.
- Support the development of appropriate delivery methods.
- Study accuracy and cost effectivenes of mine-bomb placement by different platform/guidance combinations.
- Conduct an engineering design study of penetrator weapon options and the aerodynamic controls necessary to obtain accurate placement of the explosive and of the fuze modifications for synchronized detonation and GPS-controlled permissive action links.
- Assess the probable status and distribution of mines and obstacles in and near the crater.
- Study the geology of beaches that are likely to be targets for invasion and determine the effect of the geology on the operation of the penetrators.
- Determine the hydrodynamic configuration required to penetrate the bottom in the 10 to 30 ft of water and to sufficient depth near and on the beach.
- Study the feasibility and synergism of the guinea-pig causeways following the overwhelming force and develop appropriate causeways or conversion kits to make causeways from craft of opportunity.
- Investigate the lethality of detonation of explosive patterns on the bottom (with time-fuze controls) against expected types of bottom and moored mines in depth regions characteristic of the approach lane.

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[15]Dr. E. Tremba of DNA suggested that the Boeing high-*g* centrifuge be used to investigate the phenomena involved on a laboratory scale. See, e.g., Schmidt, R.M., K.A. Holsapple, and K.R. Housen. 1986. *Gravity Effects in Cratering,* DNA Technical Report TR-86-182, Defense Nuclear Agency, Washington, D.C., May 30.

Appendix D

Committee and Staff Biographies

COMMITTEE MEMBERS

Gene H. Porter is an independent consultant in matters relating to national security planning and weapon systems development. His current clients include the Center for Naval Analyses (CNA), for which he works on matters relating to Navy acquisition programs, and the Institute for Defense Analyses, for which he works on matters relating to the Quadrennial Defense Review. His expertise is in undersea systems R&D, operations and system analysis, and acquisition management. Prior to his retirement in 1999, Mr. Porter served as a senior fellow at CNA, where he provided analysis for the Interagency Task Force on the Roles and Missions of the U.S. Coast Guard in support of both national defense goals and the more traditional humanitarian, maritime law enforcement, and regulatory missions. During his tenure at CNA, Mr. Porter also served as an advisor to the Assistant Secretary of the Navy for Research, Development, and Acquisition on matters aimed at reducing the total ownership costs of naval systems through improved management processes and better cost visibility. Prior to joining CNA, he served as director of acquisition policy and program integration for the Office of the Undersecretary of Defense for Acquisition, where he directed long-range planning, programming, and budgeting matters on new military warfare systems. His earlier career included various staff and line management positions at Sanders Corporation (a Lockheed Martin Company) in the development and manufacture of military and commercial electronic systems, to include mine and undersea warfare systems. Mr. Porter is an honors graduate of the U.S. Naval Academy. He served 5 years in nuclear submarines and then was selected for assignment to the Office of the Secretary of Defense. Mr. Porter has served on numerous scientific and advisory groups, including service as the deputy executive director of the congressionally chartered Commission on the Roles and Missions of the Armed Forces.

Seymour J. Deitchman is an independent consultant in matters relating to national security, R&D management, and systems evaluation. A mechanical and aeronautical engineer by training and earlier experience, Mr. Deitchman served as vice president for programs at the Institute for Defense Analyses. Mr. Deitchman once served as special assistant in the Office of the Secretary of Defense, where he established and oversaw the DOD program of R&D in support of U.S. military operations in Southeast Asia. He also served as director of overseas defense research at the Advanced Research Projects Agency (ARPA), where he was responsible for planning and executing ARPA's specific R&D program on counterinsurgency and related technical matters in the same area. He has been a member of numerous government and scientific advisory groups, an occasional lecturer at the National War College and Industrial College of the Armed Forces, and a U.S. delegate to the NATO Defense Research Group. Mr. Deitchman was recently honored by the Military Operations Research Society as its 2000 Wanner Award recipient. Mr. Deitchman is currently a member of the NSB.

Albert J. Baciocco, Jr., retired from the U.S. Navy as a Vice Admiral in 1987 after 34 years of distinguished service, principally within the nuclear submarine force and directing the Navy Department research and technology development enterprise. He graduated from the U.S. Naval Academy in 1953 with a B.S. degree in engineering. Upon retirement from the Navy, Admiral Baciocco formed the Baciocco Group, Inc., a technical and management consulting practice providing services to industry primarily in the areas of strategic planning, technology investment and application, and business planning and development. Admiral Baciocco is a director of American Superconductor Corporation and is associated with several new technology business enterprises. In addition, he serves on several boards and committees of government, industry, and academe, among them the board of trustees for the South Carolina Research Authority and on the board of directors for the University of South Carolina Research Institute and the Foundation for Research Development at the Medical University of South Carolina. In addition, he serves as chair of the Southeastern Universities Research Association's Maritime Technical Advisory Committee to the Thomas Jefferson National Accelerator Laboratory in Newport News, Virginia. Admiral Baciocco is the recipient of Florida Atlantic University's Honorary Doctorate in Ocean Engineering. Admiral Baciocco is currently a member of the NSB.

Arthur B. Baggeroer is the Ford Professor of Engineering for Ocean Science in the Departments of Ocean and Electrical Engineering at the Massachusetts Institute of Technology (MIT). A member of the NAE, Dr. Baggeroer's research interests primarily relate to advanced signal processing methods applied to sonar, ocean acoustics, and geophysics. During his career at MIT, Dr. Baggeroer served as director of the MIT-Woods Hole Joint Program in Oceanography and Oceanographic Engineering. During sabbatical leaves, he served as a consultant to the Chief of Naval Research at the SACLANT Center in La Spezia, Italy, and as a Green Scholar at the Scripps Institution of Oceanography. Dr. Baggeroer has served on numerous scientific and technical advisory groups and is currently a member of the NRC's Ocean Studies Board and Naval Studies Board. He is a fellow of the Institute of Electrical and Electronics Engineers and of the Acoustical Society of America.

Ruzena K. Bajcsy is assistant director for the Computer and Information Science and Engineering Directorate at the National Science Foundation (NSF). A member of the NAE and IOM, Dr. Bajcsy obtained a Ph.D. from Slovak Technical University and a second Ph.D. from Stanford University. Prior to coming to NSF, she served as the chair for the Computer and Information Science Department at the University of Pennsylvania. Dr. Bajcsy's research interests include machine perception, computer vision, characterizing and solving problems involving segmentation, and three-dimensional vision and other sensory modalities that function together with vision. She has served on numerous scientific and technical advisory groups, including the NRC's Army Technical Assessment Board. She is a fellow of the Institute of Electrical and Electronics Engineers and a founding fellow of the American Association of Artificial Intelligence.

