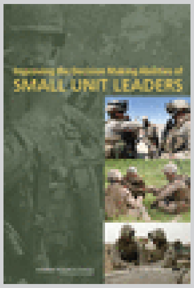

Improving the Decision Making Abilities of Small Unit Leaders

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Naval Studies Board

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Preface

In 2008, the Commandant of the Marine Corps, General James T. Conway, outlined the concept for enhanced company operations (ECO).[1] In that concept he stated:

> Conventional wisdom tells us that the battalion is the smallest tactical formation capable of sustained independent operations; current operations tell us it is the company. *Enhanced Company Operations* recognizes this operational reality and seeks to promote research, lively debate and, most of all, institutionalized training, manning, and equipping initiatives that will enable the company commander to take it to the next level.

The implementation of this concept demands that small unit leaders at the company, platoon, and squad levels[2] make more numerous and more complex decisions than are required of them in conventional warfare. Then Commanding General of the Marine Corps Combat Development Command (MCCDC), LtGen George J. Flynn, recognized this additional demand on small unit leaders and requested that the National Research Council (NRC), under the auspices of its Naval Studies Board (NSB), undertake a comprehensive study on improving the decision making abilities of small unit leaders in conducting ECO. The study that follows is the result of that request.

[1]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *A Concept for Enhanced Company Operations,* Department of the Navy, Washington, D.C., August 28.

[2]The typical size and organization of these small units are illustrated in Appendix D.

TERMS OF REFERENCE

In a letter dated January 22, 2010, to Dr. Miriam E. John, chair of the NSB, LtGen George J. Flynn, Commanding General, Marine Corps Combat Development Command, requested that the NRC conduct a comprehensive study on decision making abilities of small unit leaders in conducting ECO.

Accordingly, in August 2010, the NRC, under the auspices of its NSB, established the Committee on Improving the Decision Making Abilities of Small Unit Leaders.[3] The study's terms of reference, formulated by the staff at MCCDC and the Office of Naval Research in consultation with the chair and the director of the NSB, charge the committee to produce one report during a 12-month period. During the 12-month period, the committee met to gather information, deliberate about critical issues, and prepare its report in accordance with NRC procedures. Specifically, the charge to the committee was as follows:

- Examine the operational environment, existing abilities, and gaps (to include data, technology, skill sets, training, measures of effectiveness, etc.) for small unit leaders in conducting ECO in hybrid engagement, complex environments.
- Identify the operational and technical challenges for improving the decision making abilities of small unit leaders in conducting ECO in hybrid engagement, complex environments (including Department of the Navy science and technology efforts that might be leveraged, as well as relevant academic [activities], and other military Services', defense agencies', and/or other government activities).
- Survey and determine how the various approaches to decision making found in the literature (e.g., rational actor, heuristic, expert, norm-based, sense-making, naturalistic/recognition primed decision making) can be used to screen and improve the decision making abilities of small unit leaders in conducting ECO in hybrid engagement, complex environments, as well as to understand the decision making calculus and indicators of adversaries.
- Recommend operational and technical approaches—combined and separate—for improving the decision making abilities of small unit leaders in conducting ECO in hybrid engagement, complex environments (including any acquisition and experimentation efforts that can be undertaken by the Marine Corps and/or by other stakeholders aimed specifically at improving the decision making of small unit leaders).

THE COMMITTEE'S APPROACH

For the purposes of this report, the committee chose to examine, in part, the operational environment for small unit leaders in Iraq and Afghanistan so as to gain a better understanding of the scope of decisions required by these leaders vis-à-vis the term "ECO in hybrid engagement, complex environments" used throughout the terms of reference.

[3] Biographies of the committee members are provided in Appendix A.

The committee was first convened in August 2010. It held numerous meetings and conducted site visits over a period of 6 months, both to gather input from the relevant communities and to discuss its findings and recommendations.[4] The meetings consisted of a combination of presentations from outside experts and discussion among the committee members.

In some areas, the committee was limited in its deliberations by both the time available and the nature of the expertise required. Specifically, the committee did not investigate in detail the small unit leader selection process in the Marine Corps, believing that it did not have the expertise to do so, not to mention that such an investigation would involve a separate, comprehensive study in itself. In addition, the defense industry has a number of initiatives underway for developing and marketing various training systems, tactical decision games, and decision aids that were not accessible to the committee; here the committee chose not to recommend any specific technology or device for adoption.

