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### **Executive Summary**

The motivation for this report had its origins in the mutual interests surrounding future non-lethal weapon science and technology (S&T) by the Joint Non-Lethal Weapons Directorate (JNLWD) and the Office of Naval Research (ONR). The Committee for an Assessment of Non-Lethal Weapons Science and Technology was asked to assess current and potential areas for S&T investment in non-lethal weapons (NLWs) to support naval expeditionary forces; it found several areas that deserve such investment. In reviewing the program of record for the JNLWD, as also directed by the terms of reference, the committee evaluated the spectrum of activities that turn S&T advances into fieldable and fielded systems. As it explored the many dimensions associated with the transition of NLWs from research and development (R&D) to the field, the committee uncovered a number of areas of concern in the current JNLWD and U.S. Navy efforts related to NLWs. These concerns must be addressed by the Joint Non-Lethal Weapons Directorate, the Navy Secretariat, and the Chief of Naval Operations—or the risk is high that added investments by ONR in non-lethal weapons R&D will be of little value.

#### **NON-LETHAL WEAPONS FOR NAVAL EXPEDITIONARY FORCES**

The potential for non-lethal weapons to help meet the overall demands on naval expeditionary forces in the 21st century is clear. As discussed in subsequent chapters, the experiences of the U.S. Marine Corps in the peacekeeping and urban engagement conflicts in the past decade and the challenges to the Navy in sanctions enforcement and port protection offer compelling case studies for the importance of having non-lethal weapons options. The Marines have assumed leadership for developing requirements for clearing facilities and incapacitating personnel via non-lethal means to meet the constraints of rules of engagement in mixed combatant/non-combatant environments.

The Navy's needs for non-lethal weapons options are emerging in several different areas. One of these developed in the aftermath of the USS *Cole* incident of October 2000: comprehensive assessments of force protection measures are starting to generate a notional three-layer architecture for ship protection—an outer zone for assessing and warning of approaching vehicles and personnel (pierside and outboard; above, on, and below the surface); a middle zone for initial engagement to turn away a threat if it is still approaching, at which point non-lethal means may offer the only reasonable alternative to deterring the threat; and a third, inner zone in which lethal force could be employed. In a second area, sanctions enforcement in the Persian Gulf has highlighted the challenges of intercepting and boarding suspect vessels in the midst of heavy commercial traffic and in the face of unknown crew makeup. Non-lethal weapons options could offer a valuable means for interdiction if needed in such environments. A third compelling area of need has been identified by the Chief of Naval Operations's (CNO's) Strategic Studies Group XVIII: that is, NLWs are needed to fully enable the Sea Strike concept by filling important gaps in the spectrum of effects-based targeting. A prime example would be engagements in littoral environments where urban centers are prevalent and minimization of collateral damage is required.

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After a decade of successful, but limited, operational experience with NLWs and 5 years of progress by the JNLWD—the directorate was established in 1996 to introduce non-lethal weapons more quickly in response to warfighting needs—the future of NLWs is at a crossroads. NLWs with limited capabilities for individual, highly localized self-defense or combatant isolation are available. Because countermeasures for these capabilities may not be difficult, the demand is growing for more capable systems with wider-ranging effects. The research, development, and acquisition of these more robust capabilities will be well beyond the scope of the current joint program and will have to be integrated into the normal development and acquisition cycle of each of the Services. At the present time, the Department of the Navy is not prepared to carry out these responsibilities.

### ADDRESSING THE TERMS OF REFERENCE

The terms of reference chartered the committee to take an extensive look at the area of non-lethal weapons and also asked for an assessment of the impact of prior studies and initiatives as well as an assessment of the capabilities that turn a promising non-lethal weapons technology into a viable operational system. Because the story is complex and the issues called out in the terms of reference are highly interdependent, pointers to key sections of the report addressing each aspect of the committee's charge are provided below for the reader's use.