Ronald L. Beckwith retired as a Major General from the U.S. Marine Corps in 1991 after 34 years of service. General Beckwith's military career includes senior leadership responsibilities in expeditionary warfare, including Deputy Assistant Secretary of the Navy for Expeditionary Force Programs. Upon his retirement in 1991, General Beckwith formed LeeCor, Inc., a professional management services company serving both industry and government. A naval aviator by training, General Beckwith is interested in shallow water mine countermeasures; C4ISR; sea-lift expeditionary force fire support; training, modeling and simulation; R&D in synchronization with current defense planning; and, more recently, the development of knowledge management software used in information system applications.

John R. Benedict, Jr., is a member of the principal professional staff for the Joint Warfare Analysis Department at the Johns Hopkins University Applied Physics Laboratory. Mr. Benedict has an extensive background in naval operations analysis, primarily in the area of undersea warfare, with special emphasis on antisubmarine warfare and mine countermeasure systems. He has served as a study leader and principal investigator on a variety of tasks involving examination of performance trade-offs among platforms, sensors, and weapons. Recent efforts have included an examination of the long-term mine reconnaissance system, the organic airborne and surface influence sweep system, the airborne mine neutralization system, and the rapid airborne mine clearance system.

D. Richard Blidberg is the Director of the Autonomous Undersea Systems Institute (formerly the Marine Systems Engineering Laboratory (MSEL)). Mr. Blidberg has been involved in the development of autonomous underwater vehicle (AUV) systems for more than 20 years. Prior to co-founding the MSEL, Mr. Blidberg managed the seabed survey operations at Ocean Research Equipment, Inc.; served with the U.S. Coast Guard; and worked at the Woods Hole Oceanographic Institute. His present interests are focused on the development of technologies related to autonomous submersible vehicles and include the investigation of architectures for intelligent guidance and control of multiple autonomous vehicles. He has over 60 publications related to AUV technology and served on numerous scientific and technical advisory groups. He is currently the associate editor of the Institute of Electrical and Electronics Engineers' *Journal of Ocean Engineering.*

L. Eric Cross is Evan Pugh Professor Emeritus of Electrical Engineering, a former director of the Materials Research Laboratory at Pennsylvania State University, and a member of the NAE. His research interests include ferroelectrics; ferroelastic and secondary ferroic phenomena; phase transitions; phenomenology of proper and improper ferroelectric, dielectric, piezoelectric, and pyroelectric crystals; ceramics and composites; electrostriction; measurement of electrostrictive strain; and processing and fabrication of multilayer ceramic structures for dielectric and piezoelectric applications. Dr. Cross has served on numerous scientific and technical advisory groups. He is a fellow of the American Ceramics Society, the American Institute of Physics, the Institute of Electrical and Electronics Engineers, and the American Optical Society.

Jose B. Cruz, Jr., is the Howard D. Winbigler Chair in Engineering and a professor of Electrical Engineering at Ohio State University (OSU). A member of the NAE, Dr. Cruz previously served as dean of the College of Engineering. His research interests include multiagent control of complex systems, leader-follower strategies in dynamic games, multiagent command and control in intelligent hostile environments, and application of multiagent incentive strategies in energy systems. Prior to joining OSU, he served as chair of the Electrical and Computer Engineering Department at the University of California, Irvine. Dr. Cruz has held a number of teaching positions throughout his professional career, including positions at the Massachusetts Institute of Technology and the University of Illinois. Dr. Cruz is a fellow of the Institute of Electrical and Electronics Engineers and the American Association for the Advancement of Science.

Sabrina R. Edlow is the research team leader for the Mine Warfare Systems Team at the Center for Naval Analyses. Ms. Edlow recently led the Mine Countermeasures Force-21 study, which quantitatively balances the Navy's programming plans and strategies for evolving organic mine countermeasures systems against future warfighting requirements and capabilities. She also recently assessed war plans and executed operations for Desert Thunder and Desert Fox. Her research interests encompass a wide range of areas, including naval force structure planning, mine warfare, overhead systems, and underwater acoustic systems. A nuclear engineer by training, Ms. Edlow began her career as a design engineer at Duke Power Company, where she coordinated the nuclear fuel supply for seven nuclear reactors.

Robert A. Frosch is an associate and a senior research fellow in the Belfer Center for Science and International Affairs of the John F. Kennedy School of Government at Harvard University. He is a member of the NAE, and his interests include theoretical physics, acoustical oceanography, seismology, marine physics, R&D management, industrial research, and ecology. Dr. Frosch has served in a number of key senior leadership positions in both industry and government, among them director of Hudson Laboratories, deputy director of the Advanced Research Projects Agency, Assistant Secretary of the Navy for Research and Development, assistant executive director of the United Nations' Environment Programme, administrator of the National Aeronautics and Space Administration, and vice president of research at General Motors. Dr. Frosch served on the Fusion Science Assessment Committee, is currently serving on the NRC Committee on Grand Challenges in the Environmental Sciences, and is vice chair of the NRC's Report Review Committee.

Lee M. Hunt, an independent consultant, is the former director of the NRC's Naval Studies Board. Mr. Hunt's long-time experience with sea and land mine warfare, as well as explosive ordnance disposal, covers sea and land mine countermeasures in World War II, explosive ordnance disposal in the Korean conflict, and some 70 technical reports on land and sea mines and countermeasures during his 35 years with the NRC. In addition, since 1964 he has been a proponent of measures to reduce the global accumulation of unexploded ordnance. Since his retirement in 1995 he has authored several papers on the above subjects and has participated in several mine warfare studies, and he continues to be heavily involved in all of the above areas as vice president for academic affairs with the Mine Warfare Association. Mr. Hunt served on the NRC Committee on Alternative Technologies to Replace Antipersonnel Landmines.

William J. Hurley has been on the research staff at the Institute for Defense Analyses (IDA) since 1985 and is currently a member of IDA's Joint Advanced Warfighting Program, which helps DOD to develop new joint warfighting concepts and capabilities, design experiments to explore those concepts, and facilitate their effective implementation. From 1975 to 1985 Dr. Hurley was with the Center for Naval Analyses. His research has addressed a range of defense issues, with special emphasis on joint forces, naval forces, and undersea warfare. He has directed or co-authored more than 30 studies sponsored principally by the Office of the Secretary of Defense and the Navy. In addition, from 1991 to 1998 Dr. Hurley was the associate program director and then program director of the Defense Science Study Group, a DARPA-sponsored program of education and study that introduces outstanding young professors of science and engineering to military systems and organizations and current issues of national security. In 1993 Dr. Hurley received the Andrew J. Goodpaster Award for Excellence in Research from IDA. Dr. Hurley received a B.S. in physics from Boston College (1965) and a Ph.D. in physics from the University of Rochester (1971), and he held research positions at Syracuse University (1970-1972) and at the University of Texas (1972-1975).

