

Recommendations

The committee's recommendations build on its findings and conclusions, calling for specific actions or activities by the Joint Non-Lethal Weapons Directorate, the U.S. Navy and/or the U.S. Marine Corps, and the Office of Naval Research. In making these recommendations, the committee is assuming that all parties acknowledge the potential of non-lethal weapons for supporting a wide range of operations envisioned for naval expeditionary forces. The recommendations have been carefully developed to focus primarily on shifts in emphasis within each of the organizations noted, as opposed to calling for the commitment of more resources, at least at this time.

5.1 JOINT NON-LETHAL WEAPONS DIRECTORATE

Recommendation: 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.

The committee believes that the future impact of the JNLWD will be considerably enhanced if the JNLWD's mission space is narrowed to two core missions and the investment in each is significantly increased. The core missions recommended for the JNLWD are to speed transformation of NLWs from specialty status to that of fully integrated warfighting options through strong advocacy and to increase confidence in non-lethal weapons options by expanding DOD's understanding of the effects of NLWs on humans and materiel. These are not new missions for the JNLWD, but success, as envisioned by the committee, will require significantly stronger programs in each area.

Implicit in this recommendation is the transition of non-lethal weapons system development and acquisition responsibilities to the Services. The committee believes this is the appropriate next step toward full acceptance by the Services, when NLWs will have become a valued option for the warfighter and the JNLWD will no longer be needed to advocate their development and operational use. Institutionalizing this recommendation, which would result in changes in roles and responsibilities among the JNLWD and the Services, will require a revision to the Joint Service Memorandum of Agreement on Non-Lethal Weapons. As such, OSD/JCS, the JNLWD, and the Services will need to agree to the changes proposed above. Moreover, the assumption of end-to-end development and acquisition responsibilities by each Service will require their own commitment of resources (funding and personnel) to establish their in-house programs.

In its role as DOD focal point for non-lethal weapons, the JNLWD should aggressively stimulate and explore new ideas. The committee recommends that the JNLWD build a significantly more robust outreach and exploratory investment program, to include partnerships with DARPA, U.S. government laboratories and law enforcement communities, and allies, as well as frequent interactions with the industrial base in which the directorate reiterates its requirements for potential developers. Sponsorship of and/or active participation in conferences, publications, and meetings should be a priority. During the transition of full RDA responsibilities to the Services, the JNLWD should help stimulate individual Service investments through cofunding of mutually interesting concepts or should be the sole investor, as needed, to advance novel ideas. The directorate should also seek out groups such as the JASONS¹ in helping to identify new concepts for NLWs. The JNLWD should build a diverse collection of operational scenarios in which NLWs could provide viable options to a commander, and it should communicate these scenarios to various audiences in an effort to stimulate new ideas in which it could then invest exploratory funding.

The JNLWD should also seek to stimulate the Services' requirements process by advocating and funding functional concept assessment and ongoing experimentation. The directorate should identify partners within the Services as early as possible and should nurture such partnerships through cofunding of experimentation. Non-lethal weapons concepts should be explored through wargaming, ACTDs (e.g., MOUT and protection of ships in port), and joint and Service experimentation (e.g., fleet battle experiments, expeditionary force experiments, advanced warfighting experiments). The JNLWD should maintain the joint mission area analysis and should increase its investment in systems analyses, with particular focus on functional concept development (e.g., area denial, crowd control). As new non-lethal weapons systems concepts emerge,

¹JASON 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.

the JNLWD should partner with one or more of the Services to share in the cost of the system-specific concept exploration program. This partnership sets the stage for subsequent Service ownership—and funding—of the development and acquisition processes.

The committee believes that characterization of the effects of NLWs remains the make-or-break item that will determine their acceptance by policy-makers and subsequent operational employment by commanders. Achieving a robust understanding of the full range of physiological, biomechanical, and psychological effects on humans will require a substantial and sustained investment. The challenge is compounded by the diverse range of phenomenologies for NLWs, as well as by the fact that materiel effects must also be characterized. The committee therefore recommends that effects characterization be the second core mission for the JNLWD and that the program be significantly expanded in this area.

The ultimate goal of effects characterization is to build the necessary knowledge base and modeling capabilities to position the JNLWD to provide a “seal of approval” for specific non-lethal weapons systems. The seal of approval would indicate that the effects are well understood and documented, so that rules of engagement could be clearly defined. As the ability to characterize effects matures, the committee envisions that this “seal of approval” process, initially established and implemented by the JNLWD, will migrate to an appropriately augmented test and evaluation community.