- *Review and assessment of previous non-lethal weapons studies and initiatives.* Sections 1.1, 2.6, 2.7, 2.8, and 2.9 provide background on policy and directives, operational experience, programs and initiatives outside the Department of the Navy, and studies and conferences. Results accumulated since the establishment of the JNLWD in 1996 are highlighted.
- *Review of the JNLWD program of record.* Section 2.3 describes the directorate's short history, accomplishments, and current programs. The opening paragraphs of Chapter 3 and Section 3.1 discuss the committee's observations and findings based on its review of the current program. Its conclusions and recommendations for the JNLWD program are provided in Sections 4.1 and 5.1, respectively.
- *Review of Department of the Navy S&T programs that do, or might, contribute to the development of non-lethal weapons capabilities.* This issue presented the committee with a challenge. The U.S. Marine Corps has well-established and articulated needs for NLWs, but the Navy had not given much attention to their use until the aftermath of the USS *Cole* incident. As such, the committee spent some time studying the mission needs of the Navy in order to evaluate relevant S&T within the department. Those needs are described in Section 1.2, and current programs that are relevant to them are discussed in Sections 2.4 and 2.5. U.S. Marine Corps programs relevant to non-lethal weapons capabilities are described in Section 2.6. The committee's assessment of needs versus existing S&T programs led to the concerns expressed in its findings on the department's organizational interest (Section 3.4) and its related recommendation (Section 5.4).
- *Identification of technology developments that show promise for enhancing existing non-lethal weapons capabilities or for enabling new ones.* Responding to this task broadened the fact finding of the committee to include the means by which a promising technology is turned into an operational reality. In the process, the committee came to realize that sensor and platform capabilities had to be addressed hand in hand with non-lethal weapons technology development.

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These considerations are discussed in Sections 2.1, 3.2, 3.3, and 5.3. In looking beyond the technologies themselves, the committee also discovered the shortcomings in current understanding of non-lethal weapons effects and effectiveness. The impact of this issue on warfighter acceptance of NLWs as a useful and integral operational capability is so profound that the committee devoted two of its four recommendations to the issue. These topics are addressed in Sections 2.2, 3.1, 3.2, 3.3, Chapter 4, and Sections 5.1, and 5.2.

- *Identification of programs that duplicate efforts or could benefit from leveraging.* The committee found nothing that raised concerns regarding duplication of effort; the JNLWD has done a good job of ensuring that resources are wisely spent. The principal opportunities for leveraging are presented by sensors and platforms as critical system enablers; related observations and recommendations are provided in Sections 2.1, 3.2, and 5.3.
- *Recommendations for S&T program actions by ONR.* Section 5.3 recommends specific actions to strengthen S&T in four general areas. The recommendations include focused investment and expansion of current programs within ONR (e.g., high-power microwave), leveraging of relevant programs in sensors and platforms, and partnering with the Army for chemical non-lethal weapons development.

### STATUS OF NON-LETHAL WEAPONS TECHNOLOGIES: SYNOPSIS OF FINDINGS

The committee undertook a careful survey and assessment of non-lethal weapons technologies across a wide spectrum of phenomenologies—chemical and physical, to physiological and psychological. This survey included a number of classified programs as well as the areas discussed in this unclassified report. The committee identified several S&T areas worthy of ONR's attention:

1. Calmatives and malodorants for controlling crowds and clearing facilities, developed and applied in accordance with U.S. treaty obligations in the Chemical Weapons Convention;
2. Directed-energy systems beyond the vehicle-mounted active denial system (VMADS): high-power microwave (HPM) for stopping vehicles or vessels and solid-state lasers for advanced non-lethal weapons applications;
3. Novel and rapidly deployable marine barrier systems; and
4. Adaptation of unmanned or remotely piloted platforms and targeting/real-time battle damage assessment (BDA) sensors for non-lethal weapons applications.