Harry W. Jenkins, MajGen, U.S. Marine Corps (retired), is the director of business development and a congressional liaison at ITT Industries-Defense, where he is responsible for activities in support of tactical communications systems and airborne electronic warfare between the Navy, Marine Corps, National Guard, and appropriate committees in Congress. General Jenkins' operational background is in expeditionary warfare and the use of C4I systems. During Desert Storm, General Jenkins served as the Commanding General of the Fourth Marine Expeditionary Brigade, directing operational planning, training and employment of the ground units, aviation assets, and command and control systems in the 17,000 man amphibious force. In his last position before retirement from the U.S. Marine Corps, General Jenkins, as the director of expeditionary warfare for the Chief of Naval Operations, initiated a detailed program for C4I systems improvements for large-deck amphibious ships and reorganized the Navy's unmanned aerial vehicle (UAV) efforts for operations from aircraft carriers and amphibious ships. He is a member of numerous professional societies, including the Navy League and the Aerospace Industries Association.

Irwin Mendelson is a retired president for the Engineering Division at Pratt and Whitney, where he oversaw a total staff of 8,000 and an annual budget of $900 million and was responsible for the design, development, and installation of aircraft engine systems. A mechanical engineer by training, he specialized primarily in commercial and military aircraft engine design. During his career, Mr. Mendelson was directly responsible for the design and development of turbofan engines, jet engine fuel controls, pyrophoric ignition systems, and thrust vector controls for rockets.

John D. Pearson retired from the U.S. Navy as a Rear Admiral in 1996 after 35 years of service, principally within the surface warfare force. Admiral Pearson's last position was as commander of the Mine Warfare Command, where he was responsible for the readiness of U.S. Navy mine warfare forces in conducting offensive and defensive mine warfare operations throughout the world. Today Admiral Pearson serves as the chair of mine warfare at the Naval Postgraduate School. He has served on numerous scientific and technical advisory groups and is currently president of the Mine Warfare Association.

Ronald L. Woodfin recently retired as a staff member of the Sandia National Laboratories, where his research interests included mine countermeasures and demining, as well as the development of rigid polyurethane foam to form roadways over the barriers and/or minefields encountered in the beach and surf zone regions during an amphibious assault. Previously, he worked at the Naval Weapons Center, Naval Undersea Center, and Boeing Commercial Airplane Division. Dr. Woodfin has been an invited participant at several international demining conferences and was a member of an advisory task force on humanitarian demining for the General Board of Global Ministries of the United Methodist Church. He is on the faculty of Wayland Baptist University, Albuquerque, New Mexico, campus.

Markus Zahn is a professor of electrical engineering in the Department of Electrical Engineering and Computer Science at the Massachusetts Institute of Technology. He also directs the EECS VI-A Internship program, a cooperative work study program with industry and government. Dr. Zahn's research interests include electro-optical field and charge mapping measurements; high-voltage charge transport and breakdown phenomena in dielectrics; flow electrification phenomena; and capacitive and inductive sensors for measuring dielectric, conduction, and magnetic properties of materials. He is the author of numerous publications on electromagnetic field theory. Dr. Zahn is a fellow of Institute of Electrical and Electronics Engineers.

Edward Zdankiewicz, an independent consultant, retired as engineering department manager of Northrop Grumman Oceanic Systems in 1998, where his responsibilities included departmental management of all R&D, as well as production efforts related to acoustic and mechanical undersea systems. Prior to joining Northrop, Mr. Zdankiewicz served as Deputy Assistant Secretary of the Navy for Mine and Undersea Warfare from 1993 to 1997, providing technical guidance to the Assistant Secretary of the Navy for Research, Development, and Acquisition on antisubmarine warfare and mine warfare issues. Mr. Zdankiewicz began his professional career as a design engineer at the Naval Ordnance Laboratory, progressing to key management responsibilities in the development of submarine launched torpedoes and mines. He has served in a number of scientific and technical capacities, including as an undersea warfare specialist in the Office of the Secretary of Defense and as a military legislative assistant to Senator John Glenn.

STAFF

Charles F. Draper is a senior program officer at the National Research Council's (NRC) Naval Studies Board. Prior to joining the NRC in 1997, Dr. Draper was the lead mechanical engineer at S.T. Research Corporation, where he provided technical and program management support for satellite earth station and small satellite design. He received his Ph.D. in mechanical engineering from Vanderbilt University in 1995; his doctoral research was conducted at the Naval Research Laboratory (NRL), where he used an atomic force microscope to measure the nano-mechanical properties of thin film materials. In parallel with his graduate student duties, Dr. Draper was a mechanical engineer with Geo-Centers, Incorporated, working onsite at NRL on the development of an underwater x-ray backscattering tomography system used for the nondestructive evaluation of U.S. Navy sonar domes on surface ships.

Ronald D. Taylor has been the director of the Naval Studies Board of the National Research Council since 1995. He joined the National Research Council in 1990 as a program officer with the Board on Physics and Astronomy and in 1994 became associate director of the Naval Studies Board. During his tenure at the National Research Council Dr. Taylor has overseen the initiation and production of more than 40 studies focused on the application of science and technology to problems of national interest. Many of these studies address national security and national defense issues. From 1984 to 1990 Dr. Taylor was a research staff scientist with Berkeley Research Associates, working onsite at the Naval Research Laboratory on projects related to the development and application of charged particle beams. Prior to 1984 Dr. Taylor held both teaching and research positions in several academic institutions, including assistant professor of physics at Villanova University, research associate in chemistry at the University of Toronto, and instructor of physics at Embry-Riddle Aeronautical University. Dr. Taylor holds a Ph.D. and an M.S. in physics from the College of William and Mary and a B.A. in physics from Johns Hopkins University. In addition to science policy, Dr. Taylor's scientific and technical expertise is in the areas of atomic and molecular collision theory, chemical dynamics, and atomic processes in plasmas. He has authored or co-authored nearly 30 professional scientific papers or technical reports and given more than two dozen contributed or invited papers at scientific meetings.

Appendix E

Agendas for Meetings of the Committee for Mine Warfare Assessment

AUGUST 1-2, 2000
NATIONAL RESEARCH COUNCIL, WASHINGTON, D.C.

Tuesday, August 1, 2000

Closed Session: Committee Members and NRC Staff Only

0830 CONVENE—WELCOME, INTRODUCTORY REMARKS
Mr. Gene Porter, Committee Chair
Mr. Seymour Deitchman, Committee Vice Chair
Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0900 THE MINE THREAT—Overview of Key Technical Features of Modern Mines Present and Future; Recent Quantitative Trends in Inventories of Modern (Influence) Mines Held by Potential Hostile Nations and Projections Thru 2020; Known Role of Mines in Political/Military Doctrine of Potentially Hostile Nations; Likely Proliferation of Advanced Features Such as Wireless Remote Control, Mine Signature Reduction, and Anti-Helicopter/ACV Capabilities; Summary of Known Signatures of Mine Laying Activities, Trends; Assessment of Current and Planned Countermine Capabilities of Likely U.S. Allies Against Foregoing Threats
Mr. Don R. Jones, Office of Naval Intelligence