The committee recommends that the center-of-excellence construct continue to be used by the JNLWD to build the knowledge base and models required for effects characterization. Because of the diverse scientific disciplines involved, however, the committee believes that a more viable approach is to establish multiple COEs, each focused on a specific non-lethal weapon effect and centered on the requisite base of scientific expertise. The committee estimates that about five or six COEs (e.g., for blunt trauma, directed energy, chemical effects, and so on) would be needed to cover the range of human effects, but it recommends that the JNLWD determine the number and optimal location of each COE after a more comprehensive assessment and consultation with the Human Effects Advisory Panel. The committee also recommends that one or more COEs be devoted to supporting the characterization of materiel effects. Specific responsibilities of individual COEs are defined in the next recommendation, in Section 5.2. The JNLWD will play a crucial role in establishing and managing the COEs and in ensuring that their individual contributions are effectively integrated to build characterization capabilities for the desired system-level effects. It is envisioned, however, that the need for oversight by the JNLWD will eventually be replaced by the Services’ direct engagement with the COEs under the sponsorship of the operational test and evaluation community.

The committee recommends that the JNLWD take immediate steps to strengthen the two core missions described above while gradually transitioning their development and acquisition programs to the Services. Developmental programs should be

transferred at a mutually agreed time, but within the next 3 years. Seamless transition of these programs is vital to their continued advancement.

During FY02, the JNLWD should continue its advocacy efforts and should build expanded out-year programs to support exploratory investments and increased experimentation. The directorate should also determine which COEs are required to support the JNLWD's core mission of effects characterization, develop a baseline reflecting the current state of understanding in each area, identify centers of technical expertise, and initiate negotiations to establish COEs. During FY03, the JNLWD should have agreements in place with the COEs and should task them to begin building knowledge bases, catalog existing effects models, and define research agendas. In FY04, the JNLWD should substantially ramp up its investment in effects-related research.

The committee notes that the JNLWD will require at least its current level of funding to adequately support the two core missions at the scope described above. If the directorate's budget is reduced as responsibilities for system development and acquisition transition to the Services, it is unlikely that NLWs will achieve their envisioned potential as either an option for warfighting or for operations other than warfare. Of equal importance is the staffing of the directorate to best fit this new advocacy and effects-based focus. Most of the talent in the directorate today is well suited to its current roles in development and transition to acquisition. The future focus of the directorate will require expertise in the areas of modeling and simulation, biological and materiel effects, and, to a limited extent, science and technology for the assessment of new concepts.

5.2 CENTERS OF EXCELLENCE

Recommendation: 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 ultimate goal of a center of excellence is to build and maintain the intellectual foundation required to characterize the effects of non-lethal weapons technologies to the extent that policy makers and commanders can be confident of NLWs' viability in operational engagements. A robust understanding of effects is key to establishing policy, rules of engagement, and doctrine for NLWs. Without such understanding, non-lethal weapons options will not be fully exploited. Essential features for a center of excellence are these:

- Key personnel whose relevant technical expertise is widely recognized among their professional colleagues, whose reputations attract top talent to the COE, and whose credibility builds confidence in NLWs among policy makers and commanders;
- Laboratories and computational facilities necessary to support ongoing research, experimentation, and testing to advance the state of the art continually; and

- Synergistic partnerships with other pockets of relevant technical expertise so that the COE fully leverages work done elsewhere.

Each COE should be established with an entity having the features described above, regardless of whether it is affiliated with a government laboratory, an academic institution, or private industry. If the organization is outside the government, it is imperative that the parent organization (and key personnel) be willing to commit to a long-term relationship in support of DOD's national security mission. The committee recommends that bidirectional rotational assignments (COE personnel on temporary assignment to the JNLWD and JNLWD personnel temporarily assigned to the COE) be used to help build mutual understanding and to strengthen the working relationship.

Responsibilities of a center of excellence include these:

- Continual advancement of the state of the art in understanding effects through maintenance and execution of a focused research agenda; research may be accomplished by partners as well as by COE personnel;
- Provision of grants to medical schools and teaching hospitals for supportive research;
- Support for exploration of non-lethal weapons concepts through maintenance of a knowledge base that captures and catalogs all relevant research together with lessons learned from prior experimentation; meta-data and databases must be readily accessible and easily searchable by JNLWD and Services personnel;
- Support for experimentation with non-lethal weapons technologies through the development, validation, integration, and maintenance of models that enable effects characterization; models must be available throughout DOD; and
- Support for the seal-of-approval process for NLWs by defining effects test regimes—and, if necessary, executing tests—for developmental systems.