The committee hosted a panel of small unit leaders from the Basic School to hear their recent operational experiences and their ideas on how to improve the preparation of small unit leaders to make decisions. In this regard, the committee recognized a need for additional input from experienced small unit leaders, and so it solicited the cooperation of MCCDC in arranging a series of interviews with veterans of Iraq and Afghanistan in order to develop a better understanding of the environment and the scope of decisions required of these leaders. A few members of the committee skilled in conducting such interviews used an interview protocol to conduct the interviews.[5] The committee recognizes that the interviews were not a systematic sample of the population of small unit leaders but rather that the information related by the interviewees could be used as a way to make the committee aware of the operational environment and the scope of decisions required of small unit leaders in general.

The committee also visited Marine Corps Base Camp Pendleton, California, to observe a Joint Capability Technology Demonstration known as the Future Immersive Training Environment, or FITE. This experiment involved the Infantry Immersion Trainer, a facility designed to help Marine Corps infantry squads prepare for deployment to Afghanistan.

The committee had a report-drafting meeting in early 2011 at the Arnold and Mabel Beckman Center of the National Academies, at which it prepared the body of the report and the recommendations. The months between the committee's last meeting and the publication of the report were spent preparing the draft manuscript, gathering additional information, reviewing and responding to the external review comments, editing the report, and conducting the security review needed to produce an unclassified report.

[4] A summary of the committee meetings and site visits is presented in Appendix B.
[5] The interview protocol is summarized in Appendix E.

The committee co-chairs would like to thank the staff of the Marine Corps Combat Development Command and the staff of the Naval Studies Board for their enthusiastic cooperation, and the members of the committee for their time, dedication, and wisdom.

Robert L. Popp, *Co-Chair*
Michael J. Williams, *Co-Chair*
Committee on Improving the
Decision Making Abilities of
Small Unit Leaders

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 Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its 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:

Richard J. Genik III, Wayne State University School of Medicine,
John R. Gersh, Johns Hopkins University, Applied Physics Laboratory,
Steven M. Jones, MITRE Corporation,
Edward H. Kaplan, Yale School of Management,
Douglas L. Medin, Northwestern University,
Marc Raibert, Boston Dynamics,
Ann E. Speed, Sandia National Laboratories, and
Paul K. Van Riper, LtGen, USMC (Ret.), Williamsburg, Va.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Harry W. Jenkins, Jr., MajGen, USMC (Ret.), Gainesville, Va., and Maxine L. Savitz, Los Angeles, Calif. Appointed by the National

Research Council, they were 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 entirely with the authoring committee and the institution.

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APPENDIXES

Summary

For the past decade, the U.S. Marine Corps and its sister services have been engaged in what has been termed "hybrid warfare"—a blurring of distinct categories of warfare across the spectrum, from active combat to civilian support.[1] Military engagements in hybrid warfare occur in complex environments in which conflict involves "states or nonstate actors [that] exploit all modes of war simultaneously by using advanced conventional weapons, irregular tactics, terrorism, disruptive technologies and criminality to destabilize an existing order."[2] Uncertainty and rapidly changing conditions and missions typify these struggles. Although they are by no means unique to today's operations, the pace of change and inability to assess and predict in a timely manner the situations that Marines will face have intensified. Moreover, facing an agile, adaptive enemy means that Marines themselves must continually observe, learn, and adapt if they are to succeed.

The Marine Corps has also been engaged in what are termed "distributed operations" for the past several decades. Distributed operations are practiced by general-purpose Marine Corps forces composed of small and "highly capable units spread across a large area of operations," operating with deliberate dispersion while separated beyond the limits of mutual support.[3] This type of operation

[1]U.S. Government Accountability Office. 2010. *Hybrid Warfare,* GAO-10-1036R, Washington, D.C., September 10.

[2]Robert Wilkie. 2009. "Hybrid Warfare: Something Old, Not Something New," *Air and Space Power Journal* XXIII(4):14.

[3]Gen Michael W. Hagee, USMC, Commandant of the Marine Corps. 2005. *A Concept for Distributed Operations*, Headquarters Marine Corps, Washington, D.C., April 25.

requires decentralized yet coordinated decision making at the small unit level[4] to project a "wider, more diverse application of power and influence" [5] in order to create an advantage over an enemy. Distributed operations rely on the "ability and judgment of Marines at every level" and are made possible by the decision making abilities of small unit leaders.[6]

Enhanced company operations (ECO) build on distributed operations as an "operational art that maximizes the tactical flexibility offered by true decentralized mission accomplishment . . . and facilitated by improved command and control, intelligence, logistics, and fires capabilities."[7] As with distributed operations, decision making at the level of the small unit leader is a critical component of ECO within hybrid warfare.