The committee's review identified positive accomplishments during the past 5 years as well as areas of concern. The following advances are particularly noteworthy:

- *Joint Non-Lethal Weapons Directorate.* The JNLWD, with the U.S. Marine Corps serving as executive agent, was established in 1996. It has achieved noteworthy progress in spite of operating under the combined pressures of high visibility and very modest funding (\$20 million to \$30 million per year). Examples of its accomplishments include the qualification and transition to acquisition of non-lethal weapons capability sets for deployment by Marines and soldiers; the establishment, in principle, of the process and capabilities for assessing antipersonnel non-lethal weapons effects through the Human Effects Review Board and the

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Human Effects Center of Excellence; the recent maturing to demonstration of VMADS; and the validation of the first-ever non-lethal weapons joint mission area analysis (JMAA) by the Joint Requirements Oversight Council (JROC).

- *Operational experience.* NLWs have had limited operational use. Commanding officers who have used them, for example, in Somalia and in an ongoing operation such as Kosovo, have become highly vocal advocates—along with some who needed them but did not have them at the time.

- *Experiments and training.* Experiments at the U.S. Marine Corps Warfighting Laboratory have matured the concept of operations (CONOPS) for many individual tactical uses of NLWs, and joint training curricula at the U.S. Army's Fort Leonard Wood, Missouri, have been established.

- *Continued widespread interest and discussion.* A continuum of high-level studies and conferences has reinforced—indeed expanded—the roles in which NLWs could contribute.

- *Navy interest.* The Marine Corps has been the leading Service proponent for NLWs throughout the past decade. When this study began, Navy interest in NLWs was difficult to identify, but the findings and recommendations of the Antiterrorism/Force Protection Task Force led by the Office of the Chief of Naval Operations (OPNAV) N34 are building a strong case for NLWs as an important element for protecting ships in port.

Despite these advances and in spite of the expressed wishes of many commanders in chief and Service leaders, the following troublesome issues could preclude NLWs from becoming an integral force option:

- *Lack of new ideas.* The combined factors of high visibility and small budgets appropriately focused the JNLWD at its inception on relatively mature technologies. The most promising have moved, or are nearing transition, to acquisition and are finding interesting but limited application. Little investment has been made in new ideas requiring further research, with the result that the JNLWD now has little in the pipeline ready for development investment.

- *Little Service investment in R&D.* The Marine Corps and Army, as the primary initial sources for reallocation of funds to the JNLWD at its inception, have drawn down their own investments in R&D. Air Force investments for explicit non-lethal weapons research have always been low, although promising directed-energy concepts, funded principally for their lethal potential, have found cofunding from the directorate and other agencies for specific non-lethal weapons applications. Navy interest and actions regarding NLWs in compliance with the 1997 MOA had been very limited until recently. As a result, the Service pipelines are “dry” as well.

- *Perceived treaty constraints.* The program for chemical antimateriel and antipersonnel NLWs, after many years of Army R&D investment and the identification of a number of promising technologies, was canceled with the adoption of the Chemical Weapons Convention in the early 1990s. That program has not been started up again, in spite of legal interpretations of the treaty indicating that it does not preclude such work or the employment of such agents in specified and increasingly important military situations, such as civilian crowd control in peacekeeping or humanitarian relief operations.

- *Poor understanding of the effects and effectiveness of NLWs.* The effectiveness of NLWs is poorly understood in almost every dimension. While the process for assessing health and human effects has been established, as commended above, the funding levels and the overall

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philosophy leave much to be done in key areas, such as research into the fundamental biomechanical and physiological response mechanisms; translation of effects on individuals into effects on groups and/or effects associated with repeated exposure; development of effects models; and implementation of the models in experiments, testing, and wargaming environments. The parallel process for antimateriel NLWs, while somewhat easier to implement, is not formalized. Moreover, efforts to quantify military operational advantages and improvements in capabilities with NLWs, understanding of both U.S. vulnerabilities and enemy countermeasures to non-lethal weapons use, and development of a concept of operations (CONOPS) have been very limited. In addition, the warfighter must understand and be able to adapt to the inherently variable effects of NLWs—as a specific engagement unfolds, it is essential that the warrior have the ability to obtain and act on immediate feedback to be able to “dial an effect” for re-engagement should that prove necessary. **Well-characterized effects and effectiveness** are probably the most convincing means of gaining widespread acceptance and integration of NLWs into warfighting capabilities, yet such characterization is currently the weakest aspect of the overall non-lethal weapons program.