Because the current baseline of understanding of effects varies considerably by discipline, the size and character of each COE would also vary. Once the JNLWD has identified the desired location for a COE, the program and milestones must be established to fulfill the responsibilities delineated above. Each COE must be funded initially by the JNLWD at a sustained "foundation" level for executing core responsibilities, which include development and maintenance of the knowledge base, development of effects models, and definition of the research agenda. Service interest and cooperative funding should be developed at this initial stage. While specific amounts of funding would vary because of the relative maturity of understanding of the specific effects, the committee estimates that each COE would require a minimum of \$1.5 million per year to support these core responsibilities.

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 bear 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.

The committee noted that examples of highly productive COEs exist in other programs and agencies, and it recommends that the JNLWD visit several to identify relevant best practices to help strengthen the directorate's own COE management processes.

5.3 SCIENCE AND TECHNOLOGY

Recommendation: In cooperation with the JNLWD and 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.

While the committee identified a number of activities within ONR's portfolio and elsewhere that could contribute to more capable non-lethal weapons systems, it found little that was specifically aimed at NLWs, especially in the areas identified by the committee as most important for meeting the needs of naval expeditionary forces. At the same time, the committee found activities that it recommends that the JNLWD stop or redirect.

Chemicals

Chemical non-lethal weapons development has all but stopped since the adoption of the Chemical Weapons Convention, yet there are compelling applications in engine stopping and crowd control that cannot be achieved by other means. The Army's laboratories at Edgewood Chemical and Biological Command (ECBC) remain the center of expertise in development, characterization, and testing of chemicals for military uses. ECBC's charter does not extend to "weaponizing" such chemicals, since its principal focus is on developing countermeasures and defenses to adversaries' use of chemical and biological weapons. It is in this area that ONR and its research community can play a strong role—namely, in developing the non-lethal weapon system to include effective means of stabilization and encapsulation, delivery and dispersion, and real-time sensing and control to ensure that employment of the weapon remains within safe limits and that the desired effects are achieved. A partnership between ECBC and ONR could be very powerful for developing viable chemical antipersonnel NLWs well within the bounds of U.S. treaty obligations. That partnership should also be extended to the development of antimateriel NLWs. ECBC has a history

in that area, as well. NRL has given some consideration to the development of engine cloggers, estimating a cost of about \$5 million over 5 years.²

Because of the political sensitivities associated with antipersonnel chemical NLWs, the elements of the research program must be carefully chosen and structured to comply not only with national and international law and treaties, but also with national policy. The committee recommends the following steps:

1. *Identify opportunities for potential applications of malodorants.* The use of malodorants has potential for crowd control, facilities clearing, and area denial. Cultural variations in susceptibilities, health effects, and behavioral responses require study. Concern is expressed about the persistence of malodorants, especially if U.S. forces need to occupy an area immediately after use. Thus, accompanying neutralization or controlled decay of malodorants will also have to be studied. Analogous to techniques of chemical switching commonly used in the biochemical and chemical imaging fields, it may be possible to synthesize malodorants that can have their odor functionality chemically switched off.

2. *Increase research in the field of human response to calmatives.* Calmatives have potential as NLWs in many types of missions where calming of individuals or crowds is needed. As discussed in Section 2.1, prior research had been aimed at understanding margins of safety between loss of consciousness and death, whereas in crowd and riot control situations, the goal is to ensure a wide margin of safety between quieting and unconsciousness. The human effects of these compounds and their safety must have thorough evaluation under conditions simulating their mission uses.

3. *Target efforts to develop chemical delivery systems.* Although a number of promising chemical non-lethal weapons technologies exist, most of them lack a suitable delivery system. Few reliable, low-risk, and low-cost methods exist for delivering and dispensing chemical NLWs precisely and accurately. This capability is important for delivering antimateriel NLWs to the air intake of an engine, for example, where novel platforms such as robotic or micro-UAVs may be the only solution. It becomes critical in the delivery of calmatives, where proper doses must be achieved. Sensor systems may be able to enhance the potential for many chemical NLWs if they can help achieve accurate delivery on target at the proper dose levels. Special packaging techniques such as microencapsulation should be explored because they may be useful in creating new, more deliverable forms of chemical NLWs.