These evolving warfare concepts have dramatically changed the performance expectations of small unit leaders. Because of the considerable size of the areas of operations assigned to small units and the need to respond quickly to an agile and adaptive adversary, small unit leaders—company, platoon, and squad leaders—now frequently find themselves isolated in both space and time, with little ability to reach back to higher headquarters for timely guidance or expert assistance. Because of the need for small units to operate semiautonomously over long periods of time, their responsibilities typically go far beyond what has been traditionally expected of a small unit tightly integrated into a larger-sized organization and may include the coordination of supporting arms, logistics planning, intelligence interpretation, and even civil affairs.

The complex environments in which Marines have had to operate have also added the demand that small unit leaders possess skills heretofore not considered critical to the traditional expeditionary warfare mission of the Marine Corps. A significant component of today's engagements is aimed at "winning the hearts and minds"[8] of the local populace and thereby denying sanctuary for the adversary. This component calls on capabilities including the following: understanding and empathizing with different cultures, understanding the explicit and implicit political landscape and interests of different factions, negotiating with local leaders, and coordinating operations with other agencies, coalition forces, and nongov-

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[4]For the purposes of this report, the term "small units" refers to companies, platoons, and squads (which includes teams). See Appendix D for the typical size and organization of these small units.

[5]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, p. 32.

[6]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, p. 32.

[7]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *A Concept for Enhanced Company Operations*, Headquarters Marine Corps, Washington, D.C., August 28, p. 2.

[8]The committee is aware that the idea of operations to win the hearts and minds of indigenous populations is not a new concept. The phrase was first used by the British Army during the Malayan Emergency in 1948, but the concept has been with us since the time of Alexander. It is mentioned here not because it is new, but because it demands skills and sophistication on the part of the small unit leader not normally called for in combat operations.

ernmental organizations.[9] These capabilities are all outside the traditional scope of company, platoon, and squad leadership in the Marine Corps. Yet, these skills, and many others besides, are critical elements to success in today's operational environment.[10]

Finally, at the outset of 2012, the Secretary of Defense provided strategic guidance for the Department of Defense (DOD)—reflecting the President's strategic guidance to the DOD; noted among the primary missions of the U.S. armed forces is the ability to conduct stability and counterinsurgency operations. Specifically, "U.S. forces will retain and continue to refine the lessons learned, expertise, and specialized capabilities that have been developed over the past ten years of counterinsurgency and stability operations in Iraq and Afghanistan. However, U.S. forces will no longer be sized to conduct large-scale, prolonged stability operations."[11] Moreover, the strategic guidance continues, counterinsurgency remains important although its emphasis appears to be shifting; however, the complexity of environments in which Marines are likely to find themselves will remain, and improving the decision making abilities of small unit leaders is a long-term proposition regardless of the mission emphasis.[12]

FINDINGS AND RECOMMENDATIONS

The number and type of decisions called for from a small unit leader in today's operational environment vary from routine matters of logistics and administration to life-and-death decisions involving force protection, noncombatant status, and tactical movement. Moreover, these decisions are almost always constrained by rules of engagement, considerations of unit capability, location, and mission priority. They are frequently made under great stress and always with incomplete, confusing, or inaccurate information.

Such decisions involve difficult trade-offs between outcome and effects. More casualties might be required for mission success. Additional resources might need to be expended to reduce casualties. Leaders might opt to extend patrols to avoid hostile areas, or their mission might demand that they expose themselves to

[9]For one study relating nonviolent counterinsurgency efforts such as provision of services to successful outcomes, see Eli Berman, Jacob Shapiro, and Joseph Felter, 2011, "Can Hearts and Minds Be Bought? The Economics of Counterinsurgency in Iraq," *Journal of Political Economy* 119(4):766-819*;* available at http://dss.ucsd.edu/~elib/ham.pdf. Accessed August 26, 2011.

[10]For the purposes of this report, the committee chose to examine, in part, the operational environment for small unit leaders in Iraq and Afghanistan so as to understand better the scope of decisions required by these leaders vis-à-vis the term "ECO in hybrid engagement, complex environments," used throughout the terms of reference (see the Preface).