1015 The Mine Threat—Operational
LT Lynne A. Corso, USN, SABRE Division, Office of Naval Intelligence

1130 The Mine Threat—Very Shallow Water, Craft Landing Zone, Technology Advances in Anti-Landing Mines, Integrated Anti-Amphibious Assault Defenses
Mr. Michael Howard, Marine Corps Intelligence Activity

1300 Current DOD Mine Warfare Program, OUSD (A&T) Perspective—DOD Development and Procurement to Meet the Threat
Mr. George Leineweber, Office of the Under Secretary of Defense (Acquisition and Technology)

1430 Current DON Mine Warfare Program, DASN MUW Perspective—DON Development and Procurement to Meet the Threat
Mr. Dale Gerry, Deputy Assistant Secretary of the Navy (Mine and Undersea Warfare)

1600 Current Navy Mine Warfare Program, N85 Perspective—Top-level Navy Response to the Threat; Program Structure; Fleet Engagement Strategy; Recent At-Sea Testing Results; Congressional Certification; Status of Funding; Future Program of Record
BrigGen William Whitlow, USMC, Director, Expeditionary Warfare, Office of the Chief of Naval Operations, N85

Closed Session: Committee Members and NRC Staff Only

1815 Dinner: Guest Speaker—Mine Warfare in the Gulf War
ADM Stanley R. Arthur, USN (Ret.)

1945 End Session

Wednesday, August 2, 2000

Closed Session: Committee Members and NRC Staff Only

0800 Convene—Welcome, Composition and Balance Discussion
Mr. Gene Porter, Committee Chair
Mr. Seymour Deitchman, Committee Vice Chair
Dr. Ronald Taylor, Director, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0900 Current DON Mine Warfare Program, PEO Mine Warfare Perspective—DON Development and Procurement to Meet the Threat, to include SABRE and DET

RADM Curtis Kemp, USN, Program Executive Officer (Mine and Undersea Warfare)

1000 SURFACE MINE WARFARE SYSTEMS

CAPT Terry Briggs, USN, Program Executive Officer (Mine and Undersea Warfare), Surface Mine Warfare Systems Office (PMS 407)

Mr. Doug Gaarde, Deputy Program Executive Officer (Mine and Undersea Warfare), Surface Mine Warfare Systems Office (PMS 407)

1045 AIRBORNE MINE COUNTERMEASURES SYSTEMS

CAPT Louis Morris, USN, Program Executive Office (Mine and Undersea Warfare), Airborne Mine Countermeasures Program Office (PMS 210)

1130 MINE WARFARE SHIP SYSTEMS

CAPT Anthony Shutt, USN, Deputy Program Executive Officer (Mine and Undersea Warfare), Mine Warfare Ship Program Office (PMS 303)

1245 EXPLOSIVE ORDNANCE DISPOSAL SYSTEMS

CAPT Rick Kiser, USN, Program Executive Office (Mine and Undersea Warfare), Explosive Ordnance Disposal Program Office (PMS EOD)

1330 MINE WARFARE TECHNOLOGY PROGRAM—Existing Technology Base and Developments to Support Future Mine Warfare Acquisition

Dr. Douglas Todoroff, Associate for Mine Warfare Applications, Office of Naval Research (Code 322)

1530 MARINE CORPS LAND MINE WARFARE REQUIREMENTS—Beach Area Programs

BrigGen John F. Goodman, USMC, Deputy Commanding General, Marine Corps Combat Development Command

1700 ADJOURN

SEPTEMBER 5-6, 2000
NATIONAL RESEARCH COUNCIL, WASHINGTON, D.C.

Tuesday, September 5, 2000

Closed Session: Committee Members and NRC Staff Only

0800 CONVENE—Welcome, Introductory Remarks, Proposed Sub-Panels, Provisional Report Outline

Mr. Gene Porter, Committee Chair

Mr. Seymour Deitchman, Committee Vice Chair

Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0900 MINE COUNTERMEASURES (MCM) FORCE 21 STUDY
Ms. Sabrina Edlow, Committee Member, Co-Author MCM Force 21 Study, Center for Naval Analyses

1100 INTEGRATED WARFARE ARCHITECTURE (IWAR) FOR MINE WARFARE
CDR Edward L. Brownlee, USN, Assessment Division, Office of the Deputy Chief of Naval Operations for Resources, Warfare Requirements, and Assessment, N81X

1300 MARINE CORPS LAND MINE WARFARE REQUIREMENTS—Beach Area Programs
Col Thomas E. Seal, USMC, Director, Warfighting Requirements Division, Marine Corps Combat Development Command

1430 NAVY SEA MINES—Past, Present, and Future
Mr. William C. Jones, Head, Mines Division, NAVSEA/Panama City Coastal Systems Station

Closed Session: Committee Members and NRC Staff Only

1600 COMMITTEE DISCUSSION—Proposed Sub-Panels, Provisional Report Outline
Mr. Gene Porter, Committee Chair
Mr. Seymour Deitchman, Committee Vice Chair

1730 RECEPTION AND WORKING DINNER—Report Discussion
Mr. Gene Porter, Committee Chair
Mr. Seymour Deitchman, Committee Vice Chair

1930 END SESSION

Wednesday, September 6, 2000

Closed Session: Committee Members and NRC Staff Only

0830 CONVENE—Welcome, Introductory Remarks, Report Discussion
Mr. Gene Porter, Committee Chair
Mr. Seymour Deitchman, Committee Vice Chair
Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0930 N87 MINE COUNTERMEASURES STUDY—NCW Implementation Principles; End-to-End Clearance Metrics; MCM Design Principles Required to Achieve Meaningful MCM Clearance Rates

RADM Thomas J. Elliott, Jr., USN, Deputy Director, Submarine Warfare Division, Office of the Deputy Chief of Naval Operations for Resources, Warfare Requirements, and Assessment, N87B

CDR Richard Medley, USN, Submarine Warfare Division, Office of the Deputy Chief of Naval Operations for Resources, Warfare Requirements, and Assessment, N873B

1200 DARPA MINE WARFARE PROGRAM—Water Hammer Program

Dr. Sheldon Meth, Chief Scientist, Special Projects Division, Science Applications International Corporation

1300 DARPA MINE WARFARE PROGRAM—Synthetic Aperture Sonar Program

Dr. Steven Borchardt, Chief Technology Officer, Dynamic Technology, Incorporated

1400 JOINT COUNTERMINES ADVANCED CONCEPT TECHNOLOGY DEMONSTRATION—Summary of Results and Lessons Learned

Mr. Barry P. Blumenthal, Office of the Chief of Naval Operations, N816T

1530 SURF ZONE AND BEACH ZONE BREACHING BY EXPLOSIVE CHANNELING—Summary of Naval Surface Warfare Center/Indian Head Efforts

Dr. Sidney Reed, Consultant, Naval Studies Board

1700 ADJOURN

OCTOBER 3-5, 2000
NATIONAL RESEARCH COUNCIL, WASHINGTON, D.C.