Directed Energy

The recommended actions for directed-energy NLWs touch numerous organizations because of the various stages of development around the technologies

²Mowrey, Robert, "Material Failure/Additives to Fluids," briefing to the committee on March 7, 2000, Naval Research Laboratory, Washington, D.C.

assessed: (1) VMADS adapted to naval force protection needs should be assessed by the Office of the Chief of Naval Operations, Warfare Integration and Assessment Division (N70) and/or the Assessment Division (N81); (2) ONR, through NRL, should complete work started on high-power microwave for non-lethal weapons applications and transition it to development and acquisition if it is promising; and (3) the JNLWD should reassess its commitment to ATL and PEP.

1. *VMADS, adapted to naval force protection needs, should be assessed by N70 and/or N81.* VMADS has emerged as a candidate for ship-based port protection. The committee urges N70, in partnership with N81, to undertake a careful assessment of the potential cost-effectiveness of VMADS, given the number of unknowns that still exist in weaponizing the concept. The current version of the VMADS prototype has long warm-up times and its mobility is limited. In addition, a more thorough assessment of its health effects, its effectiveness if used against uncooperative crowds, and the ease with which it might be countered is essential before a commitment to development and acquisition should be made.

2. *ONR, through the Naval Research Laboratory, should complete work started on the high-power microwave for non-lethal weapons applications and transition it to development and acquisition if it is promising.* Excellent work is underway at NRL in coming to understand the mechanisms of interaction of HPM with important targets for defensive purposes. Although the uses of HPM have been studied for some time, nearly all of the work has been demonstrations of an effect, with little effort to determine the mechanisms of disruption or damage. A careful analysis of these disruption mechanisms will lead to improvements and robustness in HPM systems of interest for naval non-lethal weapons applications. The NRL program is structured in a more scientific and systematic manner than any the committee has seen, and it shows considerable promise for producing results that will either clearly pave the way for non-lethal weapon development or stop further investment.

3. *The JNLWD should reassess its commitment to ATL and PEP.* Although there is the potential for aircraft-based high-energy laser (HEL) systems to deliver rheostatically controlled fluence to precisely selected targets, many of the enabling technologies lack maturity. One such area is precision pointing. Techniques and algorithms that can operate in the presence of atmospheric turbulence and aircraft vibration have not been identified. Another technology area of concern is the laser system itself. Currently proposed systems are based on chemical laser technology such as COIL. This choice of laser system suffers limitations of high atmospheric absorption and logistic difficulties associated with its chemical fuels. The committee recommends that research and development of these systems be conducted in existing HEL weapons programs, such as the airborne laser (ABL) or the theater high-energy laser (THEL), within the Air Force research community. As the enabling technologies mature, pursuit of them

as non-lethal weapons applications may be appropriate, but in and of itself, ATL does not yet offer a convincing case as a cost-effective NLW system.

The development of PEP is at a very early stage. It requires critical analysis and review of both technology and human effects before its development proceeds. The committee urges the JNLWD to undertake an independent review across the entire scope of the PEP program to better understand the required and prioritized investment approach, if indeed the review board endorses the development of PEP for non-lethal weapons purposes.

While chemical lasers do not yet hold much promise for non-lethal weapons applications, solid-state lasers may. Little effort has been made to assess and develop solid-state lasers for the non-lethal weapons applications at which ATL and PEP are directed. A modest investment to gain an understanding of the viability and scope of NLWs based on solid-state lasers is warranted, and the results of that effort should be used to provide the focus for NLW-related solid-state laser research.

Barriers

On the basis of initial results with systems such as the running gear entanglement system, the committee recommends that ONR explore novel and quickly deployable marine barrier systems relevant to stopping larger ships and/or protecting ports—objectives encountered uniquely by the Navy.

Platforms and Sensors

Even more generally than described for weaponizing chemical NLWs, ONR should address the unique *system* needs of NLWs in platform and sensor development. Particular areas of emphasis are recommended as follows:

1. *Accelerate technology programs that explore the creative use of remotely piloted and robotic vehicles to deliver NLWs.* Considerable research in robotic and remote precision delivery of lethal weapons systems is well underway in many agencies. Small UAVs, UUVs, and remote-controlled surface (water) vehicles offer attractive ways to deliver NLWs at large standoff distances with greater accuracy. They also permit remote sensing with a variety of sensor types to ensure effective employment of the NLWs. Additionally, remotely piloted vehicles can achieve and sustain higher speed and acceleration and may have a greater ability to follow a rapidly moving target (such as a speeding boat) than a humanly operated vehicle. These low-cost and flexible delivery systems (such as Roboski, and low-cost UAVs such as LEWK) have the potential to greatly expand and enhance the effectiveness of NLWs. The committee does not recommend new or unique platform programs for NLWs, but, instead, it recommends creative addendums to modify and test existing small, remotely operated or robotic platforms as carriers for NLWs and their sensor systems.