[11]U.S. Department of Defense. 2012. *Sustaining U.S. Global Leadership: Priorities for 21st Century Defense*, Washington, D.C., January, p. 6.

[12]U.S. Department of Defense. 2012. *Sustaining U.S. Global Leadership: Priorities for 21st Century Defense*, Washington, D.C., January.

casualties in order to penetrate hostile areas. The number of trade-offs is almost endless.

Indeed, while the committee was able to examine in part the operational environment, existing abilities, and gaps for small unit leaders (as requested in the first bullet item of the terms of reference),[13] these constantly shifting variables made it difficult for the committee to develop recommendations consisting of *the* operational and technical approaches for improving the decision making abilities of small unit leaders (as requested in the fourth bullet item of the terms of reference). Put another way: it would be difficult for the committee to describe a meaningful set of metrics that could be used to declare objectively that its recommendations, if accepted, would result in "better" decisions for small unit leaders.

Furthermore, the Marine Corps has long recognized that the ability of leaders to make sound decisions is best measured by these leaders' performance over time in changing circumstances. The Report of Fitness for officers and noncommissioned officers (NCOs) requires the immediate supervisor of every Marine officer and NCO to rate that individual's judgment, decision making ability, and initiative. Over time, these reports form an accurate picture of the decision making ability of a Marine leader. The committee could find no way to improve on this tried-and-true method.

Accordingly, the committee's findings and recommendations were made pragmatically: that is, the committee examined existing organizations, training, and operational realities and tried to find and recommend ways to ease the burden on small unit leaders and to better prepare the small unit leader for success.[14] In general, the committee is very impressed with the progress that the Marine Corps has made in preparing its small unit leaders for operations in Iraq and Afghanistan. At the same time, however, small unit leaders are still overcoming a set of institutional hurdles with respect to their selection and training and the support that they receive, and their role in the operational environment is changing as well, given the evolving and complex nature of that environment. Here, the committee has endeavored to identity the major challenges facing small unit leaders and the Marine Corps, and trusts that its recommendations offer some useful solutions to addressing these challenges.

The committee realizes that some of its findings and recommendations are beyond the purview of the Commanding General, Marine Corps Combat Devel-

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[13]This study's terms of reference are provided in the Preface.

[14]The findings and recommendations of the committee are also based on its members' expertise and experience, along with its data-gathering efforts over the course of this study (see Appendix B for a summary of the committee's meetings and site visits). Its data gathering included the limited interviews that a subgroup of the committee conducted with a number of Marine small unit leaders who had recently returned from deployment to Iraq and Afghanistan (the interview protocol is presented in Appendix E).

opment Command (CG, MCCDC).[15] However, the committee anticipates that its findings and recommendations may be helpful to the CG, MCCDC, in terms of identifying, implementing, and/or advocating changes in four major areas: selection, training, support, and sustainment. Finally, the committee understands the dynamic nature of conflict and the operational environment, and realizes that the Marine Corps may be in the process of implementing some of the committee's recommendations even as this report is being published.

Selection

FINDING 1: The U.S. Marine Corps lacks up-to-date descriptions and requirements that define the job responsibilities of small unit leaders (company commanders, platoon leaders, and squad leaders), making it difficult to provide job-appropriate training and preparation for them. It is also difficult to assess the small unit leader's effectiveness in the operational environment. Furthermore, despite the fact that small unit leaders are assuming significant responsibilities, the Marine Corps has not established an institutional selection process for the positions of company commander and squad leader.[16]

RECOMMENDATION 1: Assess the pros and cons of establishing a Corps-wide process for the selection of squad leaders and company commanders. Such a process does not need to be centralized, but any form of implementation should be undertaken consistently across the Marine Corps. Continue to monitor progress in the development and validation of psychometric and physiologically based indicators that may have mid- and long-term potential to enhance selection.

Training

FINDING 2: The Marine Corps has invested in a number of novel approaches to training and education, such as Mojave-Viper, Combat Hunter, the Future Immersive Training Environment (FITE) of the Infantry Immersion Trainer facility, and the Center for Advanced Operational Culture and Learning. However, it is not clear whether novel training and educational opportunities are available to all small units and their leaders, nor has the Corps developed a formal training and development sequence which ensures that Marines are provided access to

[15]The CG, MCCDC, is also the Deputy Commandant for Combat Development and Integration (DC, CD&I).