Tuesday, October 3, 2000 (Plenary)

Closed Session: Committee Members and NRC Staff Only

0830 CONVENE—Welcome, Introductory Remarks, Report Discussion

Mr. Gene Porter, Committee Chair

Mr. Seymour Deitchman, Committee Vice Chair

Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0900 JOINT STAFF MINE WARFARE PERSPECTIVE—Mine Threat with Respect to the Contingency Planning Process; Relation of Chairman's Recent Integrated Priority List to Navy's Mine Warfare Program

LTC Robert Brown, USA, Joint Warfighting Capability Assessment, Joint Staff, J8

LCDR Mark Guevarra, USN, Joint Warfighting Capability Assessment, Joint Staff, J8

1045 SURFACE WARFARE DEVELOPMENT GROUP (SWDG) MINE WARFARE READINESS AND EFFECTIVENESS MEASURING (MIREM) PROGRAM—Data Collection Process and Key Metrics; Performance of Legacy MCM Systems in MIREM; Specific MIREM Exercises with Organic MCM Systems (RMS Prototype, SQS-53 "Kingfisher," Magic Lantern)
CDR Patrick Bowe, USN, Expeditionary Warfare Division, N752G

1300 MINE WARFARE—METEOROLOGY AND OCEANOGRAPHY (METOC) SUPPORT
CDR James Berdeguez, USN, Expeditionary Warfare Division, N752K
Mr. William Lingsch, Naval Oceanographic Office, Stennis Space Center, Mississippi

1430 INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE SYSTEMS FOR MINE WARFARE MISSIONS—Organizations with This Responsibility and the Capabilities Provided; Process for Tasking Sensors; Results of "Real World" Surveillance Tests
Dr. Frank Herr, Director, Office of Naval Research (Code 321)

1600 MINE WARFARE TRAINING AND EDUCATION—Officer/Enlisted Paths for Mine Warfare; Mine Warfare Curriculums Compared to Other Naval Warfare Areas; Fleet Battle Experiments; Role of Mine Warfare Fleet Training
CAPT David Grimland, USN, Mine Warfare Command

1730 END SESSION

Wednesday, October 4, 2000 (Panel 2[1])

Closed Session: Committee Members and NRC Staff Only

0830 CONVENE—Welcome, Introductory Remarks, Report Discussion
Mr. Gene Porter, Committee Chair
Ms. Sabrina Edlow, Panel 2 Chair
Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public: Classified Discussion (Secret)

0900 LEGACY MINE COUNTERMEASURES SYSTEM BASELINE CAPABILITIES (SURFACE MINE COUNTERMEASURES, AIRBORNE MINE COUNTERMEASURES, EXPLOSIVE ORDNANCE DISPOSAL)—Operational Requirements Documents; Demonstrated Capabilities at-Sea (search/clearance rates); Technical and Operational Limitations; Associated Training and Manning Plans; Funding Profile and Budget Information
Mr. Douglass Gaarde, Surface Mine Warfare Office (PMS 490B)

[1]Including members of Panel 1.

CAPT Louis Morris, USN, Airborne Mine Countermeasures Program Office (PMS 210)

Mr. Robert Simmons, Space and Naval Warfare Systems Command

1300 ORGANIC MINE COUNTERMEASURES SYSTEM CAPABILITIES (RMS, LMRS, AQS-20X, AMNS, OASIS, ALMDS, RAMICS)—System Operational Employment Concept; Operational Requirements Document; Demonstrated Performance to Date (from various tests including any at-sea results); Technical and Operational Limitations; Technical and Operational Risks (including risk mitigation measures being undertaken by the program); Development Time Line and Associated Funding; Procurement and Operating Cost Funding; Plan for "Mainstreaming" into Fleet (including plans for training and manning)

CAPT Terry Briggs, USN, Surface Mine Warfare Office (PMS 490)

Mr. Henry Scheetz, Airborne Mine Countermeasures Systems Program Office (PMS 210)

Mr. Robert Simmons, Space and Naval Warfare Systems Command

Mr. Leslie Taylor, Naval Surface Warfare Center, Indian Head Division

Closed Session: Committee Members and NRC Staff Only

1600 PANEL DISCUSSION

Moderator: Ms. Sabrina Edlow, Panel 2 Chair

1700 END SESSION

Wednesday, October 4, 2000 (Panel 3[2])

Closed Session: Committee Members and NRC Staff Only

0830 CONVENE—Welcome, Introductory Remarks, Report Discussion

Mr. Seymour Deitchman, Committee Vice Chair

Mr. Lee Hunt, Panel 3 Chair

Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0900 GENERAL DISCUSSION:

AMPHIBIOUS ASSAULT PLANS AND REQUIREMENTS—Number and Width of Cleared Approach Lanes and Terminal Lanes as a Function of Assault

[2]Including members of Panel 1.

Phases; Distance Between Cleared Terminal Lanes; Number and Types of Vehicles Expected Per Set as a Function of Phases; Turn Around Area Required; Maximum Slope Negotiable by Fully Loaded LCAC, AAAV; Navigation Capability of Assault Vehicles; Time Allowed for Breaching

DESCRIPTION OF PHYSICAL ENVIRONMENT FROM SURF ZONE TO BEACH EXIT—Range of Zonal Types (gross percentage of each type to be expected); Depth of Offshore Bar (surf zone); Distance from Bar to High Water Mark; Tidal Range; Depth of Intervening Water Bottom and Beach Types (sediment); Slope of Beach; Beach Width for Breaching

DESCRIPTION OF MINE TYPES AND DISPOSITION TO BE EXPECTED IN SURF ZONE/CRAFT LANDING ZONE/BEACH EXIT—Overall Dimensions; Charge Size; Sensor Mechanism; Case, Electronics, and Mechanical Hardness; Stability in Surf Zone; Burial Potential

DESCRIPTION OF OBSTACLE TYPES AND DISPOSITION TO BE EXPECTED IN SURF ZONE/CRAFT LANDING ZONE/BEACH EXIT—Spacing Between Obstacles; Sequencing of and Distance Between Obstacle Types; Distance Extended Seaward; Spatial Relationship to Mines; Description of Classical Mine and Obstacle Defense (including worst case)

CDR Edward Brownlee, USN, Assessment Division, N81X
Mr. Scotty Burleson, Mine Warfare Command
CAPT David Grimland, USN, Mine Warfare Command
Mr. Walter Rankin, Naval Surface Warfare Center, Dahlgren Division, Coastal Systems Station
Mr. Henry Scheetz, Airborne Mine Countermeasures Systems Program Office (PMS 210)
Maj Timothy Seamon, USMC, Marine Corps Combat Development Command
Mr. Robert Simmons, Space and Naval Warfare Systems Command
Mr. Leslie Taylor, Naval Surface Warfare Center, Indian Head Division

1300 GENERAL DISCUSSION (Continued)

Closed Session: Committee Members and NRC Staff Only

1600 PANEL DISCUSSION
Moderator: Mr. Lee Hunt, Panel 3 Chair

1700 END SESSION

Thursday, October 5, 2000 (Plenary)