2. *Expand efforts to develop, improve, and better utilize existing sensor technologies for non-lethal weapons applications.* Because NLWs generally have a more limited effective range than their lethal counterparts, the successful use of NLWs depends more critically on the ability to selectively and accurately hit a target. Sensors will play a critical role in determining the success of missions using NLWs. Remote sensors are especially important for these missions for gathering intelligence, identifying intruders both on land and in the water, identifying potential targets and their intent, precision targeting, and determining battle damage. In addition, remote sensors can measure, in real time, the intensity of the non-lethal munition's effect at the target and can send this information back to adjust, for example, power levels or chemical agent concentrations to obtain the desired level of effect. Much work has been done on relevant sensor technology, much of it sponsored by DOD. Low-cost, expendable sensors that measure and report RF levels, chemical concentrations, explosives, or sounds, and that could be dispensed from small, low-flying UAVs would be especially useful for many types of non-lethal weapons missions. Remote sensors suitable for robotic marine vehicles and underwater sensors to detect and target swimmers are important for missions of in-port ship protection. The committee does not recommend the independent development of new sensors, but recommends instead the identification of promising sensor programs in DOD, accompanied by creative adaptation and testing of such sensors for the tailored needs of non-lethal weapons systems.

3. *Investigate acoustic detectors and sources for use in underwater NLW systems.* Underwater applications present a potentially more promising scenario, however, due to the increased coupling of acoustic energy. Past investigations have considered the use of ship sonar against underwater threats. Also being investigated are underwater acoustic sources as warning or non-lethal options against such threats. Unknowns include environmental effects on fish and marine mammals.

5.4 DEPARTMENT OF THE NAVY

Recommendation: 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.

NLWs are shifting from limited, specialized use status to operational priority for the Marine Corps in both conventional and OOTW scenarios, and they are emerging as important for both defensive and offensive missions in the Navy. If not given senior-level attention, by both the Navy and Marine Corps however—at least for some period of time—NLWs may never receive the assessment and commitment needed to enter the development and acquisition process to meet

naval needs. As the newcomer competing for resources against more traditional areas, coupled with the last few years' reliance on the JNLWD to "just take care of it," NLWs may otherwise never be fully integrated into naval force capabilities. The broad range of non-lethal weapons naval applications further compounds the problem by having many versus a single logical proponent for maturation, so that no one really "owns" the area.

The committee believes it is imperative that senior officials 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. This requires that those with assigned responsibility for operational implementation of weapons systems, as well as for R&D, gain an appreciation of the applicability of NLWs across the entire spectrum of naval conflict from both an offensive and a defensive perspective. This can be accomplished only through active participation in a process that engages senior naval officers' personal attention. A senior working group that meets on a scheduled basis would facilitate all aspects of support for non-lethal weapons systems. Specifically, the committee believes the working group must develop a naval non-lethal weapons master plan for naval expeditionary forces.

The committee recommends that the overall structure and membership of the working group be established jointly among the Secretary of the Navy, the Chief of Naval Operations, and the Commandant of the Marine Corps and coordinate its efforts with the IPT process of the JNLWD. Significant involvement by N70 would be expected because of its role as honest broker and integrator, but other elements should be active participants. Subgroups to address Navy- and Marine-specific needs may be warranted, but an integrated naval plan should remain the end goal. This working group should have liaison with warfighting CINCs for their input on requirements.

To accomplish this task the working group should do the following:

- Become knowledgeable about the advancing technologies associated with NLWs;
- Understand the operational capabilities of NLWs;
- Understand offensive and defensive vulnerabilities of non-lethal weapons systems and infrastructure critical to NLWs;
- Accelerate the creation of formal requirements documents for non-lethal weapons systems;
- Ensure that adequate funding is available to support development, testing, and fielding of NLWs;
- Ensure that non-lethal weapons technologies are integrated into full weapons systems, including sensors, delivery mechanisms, and combat assessment capabilities;
- Be knowledgeable about effects data generated by the centers of excellence and of the efforts in other Services;

- Be able to articulate publicly the technological, operational, and policy issues associated with NLWs;
- Incorporate NLWs into high-level wargames, simulations, and studies;
- Create a mechanism to ensure that NLWs will become fully integrated into, and can compete fairly in, the requirements and development processes for all naval systems; and
- Publish the master plan to include lead organizational roles and responsibilities and insertion of NLWs into the future naval capabilities process.