[16]A Corps-wide selection process for platoon leaders already exists. All Marine officers attend the Basic School, a 6-month, officers' school that equips them with the skills needed to serve as second lieutenants. After completing their training at the Basic School, infantry officers attend the Infantry Officers School, and other officers attend schools of varying length in their occupational specialties. Their standing in these schools serves as the criteria for their selection as platoon leaders, since they have no operational experience.

new training and educational opportunities at appropriate points in their careers. In addition, at the time that the committee was conducting its review, the Corps had not identified a responsible organization to ensure that such training and education programs are properly developed, staffed, operated, and evaluated for their efficacy.

RECOMMENDATION 2: Continue to develop and implement in-garrison and predeployment team training techniques and opportunities to increase the sensitivity and timeliness of small unit training with respect to rapidly evolving hybrid warfare issues. Specifically:

- Identify a responsible organization to ensure that training and education programs are properly developed, staffed, operated, and evaluated;
- Continue to expand and develop training for squad leaders;
- Support an increase in the availability and realism of individual and team immersive training, with learning objectives similar to programs such as Mojave-Viper and FITE;
- Adopt proven team training techniques to foster unit cohesion and continuous improvement;
- Develop training systems that respond to field experience in order to incorporate and convey lessons learned more quickly; and
- Explore the use of social media to capture and share insights of small unit leaders as a next-generation lessons learned program.

FINDING 3: Training must evolve in tandem with the rapidly changing combat environment. However, the Systems Approach to Training relies on a 2-year cycle for evaluating and restructuring formal training practices. Given the rapid evolution of the combat environment, the penetration of knowledge from the battlefield into predeployment training is much too slow. In addition, the traditional mechanisms of the Marine Corps for capturing and transferring experiential knowledge, such as lessons learned, cannot keep pace with the evolution of operations. Marine small units are addressing this problem in-theater by developing training scenarios that exercise skills deemed necessary for the battlefield.

RECOMMENDATION 3: Support small units with in-theater training by adapting training and delivery methods and employing appropriate technologies:

- Develop a rapid-response training capability that allows faster reaction to the evolution of enemy tactics and techniques. For example, computer-based scenarios might be developed, then modified by small unit leaders in reaction to changing missions and tactical circumstances.
- Expand current efforts in cultural and language training to include computer-based courses and on-demand reachback for small unit leaders.

Support

FINDING 4: Marine companies and their constituent small units are assuming responsibilities analogous to those of a battalion but are not provided adequate personnel or material support for critical functions, including logistics, intelligence, communications, and information technology.

RECOMMENDATION 4: Provide primary or collateral billets at the company level to perform the functions of logistics, civil affairs, and operations and communications. Develop and provide courses of instruction that are scaled to the company level and tailored to these staff functions.

FINDING 5: Small unit leaders lack adequate information and analytic support for the cognitive work of sensemaking and situational assessment. In particular, problems with intelligence collection and dissemination, coupled with the paucity of working communications equipment, inadequate bandwidth, and delays in response times from higher levels of command, are detrimental to both decision making and morale at the small unit level. In addition, delays associated with the formal capture, recording, and transfer of theater-related experiential knowledge (such as through lessons learned) make it difficult for deployed units to benefit from the recent experiences of other Marines.

RECOMMENDATION 5: Provide technical and engineering solutions to support the small unit leader through well-tailored human-centric products for supplementing limited manpower in order to improve connectivity, information integration, and aids to decision making. Specifically:

- Provide increased communications bandwidth for voice, text, graphics, and data to small units, with priority to those in remote locations;
- Develop tactical decision aids designed for small unit leaders in order to support cognitive work such as sensemaking, situational assessment, problem detection, planning, and coordination and collaboration;
- Enable Marines to use electronic platforms that allow a free, supervised (but not moderated) exchange of current experiences in-theater; and
- Provide small unit leaders with reachback capability to obtain online expertise, data, and software to support their diverse roles.

Sustainment

FINDING 6: Marine small units and their leaders have spent the past decade conducting distributed operations in hybrid environments, facing a determined and observant insurgency while conducting a range of humanitarian, stabilization, and reconstruction activities. Not only have these units and their leaders become extremely adept at making do with limited resources, but they have also developed unique skills, understanding, and insights related to the conduct of hybrid operations in counterinsurgency warfare in Iraq and Afghanistan. As they return to garrison, small units and their leaders bring with them a wealth of knowledge about these environments, as well as key insights into what tools, technologies, training, and other support elements are most important for the successful conduct of operations. Without mechanisms to capture and build on the unique experiential knowledge of small unit leaders, the Marine Corps could easily lose this tremendous resource.