Closed Session: Committee Members and NRC Staff Only

0830 CONVENE—Introductory Remarks, Report Discussion
Mr. Gene Porter, Committee Chair
Mr. Seymour Deitchman, Committee Vice Chair
Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0845 OVERVIEW OF THE MINE WARFARE COMMAND
Mr. Scotty Burleson, Mine Warfare Command
CAPT David Grimland, USN, Mine Warfare Command
1030 OVERVIEW OF THE COASTAL SYSTEMS STATION
Mr. Walter Rankin, Naval Surface Warfare Center, Dahlgren Division, Coastal Systems Station
1200 ADJOURN (EXCEPT INTEGRATION PANEL)

Thursday, October 5, 2000 (Integration Group[3])

Closed Session: Committee Members and NRC Staff Only

1300 REPORT DISCUSSION
Moderators:
Mr. Gene Porter, Committee Chair
Mr. Seymour Deitchman, Committee Vice Chair
1700 ADJOURN

NOVEMBER 13-15, 2000
NATIONAL RESEARCH COUNCIL, WASHINGTON, D.C.

Monday, November 13, 2000 (Plenary)

Closed Session: Committee Members and NRC Staff Only

0830 CONVENE—Welcome, Introductory Remarks, Report Discussion
Mr. Gene Porter, Committee Chair
Mr. Seymour Deitchman, Committee Vice Chair
Dr. Charles Draper, Senior Program Officer, Naval Studies Board

[3]The integration group includes Gene Porter, Seymour Deitchman, Sabrina Edlow, William Hurley, and Lee Hunt.

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0900 OPTEVFOR Role in Assessing Mine Warfare Systems
CDR John R. Ericson, USN, Director, Mine Warfare Division, Operational Test and Evaluation Force

1030 USAF Maritime Mining Support
Maj. James R. Auclaire, USAF, Liaison Officer, Mine Warfare Command

1300 Navy/Marine Corps Experimentation and Inclusion of Mine Warfare—Overview and Mine Warfare Issues of Fleet Battle Experiments, Sea Dragon/Hunter Warrior/Urban Warrior/Kernel Blitz 99 Exercises
CAPT Patrick L. Denny, USN, Maritime Battle Center, Navy Warfare Development Command

1430 Ship Protection—Navy Programs for Limiting Vulnerability and Improving Ship Self-Defense (Degaussing, Quieting, Withstanding Explosions); Discussion of Recent Attack on USS Cole in Aden
Mr. John A. Schell, NAVSEA 05 Ship Survivability
Mr. Randall L. Horne, Coastal Systems Station, Project Engineer, Foreign Mines, Force Protection, Modeling and Simulation

1730 End Session (Working Dinner for Panel 2 Offshore Countermine Warfare Members)

Tuesday, November 14, 2000 (Panel 1)

Closed Session: Committee Members and NRC Staff Only

0830 Convene—Welcome, Introductory Remarks, Report Discussion
Messrs. Gene Porter and Seymour Deitchman, Committee Chair and Vice Chair
Dr. William Hurley, Panel 1 Chair
Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0900 General Discussion

Naval Mines in Service—Weapon Characteristics and Current Capabilities of Quickstrike Family (Bottom), Mk 56 (Moorad), Mk 60 (Encapsulated Torpedo, CAPTOR), Mk 67 (Submarine Launched Mobile Mine, SLMM)

NAVAL MINES IN DEVELOPMENT—Target Detection Device (TDD) for Mk 71, Improved Submarine-Launched Mobile Mine (ISLMM), Littoral Sea Mine, LongStrike, Remote Control, Deployable Autonomous Distributed Systems (DADS), ONR S&T

MINE DELIVERY PLATFORMS—F-14, F/A-18, P-3, B-52, B-1B, B-2, SSN 636, SSN 688, SSN 21, NSSN

NAVAL MINING INFRASTRUCTURE—Uniform, Civil Service, Industry

Maj. James R. Auclaire, USAF, Liaison, Mine Warfare Command

Representatives from:
Naval Surface Warfare Center, Dahlgren Division, Coastal Systems Station
Office of the Chief of Naval Operations N75 Expeditionary Warfare
Office of the Chief of Naval Operations N78 Air Warfare Divisions
Office of Naval Research
Program Executive Office for Mine and Undersea Warfare

1200 ARMY SCIENCE BOARD—Mine Warfare Study
Mr. Frank Kendall, Member, U.S. Army Science Board

1300 GENERAL DISCUSSION (CONTINUED)

Closed Session: Committee Members and NRC Staff Only

1600 PANEL DISCUSSION
Moderator: Dr. William Hurley, Panel 1 Chair

1700 ADJOURN

Tuesday, November 14, 2000 (Panel 2)

Closed Session: Committee Members and NRC Staff Only

0830 CONVENE—Welcome, Introductory Remarks, Report Discussion
Messrs. Gene Porter and Seymour Deitchman, Committee Chair and Vice Chair
Ms. Sabrina Edlow, Panel 2 Chair
Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0900 GENERAL DISCUSSION: ABILITY AND READINESS OF CH-60 TO SUPPORT ORGANIC MCM

CAPT William E. Shannon, USN, Naval Air Systems Command (PMA 299)
CAPT Tom Barns, USN, OCNO Air Warfare Division, N78OH
CDR Paul Lluy, USN, OCNO Airborne Mine Countermeasures, N752E
CDR John R. Ericson, USN, Director, Mine Warfare Division, Operational Test and Evaluation Force
LCDR James Sperbeck, USN, Naval Air Systems Command (PMA 299)

1300 GENERAL DISCUSSION: REMOTE MINE-HUNTING SYSTEM—DDG-91+, DD-, AND LPD-17 ABILITY AND READINESS TO SUPPORT ORGANIC MCM
CDR John R. Ericson, Director, Mine Warfare Division, Operational Test and Evaluation Force, Norfolk, Virginia

Representatives from:
DD-21 Program Office
Office of the Chief of Naval Operations N75 Expeditionary Warfare Division
Office of the Chief of Naval Operations N76 Surface Warfare Division
Naval Surface Force, U.S. Atlantic Fleet
U.S. Atlantic Fleet

Closed Session: Committee Members and NRC Staff Only

1600 PANEL DISCUSSION
Moderator: Ms. Sabrina Edlow, Panel 2 Chair
1700 END SESSION

Tuesday, November 14, 2000 (Panel 3)

Closed Session: Committee Members and NRC Staff Only

0800 CONTINENTAL BREAKFAST
0830 CONVENE—Welcome, Introductory Remarks, Report Discussion
Messrs. Gene Porter and Seymour Deitchman, Committee Chair and Vice Chair
Mr. Lee Hunt, Panel 3 Chair
Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0900 GENERAL DISCUSSION: MINE AND OBSTACLE BREACHING IN SUPPORT OF INSHORE MCM OPERATIONS