- *Lack of systems concepts.* Given that the effectiveness of non-lethal weapons options is not well understood, it comes as no surprise that systems concepts and assessments are generally immature. Complete systems concepts, including delivery vehicles and sensors for targeting and effects assessment (i.e., the non-lethal equivalent of BDA), are few. Logistics and maintenance considerations are limited to ensuring compatibility with whatever exists. Fully integrated lethal and non-lethal weapons capabilities remain to be assessed, although such force mixes are essential to implementing effects-based targeting.

- *Overhead for entering the normal acquisition process.* The JNLWD funding is largely budget category 6.3, that is, funding allocated for exploratory development. The directorate’s leadership has taken on the role of entering new concepts into the formal milestone acquisition process—which was designed to provide the scrutiny needed for large acquisitions but is ill-suited for the small levels of funding involved in JNLWD initiatives. Moreover, as a joint office, the directorate must work to find a Service partner for transition, a task that is made more difficult for the directorate because it is not part of the normal procurement planning cycle of any of the Services. On the other end, the “color” and total amount of JNLWD money make investment in research difficult. In short, following the normal Department of Defense (DOD) acquisition process does not serve the directorate, the Services, or DOD efficiently for a program that is so small and constrained yet is viewed as filling a much-needed role.

- *Organizational support within the Department of the Navy.* In contrast to the long-standing emphasis by the Marine Corps on expanding its non-lethal weapons capabilities, formal Navy interest, as evidenced by assessment, requirements, acquisition, or actions consistent with the 1997 MOA (see Box 1.1), has been practically nonexistent. Within OPNAV N757 only a single person has sole, and limited, responsibility for coordination of non-lethal weapons issues with the JNLWD. This approach has probably been adequate, given the focus to date on acquisition of individual warfighter tool kits, but it will not suffice as more complex and more capable non-lethal weapons systems (such as VMADS) mature. It will also not suffice for introducing NLWs as an integrated part of naval expeditionary force capabilities.

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### OVERALL CONCLUSIONS

Because of the range of effects introduced by NLWs, it is readily apparent that the issues associated with their development and use are more complex than issues associated with the development and use of their lethal counterparts. The committee agrees that, while progress since the establishment of the JNLWD has been laudable, important areas of concern remain. These concerns led the committee to the following conclusions:

- Without compelling new ideas, NLWs will remain a specialty item in the warfighter's tool kit and will never become the effective element of warfighting that countless studies and limited operational experience have affirmed NLWs can be.
- Without a different process for introducing new non-lethal weapons capabilities—one more integrated into each Service's normal development and acquisition cycle—the current scope of the program offers only a low probability of moving even the best ideas to the field in the future.
- Without a much stronger overall program to understand and characterize the effects and effectiveness of non-lethal weapons, commanders will remain reluctant to request or employ them.
- Without concepts for the use of non-lethal weapons, developers will not be successful in focusing ideas and programs.

In short, major changes in approach are needed to achieve the potential of NLWs for U.S. forces in general and naval forces in particular.

### RECOMMENDATIONS

In developing its recommendations, the committee recognized that the terms of reference for the study had been written prior to the USS *Cole* incident, yet the study was conducted in the post-*Cole* environment in which a more urgent need for non-lethal options emerged for the Navy. Moreover, the critical gap in the technical understanding of non-lethal effects added to the committee's concerns that "business as usual" would not allow important S&T ideas to make the transition to acquisition and deployment in a reasonable timeframe. The terms of reference directed the committee to review the JNLWD program of record. In doing so, the committee concluded that organizational as well as technical recommendations were required. While no formal analysis of organizational alternatives was made, the committee did consider and reject the extreme alternatives of the JNLWD being shut down and that of the JNLWD continuing on as it is, and accepted instead the alternative that the JNLWD needs to change its present focus.