RECOMMENDATION 6: Consider ways to engage experienced junior enlisted leaders so that they can continue in a leadership role and the Marine Corps can benefit from their leadership expertise. For example, include junior enlisted leaders with hybrid ECO deployed experience to support the following:

- "Schoolhouse" programs in the Marine Corps dealing with hybrid warfare, ECO, and leadership;
- The design and development of future technologies and systems (e.g., social media) to enhance the small unit's ability to successfully engage in distributed operations; and
- The design and development of immersive training and educational programs to prepare Marines for future hybrid engagements.

FINDING 7: Established and emerging research in human cognition and decision making is highly relevant to developing approaches and systems that support small unit decision making. Cognitive psychology can provide significant guidance in developing technologies that support the decision maker, including approaches to information integration, tactical decision aids, and physiological monitoring and augmented cognition. However, technologies that do not incorporate human-centered design methods—such as those of cognitive systems engineering—may not generate *useful* and *usable* in-theater decision aids for the small unit leader. Lastly, the emerging field of cognitive neuroscience may have significant potential for developing the understanding of the fundamental neurophysiological mechanisms underlying human decision making. Although research in this area is very new, over the next few decades it may generate a fundamental paradigm change in scientific approaches to understanding human perception, sensemaking, and decision making.

RECOMMENDATION 7: Continue to invest in and leverage promising areas of science and technology research in the near term, midterm, and far term to enhance the decision making performance of small unit leaders.

- In the near term:

—Invest in means to capture and disseminate or share knowledge across the Marine Corps, accompanied by good but easy-to-manage measures for tracking the effect of the capture of new knowledge and of training initiatives;

—Incorporate human systems integration into the Navy/Marine Corps acquisition process in order to ensure that decision-support systems such as communications technologies, information integration systems, tactical decision aids (TDAs), and physiological monitoring systems are based on Marine missions and operator needs; and

—Develop single-purpose applications ("apps") for smartphones and tablets to support sensor collection management, sensor signal processing, situational assessment and forecasting, and TDAs in planning and course-of-action evaluation.

- In the midterm, develop and implement the following:

—Team training and leadership training, applying the principles of resilience engineering as described in Chapter 3 of this report, in order to build small units and small unit leaders that are more resilient;

—Deployable training simulators that can be used in-theater and that can be modified by Marines, not programmers, to adapt to their current situation; and

—Training and mission-rehearsal systems, visualization aids, and TDAs for nonkinetic operations that build on current applied research in the DOD's program in Human Social Cultural Behavior.

- In the far term, explore the future potential for the following:

—Physiological identification of stress and fatigue levels, the use of biomarkers, and real-time physiological monitoring for "state" assessment to determine the possible effect of factors that might contribute to poor judgment;

—Research on state assessment and trait identification to explore the potential to identify and select good candidates for the small unit leader in hybrid warfare situations; and

—Innovative training techniques such as intelligent tutoring and adaptive learning.

1

Introduction: The Operational Environment

This chapter provides context for understanding how the U.S. Marine Corps (USMC) has evolved its approaches to supporting small unit leaders in making decisions and taking action in the operational environments of Iraq and Afghanistan. As the chapter emphasizes, the challenges that Marine small units face in those theaters are not entirely novel, nor are they specific to Iraq or Afghanistan. Instead, they are rooted in a complicated mix of changes and stressors to which the Marine Corps has been adapting since the early 1990s.

1.1 HYBRID WARFARE

As the wars in Iraq and Afghanistan reach a decade in duration, adjectives like "hybrid" and "complex" have become standard terms to describe the diverse operational environments in which Marine small units must operate. As discussed below, whether hybrid environments truly represent a new form of warfare is a matter of some debate, but military experts do seem to agree that conflict patterns have become more complicated in the post-Cold War era.