Dr. Thomas F. Swean, Program Officer, Ocean Engineering and Marine Systems, ONR 321
CDR David Jardot, USN, Section Head for Test and Evaluation of EOD, Naval Command Operational Test and Evaluation Force

Representatives from:
Office of Naval Intelligence
Naval Oceanographic Office
Office of the Chief of Naval Operations N75 Expeditionary Warfare Division
Marine Corps Combat Development Command

1200 WORKING LUNCH
1300 GENERAL DISCUSSION (CONTINUED)

Closed Session: Committee Members and NRC Staff Only

1600 PANEL DISCUSSION
Moderator: Mr. Lee Hunt, Panel 3 Chair
1700 ADJOURN

Wednesday, November 15, 2000 (Panel 2)

Closed Session: Committee Members and NRC Staff Only

0800 CONTINENTAL BREAKFAST
0830 CONVENE—Welcome, Introductory Remarks, Report Discussion
Messrs. Gene Porter and Seymour Deitchman, Committee Chair and Vice Chair
Ms. Sabrina Edlow, Panel 2 Chair
Dr. Charles Draper, Senior Program Officer, Naval Studies Board

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0900 GENERAL DISCUSSION: UPDATE ON THE IMPLEMENTATION PLAN FOR MAINSTREAMINING MINE WARFARE AND THE TRANSITION TO ORGANIC MCM CAPABILITIES

Representatives from:
Office of the Chief of Naval Operations N75 Expeditionary Warfare Division
DASN for Mine and Undersea Warfare
Mine Warfare Command

1200 WORKING LUNCH

Closed Session: Committee Members and NRC Staff Only

1300 PANEL DISCUSSION
Moderator: Ms. Sabrina Edlow, Panel 2 Chair

1400 ADJOURN

DECEMBER 6-7, 2000,
MINE WARFARE COMMAND, CORPUS CHRISTI, TEXAS

Wednesday, December 6, 2000

0810 CONVENE—Welcome, Introductory Remarks
Mr. Gene Porter, Committee Chair
Mr. Seymour Deitchman, Committee Vice Chair
Dr. Charles Draper, Senior Program Officer, Naval Studies Board

0815 FULL SPECTRUM MINE WARFARE THREATS
Briefer: CDR Droddy, USN
Attendees:
RADM Betancourt, USN
CAPT Rennie, USN
CAPT Jones, USN
CAPT Grimland, USN
CDR Carlson, USN
LCDR Beaver, USN
Mr. Burleson

0845 MINE WARFARE FORCE OVERVIEW
Briefer: Mr. Burleson
Attendees:
RADM Betancourt, USN
CAPT Rennie, USN
CAPT Jones, USN
CAPT Grimland, USN
CDR Droddy, USN
LCDR Beaver, USN

0930 BREAK

0945 CURRENT MINE WARFARE FORCE CAPABILITIES
Briefer: CAPT Grimland, USN
Attendees:
RADM Betancourt, USN
CAPT Rennie, USN
CAPT Jones, USN
CDR Droddy, USN
LCDR Beaver, USN
Mr. Burleson

1045 MAINSTREAMING MINE WARFARE AND ORGANIC MINE WARFARE
Briefer: CAPT Grimland, USN
Attendees:
RADM Betancourt, USN
CAPT Rennie, USN
CAPT Jones, USN
LCDR Beaver, USN
Mr. Burleson

1230 MINING
Briefer: CDR Swart, USN
Attendees:
RADM Betancourt, USN
CAPT Rennie, USN
CAPT Jones, USN
CAPT Grimland, USN
LCDR Beaver, USN
Mr. Burleson

1330 FUTURE MINE WARFARE CONCEPTS
Briefer: CAPT Grimland, USN
Attendees:
RADM Betancourt, USN
CAPT Rennie, USN
CAPT Jones, USN
LCDR Beaver, USN
Mr. Burleson

1430 FORCE C4I
Briefer: CDR Droddy, USN
Attendees:
RADM Betancourt, USN
CAPT Rennie, USN
CAPT Jones, USN
CAPT Grimland, USN
LCDR Beaver, USN
Mr. Burleson

1445 Force METOC
RADM Betancourt, USN
CAPT Rennie, USN
CAPT Jones, USN
CAPT Grimland, USN
CDR Droddy, USN
LCDR Beaver, USN
Mr. Burleson
1500 Depart CC Bay Club for CMWC
1515 Demonstrations:
Group 1: Bottom Mapping and METOC (LCDR Beaver, USN)
Group 2: MEDAL in CMWC (Mr. Burleson)
1545 Demonstrations:
Group 1: MEDAL in CMWC (LCDR Beaver, USN)
Group 2: Bottom Mapping and METOC (Mr. Burleson)
1615 End Session

Thursday, December 7, 2000

Data-Gathering Meeting Not Open to the Public:
Classified Discussion (Secret)

0800 HM-15 Brief and Tours—Static Displays; PMA Demonstration
LCDR Beaver, USN
Mr. Burleson
0915 Depart HM-15 for MWTC
1015 MWTC/MICFAC Brief and Tour
LCDR Beaver, USN
Mr. Burleson
1345 RSG Brief and Tour
LCDR Beaver, USN
Mr. Burleson
1500 Depart RSG for USS (MCM) and USS (MHC)
1510 MCM/MHC Tours
Group 1: USS (MCM) (LCDR Beaver, USN)
Group 2: USS (MHC) (Mr. Burleson)
1600 MCM/MHC Tours
Group 1: USS (MHC) (LCDR Beaver, USN)
Group 2: USS (MCM) (Mr. Burleson)
1700 HOTWASH
1730 Adjourn

Appendix F

Acronyms and Abbreviations

AA	antiair
AAV	amphibious assault vehicle
AAAV	advanced amphibious assault vehicle
AAW	antiair warfare
ABS	assault breaching system
ACTD	advanced concept technology demonstration
ADS	advanced deployable system
ALMDS	airborne laser mine detection system
AMCM	airborne mine countermeasures
AMDS	advanced mine detection system
AMNS	airborne mine neutralization system
AOR	area of responsibility
AOSS	Autonomous Off-Board Surveillance Sensor (program)
AP	antipersonnel (mine)
ARG	amphibious ready group
AROSS	airborne remote optical spotlight system
ASDS	advanced SEAL delivery system
ASN (RDA)	Assistant Secretary of the Navy for Research, Development, and Acquisition
ASTAMIDS	airborne standoff minefield detection system
ASUW	antisurface warfare
ASW	antisubmarine warfare
AT	antitank (mine)
ATD	advanced technology demonstration
ATF	amphibious task force
ATO	air tasking order