The committee's recommendations are made in order that any S&T investment on the part of ONR will have a reasonable probability of successful transition to the warfighter. The recommendations identify a pragmatic approach (i.e., mindful of resource constraints), principally through significant shifts in the emphasis of the currently available resources to the JNLWD and the assumption of research, development, and acquisition (RDA) responsibilities by the Navy and Marine Corps. This section provides an overview of the committee's recommendations. Chapter 5 presents detailed recommendations for their implementation.

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***Joint Non-Lethal Weapons Directorate: As the Department of Defense's focal point for non-lethal weapons, the Joint Non-Lethal Weapons Directorate should focus its resources on stimulating and exploring new ideas, and on strengthening the DOD's ability to characterize the effects and effectiveness of non-lethal weapons.***

At this juncture in the maturing of the JNLWD, the committee recommends that the directorate declare success in its initial phase of meeting the demand for quickly fielded capabilities and, for the future, move to a new and more robust role that is much better aligned with its joint status. This next phase for the JNLWD should focus on two principal roles: (1) advocacy backed by funding and expertise to support joint experimentation, systems modeling and analysis, functional concept exploration programs, and advanced concept technology demonstrations (ACTDs), along with stimulating new ideas from the S&T community while the Services build up their own programs; and (2) establishing, maturing, and overseeing multiple centers of excellence (COEs) for the study of human and materiel effects. With the COEs to support it, the directorate should be assigned the role of independent assessor of any new non-lethal weapons concept, to affirm that effects are properly characterized and understood. This refocusing of the directorate away from non-lethal weapons development and toward a transition to acquisition roles would allow it to address the critical limiting factor for widespread integration of NLWs: namely, the lack of a clear understanding of the effects and effectiveness of NLWs.

In parallel with the refocusing of the JNLWD's roles, the Services must assume their full range of responsibilities for the research, development, and acquisition of non-lethal weapons systems to meet their own specific needs instead of continuing with the current process whereby the directorate awkwardly picks up interim steps at the 6.3 budget stage. Given that the Marine Corps has both the most mature understanding of, and experience with NLWs, and that the Navy is motivated by needed improvements in port protection and expanded strike capabilities, ONR should have ample justification to invest in non-lethal weapons R&D as a part of an overall transition within the Department of the Navy toward assuming end-to-end responsibilities for non-lethal weapons development, acquisition, and deployment.

Implementing these changes in roles and responsibilities across the JNLWD and the Services will require a revision to the Joint Service Memorandum of Agreement on Non-Lethal Weapons. The Office of the Secretary of Defense, the Joint Chiefs of Staff, and the Services, in addition to the JNLWD, will have to agree to the changes proposed above. Moreover, the Services' assumption of end-to-end development and acquisition responsibilities will require the commitment of their own resources (funding and personnel) to establish their in-house programs.

***Centers of Excellence: The Joint Non-Lethal Weapons Directorate should establish and sustain human and materiel effects-focused centers of excellence to support a "seal of approval" process for non-lethal weapons systems.***

The program dimension involving COEs should remain with the JNLWD, as noted above. It is emphasized here, regardless of the future direction and focus of the directorate, because the human effects issue is critical for expanded NLW use. The scope of the COEs should be comprehensive and should include responsibilities for the following:

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- Developing and implementing a focused research agenda to advance the state of fundamental understanding;
- Creating and sustaining effects databases, and identifying shortfalls in the knowledge base;
- Prioritizing and executing research to fill knowledge gaps;
- Developing, validating, and integrating effects models;
- Serving as a consultant to the development community to define test regimes and protocols for developmental systems and transition to acquisition; and
- Providing expertise to support JNLWD independent assessment function.