The North Atlantic Treaty Organization (NATO) defines hybrid threats as those "posed by any current or potential adversary, including state, non-state, and terrorists, with the ability, whether demonstrated or likely, to simultaneously employ conventional and non-conventional means adaptively in pursuit of their objectives."[1] In NATO's assessment, hybrid threats are characterized by "interconnected individuals and groups" that possess the following traits:

[1]U.S. Government Accountability Office. 2010. *Hybrid Warfare,* GAO-10-1036R, Washington, D.C., September 10, p. 15.

- They are sophisticated users of new communications technologies for purposes of information exchange and collaboration.
- They recognize the strategic value of the 24-hour international media cycle and exploit it to effect particular ends.
- They are agnostic with regard to warfare tactics, employing conventional, cyber, and criminal modes of operation.
- They can adeptly interpret international laws of war to put NATO and other state forces at strategic and tactical disadvantage.[2]

The NATO Bi-Strategic Command has assessed hybrid threats as one of the most challenging problems of the post-Cold War era, because globalization, the rapid proliferation of new communications technologies, and the expansion of global transportation networks have effectively minimized the traditional significance of geographic and political boundaries.[3]

The U.S. Department of Defense (DOD) has similarly recognized the importance of these trends in shaping today's conflict environments. For example, the *National Defense Strategy* of 2005 identified "irregular, catastrophic, and disruptive methods" as the hallmark characteristics of war in the 21st century.[4] Lacking the resources to match the military capabilities of the United States, adversaries were likely to pursue "complex irregular warfare" instead.[5] Similarly, the Marine Corps has asserted the importance of "midrange threat": violent, transnational extremism and irregular warfare, fueled by economic, political, and social disenfranchisement among growing populations of young adults throughout North Africa, the Middle East, and Central Asia.[6]

Interestingly, however, the U.S. Government Accountability Office (GAO) recently pointed out that neither the term "hybrid threat" nor the term "hybrid warfare" has been officially adopted in DOD doctrine, although the word "hybrid" is common parlance among DOD's civilian and military leadership. In the GAO's assessment, "hybrid" describes a model of conflict with the following characteristics: it rapidly and unpredictably shifts between conventional and irregular tactics, including criminal and terrorist activity; it can involve both state and nonstate

[2]North Atlantic Treaty Organization. 2010. *Bi-SC Input to a New NATO Capstone Concept for the Military Contribution to Countering Hybrid Threats,* August 25, p. 3.

[3]North Atlantic Treaty Organization. 2010. *Bi-SC Input to a New NATO Capstone Concept for the Military Contribution to Countering Hybrid Threats,* August 25, p. 3.

[4]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, p. 6.

[5]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, p. 6.

[6]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, p. 9.

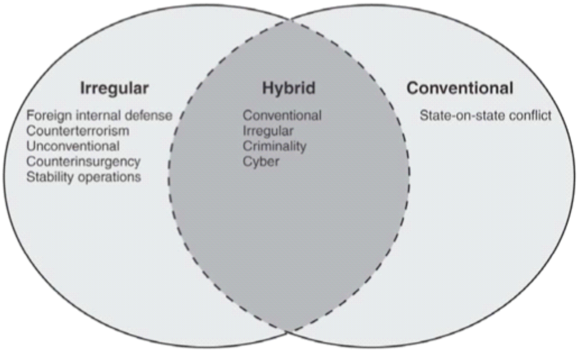

FIGURE 1.1 Conceptual model of hybrid warfare. SOURCE: U.S. Government Accountability Office. 2010. *Hybrid Warfare,* GAO-10-1036R, Washington, D.C., September 10, p. 16.

actors; and it actively exploits both military and civilian institutions, including the media, to tactical and strategic effect.[7] See Figure 1.1.

If there is general consensus about the characteristics of hybrid warfare, there is far less agreement as to the novelty of this form of conflict. According to the GAO, the U.S. Air Force views hybrid warfare as "more potent and complex" than more traditional forms of irregular warfare, whereas the U.S. Special Operations Command, the U.S. Navy, and the U.S. Marine Corps all equate hybrid warfare with full-spectrum conflict.[8]

It is perhaps more accurate to view hybrid warfare as a blending or blurring of categories that were once treated as distinct rather than as an entirely novel form of warfighting. Certainly the emergence of hybrid conflict patterns does not signal the end of traditional or conventional warfare,[9] but it does mean that U.S. military forces must be prepared for a range of conflicts. In these environments, U.S. forces are likely to face "states or nonstate actors [who] exploit all modes of war simultaneously by using advanced conventional weapons, irregular tactics, terrorism, disruptive technologies and criminality to destabilize an existing order."[10] If the destruction of social order meets the strategic ends of the adversary, this implies

[7]U.S. Government Accountability Office. 2010. *Hybrid Warfare,* GAO-10-1036R, Washington, D.C., September 10, pp. 11-18.