BEZ	beach exit zone
BLT	battalion landing team
C2	command and control
C4I	command, control, communications, computing, and intelligence
C4ISR	command, control, communications, computing, intelligence, surveillance, and reconnaissance
CAD/CAC	computer-aided detection/computer-aided classification
CAPTOR	encapsulated torpedo
CATF	commander, amphibious task force
CEP	circular error probable
CINC	commander in chief
CJTF	commander, joint task force
CLDG	closed-loop degaussing system
CLF	commander, landing force
CLZ	craft landing zone
CMC	Commandant of the Marine Corps
CMCO	countermine and counterobstacle
CMR	clandestine mine reconnaissance
CMR/CS	clandestine mine reconnaissance and countermeasures system
CMW	countermine warfare
CNO	Chief of Naval Operations
COBRA	coastal battlefield reconnaissance and analysis
COMNAVCENT	Commander, Navy Central Command
CONOPS	concept of operations
CONUS	continental United States
COTS	commercial off-the-shelf
CRD	capstone requirements document
CRW	continuous rod warhead
CVBG	carrier battle group
CVN	aircraft carrier, nuclear powered
CZ	craft zone
DADS	deployable autonomous distributed system
DARPA	Defense Advanced Research Projects Agency
DASN	deputy assistant secretary of the Navy
DBS	digital broadband sonar
DDG	guided missile destroyer
DET	distributed explosive technology
DRM	design reference mission
DST	Destructor (mine)

EN	enhanced neutralization
EOD	explosive ordnance disposal
EODMU	explosive ordnance disposal mobile unit
EOID	electro-optical identification
ESG	executive steering group
ESM	electronic support measure
FNC	future naval capability
FOC	full operational capability
FYDP	future year defense program
GCCS	global command and control system
GCCS(M)	global command and control system (maritime)
GCE	ground combat element
GOATS	generic ocean array technology system
GPS	Global Positioning System
GSORTS	GCCS status of operational readiness and training systems
HFS	high-frequency sonar
HWM	high-water mark
I&W	indications and warning
ICLZ	initial craft landing zone
ICWS	integrated combat weapon system
IDTL	interdeployment training cycle
IOC	initial operational capability
IR	infrared
ISLMM	improved submarine-launched mobile mine
ISR	intelligence, surveillance, and reconnaissance
IUSS	integrated underwater surveillance system
IWAR	integrated warfare architecture
JAG	Judge Advocate General
JCM	joint countermine
JCS	Joint Chiefs of Staff
JDAM	joint direct attack munition
JDAM-ER	joint direct attack munition, extended range
JFC	joint force commander
JLAN	joint littoral awareness network
JLOTS	joint logistics over the shore
JMCIS	joint maritime command information system
JOA	joint operational area
JSTARS	joint surveillance and target attack radar system

JTF	joint task force
L&R	launch and recovery
LCAC	landing craft, air-cushioned
LCS	line charge system
LDC	linear demolition charge
LDP	littoral penetration point
lidar	laser imaging detection and ranging
LIDAR	light detecting and ranging
LMRS	long-term mine reconnaissance system
LOD	line of departure
LOS	line of sight
LOTS	logistics over the shore
LPA	littoral penetration area
LPD	amphibious transport dock
LPH	amphibious assault ship with helicopter
LPI	low probability of intercept
LPP	littoral penetration point
LPS	littoral penetration site
LPZ	littoral penetration zone
LRS	littoral remote sensing
LSD	landing ship, dock
LSM	littoral sea mine
LSS	littoral surveillance system
M3	mainstreaming mine warfare implementation master plan
MADOM	magnetic acoustic detection of mines
MAGTF	Marine air-ground task force
CMAS	mission capability assessment system
MCCDC	Marine Corps Combat Development Command
MCIA	Marine Corps intelligence activity
MCM	mine countermeasures
MCS	mine control ship
MCWL	Marine Corps Warfighting Laboratory
MEB	Marine expeditionary brigade
MEDAL	mine warfare environmental decision aids library
MEF	Marine expeditionary force
METOC	meteorology and oceanography
MEU	Marine expeditionary unit
MHC	mine-hunting, coastal (ship)
MIFAC	mobile integrated command facility
MINWARCOM	Mine Warfare Command

MIREM	mine warfare readiness and effectiveness measurement (program)
MIWC	mine warfare commander
MMS	marine mammal system
MNS	mine neutralization system
MODS	mine/obstacle defeat system
MOP	magnetic orange pipe
MOU	memorandum of understanding
MPF	maritime prepositioning force
MSL	minesweeping launch
MWTC	Mine Warfare Training Center
NAVOCEANO	Naval Oceanographic Office
NAVSEA	Naval Sea Systems Command
MOMBO	nonmine, minelike bottom object
NSB	Naval Studies Board
NSFS	naval surface fire support
NSPG	Navy Strategic Planning Group
NSSN	(new) nuclear-powered attack submarine
NWDC	Naval Warfare Development Command
O&M	operations and maintenance
OASIS	organic airborne and surface influence sweep
OMFTS	Operational Maneuver From the Sea
ONR	Office of Naval Research
OPNAV	Office of the Chief of Naval Operations
ORD	operational requirements document
OSD	Office of the Secretary of Defense
OTH	over the horizon
PEO MUW	Program Executive Office for Mine and Undersea Warfare
PMAR	primary mission area requirement
POA&M	plan of action and milestones
PUMA	precision underwater mapping
R&D	research and development
RAMICS	rapid airborne mine clearance system
RDT&E	research, development, testing, and evaluation
RF	radio frequency
RLT	regimental landing team
RMA	reliability, maintainability, availability
RMS	remote mine-hunting system
ROE	rules of engagement

RSG	readiness support group
S&T	science and technology
SABRE	shallow water assault breaching
SAS	synthetic aperture sonar
SDV	SEAL delivery vehicle
SEAL	sea-air-land team
SHAREM	ship ASW readiness and effectiveness measurement (program)
SLEP	service life extension plan
SLMM	submarine-launched mobile mine
SLOC	sea line(s) of communication
SMCM	surface mine countermeasures
SORTS	ship's operational readiness training status
SPAWAR	Space and Naval Warfare Systems Command
SPIRNET	secret Internet Protocol router network
SSN	nuclear-powered attack submarine
STOM	Ship to Objective Maneuver
STOVL	short takeoff and vertical landing
SVP	sound velocity profile
SW	shallow water
SWATH	small waterplane area twin hull
SWDG	Surface Warfare Development Group
SZ	surf zone
TAD	theater air defense
TBMD	theater ballistic missile defense
TDD	target detection device
TEMP	test and evaluation master plan
TENCAP	tactical exploitation of national capabilities
TES	tactical exploitation system
TR	tilt rod
TRANSCOM	U.S. Transportation Command
TUAV	tactical unmanned aerial vehicle
UAV	unmanned aerial vehicle
UBA	underwater breathing apparatus
UMCM	undersea mine countermeasures
USMC	U.S. Marine Corps
UUV	unmanned undersea vehicle
VCNO	Vice Chief of Naval Operations
VDS	variable depth sonar

VEMS	versatile exercise mine system
VERTREP	vertical replenishment
VSTOL	vertical short takeoff and landing
VTOL	vertical takeoff and landing
VSW	very shallow water
WC-TMD	wind-corrected tactical munitions dispenser