The directorate has recognized the utility of the COE approach with the establishment of the Human Effects Center of Excellence at Brooks Air Force Base, San Antonio, Texas. Additional COEs are needed, however, because of the unique expertise required to understand each of the effects associated with the wide variety of NLWs (e.g., blunt trauma with kinetic energy non-lethal weapons, penetration of skin and effects on the retina of the eye with millimeter and microwave radiation, chemical effects of calmatives and malodorants, effects of antimateriel NLWs, and so on). Research within or supported by each COE should encompass the determination of thresholds for permanent damage or injury. The committee estimates that about five or six COEs would be needed, each focused on a particular class of NLW, examples of which are noted above. Each COE should be funded initially by the JNLWD at a sustaining “foundation” level of a minimum of \$1.5 million per year to support the critical mass of expertise required to maintain the knowledge base, set the research agenda, and model fundamental effects. Service funding and cooperative funding should be developed at this initial stage.

Funding for the research agenda is not included in this foundation level, nor is funding to accomplish the integration and accreditation of models needed to support the seal of approval process. The JNLWD must develop a prioritized research agenda that integrates the agendas from the individual COEs, and it must then augment COE funding to support research priorities. After the initial stage, Service funding should bare the majority of the COE funding; however, the JNLWD must also augment COE funding to support integration and accreditation of effects models with DOD program managers funding system-specific models and tests.

***Science and Technology: In cooperation with the JNLWD and the other Services, ONR should invest in a richer portfolio of NLW-specific R&D activities in the areas of chemicals; directed energy; barriers and entanglements; underwater defensive systems; and platform, sensor, and command and control system enablers.***

Areas for ONR emphasis include HPM research and development as planned by the Naval Research Laboratory (NRL), barrier and entanglement deployment systems for stopping vessels, accelerated research on solid-state lasers for operational non-lethal weapons applications, weaponization of antimateriel chemical NLWs for use in stopping engines and as antipersonnel calmatives, and use of unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs), and unmanned underwater vehicles (UUVs) as delivery platforms. In the chemicals area, the committee recommends a strong partnership with the Army’s Edgewood Chemical and Biological Command (ECBC), which has expertise in and a history of screening chemicals for such applications. ONR should also support platform and sensor development to address the



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Navy's unique needs for remote deployment and effects assessment of non-lethal weapons technologies, for example in port underwater, surface, and air defense non-lethal weapons systems. Particularly stressing is the time line for the BDA equivalent function of effects assessment with non-lethal weapons systems, which places more stringent requirements on the sensor system(s) associated with their use.

A second specific recommendation concerns the VMADS, recently demonstrated as a potentially effective antipersonnel NLW and envisioned for mounting on a ground vehicle. Suggestions have been made within the Navy about its deployment shipboard for port protection, but the idea should be fully assessed within the Department of the Navy to establish the cost-effectiveness of such a system before development resources are committed. A final recommendation related to S&T is made to the JNLWD, which is currently supporting two chemical laser programs, the advanced tactical laser (ATL) and the pulsed-energy projectile (PEP). The evidence presented to the committee supporting claims of the viability of both these concepts for non-lethal weapons use was not convincing. The directorate is urged to reassess its investments in these programs.

***Department of the Navy: The Secretary of the Navy, the Chief of Naval Operations, and the Commandant of the Marine Corps should establish a senior-level working group to actively oversee the integration of non-lethal weapons into naval warfighting requirements, research and development programs, acquisition plans, and operations.***

Non-lethal weapons represent a new capability that must compete in a resource-constrained environment with traditional capabilities that already have well-established requirements and proponents. Without the attention of senior leadership for some period of time, integration of NLWs into the naval forces will most likely proceed at a glacial pace—or may never happen. The broad range of non-lethal weapons applications compounds the problem in that there are many potential candidates (and corresponding proponents) for maturation rather than a single logical one, so that in the end, no one “owns” (i.e., responsible for) the requirements and development process for the area.

The committee believes it is imperative that senior officials and officers within the Department of the Navy, acting on behalf of naval force (i.e., Navy and Marine Corps) requirements, become knowledgeable about and take responsibility for the development and integration of non-lethal weapons systems into naval mission readiness. The recommended mechanism is a working group chartered to develop a naval non-lethal weapons master plan for naval expeditionary forces. Such a plan should establish mechanisms to ensure that non-lethal weapons will become fully integrated into, and can compete fairly in, the requirement and development process for all naval systems.