[8]U.S. Government Accountability Office. 2010. *Hybrid Warfare,* GAO-10-1036R, Washington, D.C., September 10, p. 17.

[9]Frank G. Hoffman. 2007. *Conflict in the 21st Century: The Rise of Hybrid Wars,* Potomac Institute for Policy Studies, Arlington, Va., December, p. 9.

[10]Robert Wilkie. 2009. "Hybrid Warfare: Something Old, Not Something New," *Air and Space Power Journal* XXIII(4):14.

that maintaining and/or restabilizing basic social, political, and economic infrastructure in the country of conflict is more than a humanitarian responsibility; it is a military necessity.[11] As a result, operations in these environments necessarily encompass "all elements of warfare across the spectrum," [12] from active combat to civilian support. Thus, the responsibilities facing conventional and expeditionary military forces are considerable.[13] U.S. military leaders have recognized that effective prosecution of the enemy in a hybrid warfare environment requires "a highly adaptable and resilient response from U.S. forces."[14]

1.1.1 "The Strategic Corporal" at the End of the Cold War

Over the past decade, USMC leadership has invested significant resources in a rethinking of the conceptual underpinnings of expeditionary warfare and meanwhile has enhanced the operational capabilities of the Marine Corps to meet the conditions of hybrid warfare. However, it is important to note that the investments of the Marine Corps were not made solely in response to conflicts in Iraq and Afghanistan, even though these conflicts continue to motivate adaptation in the approach of the Corps to its expeditionary mission. Even before the Cold War ended, the landmark doctrinal publication *Warfighting* acknowledged the dynamism of conflict and the evolution of warfare, calling for the Marine Corps to refine, expand, and improve its capabilities lest it become outdated and stagnant and risk defeat.[15] Indeed, the role and responsibilities of Marine small units and their leaders have been evolving since the end of the Cold War, as the Marine Corps has experienced rapid change in both the pace and the nature of its deployments.

As the bilateral nation-state framework of the Cold War disintegrated in the 1990s, latent instabilities erupted into violent conflict in Eastern Europe, Africa, and Central Asia. Driven by long-standing political tensions and differences in economic conditions, the devastating wars that occurred in Somalia, Rwanda, Bosnia, and Sierra Leone (among other locations) were fueled by complex dynamics of identity and ideology. At the same time, the United States, Europe, Japan, and other industrialized countries found themselves facing increasingly significant

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[11] John J. McCuen. 2008. "Hybrid Wars," *Military Review* LXXXVIII(2):106.

[12] U.S. Government Accountability Office. 2010. *Hybrid Warfare,* GAO-10-1036R, Washington, D.C., September 10, p. 11.

[13] Robert M. Gates, Secretary of Defense. 2010. *Quadrennial Defense Review*, Department of Defense, Washington, D.C., February, p. 8.

[14] U.S. Government Accountability Office. 2010. *Hybrid Warfare,* GAO-10-1036R, Washington, D.C., September 10, p. 11.

[15] See Preface by Gen Alfred M. Gray, USMC (Ret.), in Gen Charles C. Krulak, USMC, Commandant of the Marine Corps, 1997, *Warfighting*, Marine Corps Doctrinal Publication 1, Washington, D.C. Also see Gen Alfred M. Gray, USMC, Commandant of the Marine Corps, 1989, *Warfighting*, Marine Corps Fleet Marine Force Manual 1, Headquarters Marine Corps, Washington, D.C.

threats emanating from trans-state criminal and terrorist networks. The most ominous of these was Al Qaeda, which successfully executed a series of devastating attacks on U.S. targets in Yemen, Tanzania, and Kenya in the late 1990s.

In responding to these challenges, the United States drew heavily on the Marine Corps, which has long provided the nation with unique mobility, versatility, and expertise in expeditionary warfare. During the Cold War, the Marines had been called into action once every 15 weeks; in the 1990s, operational demands nearly tripled, and by 1998, Marine units were being deployed roughly once every 5 weeks to locations around the world.[16] Most prominently, Marine units supported humanitarian missions in Rwanda and Zaire, played a key role in stabilizing Bosnia after the 1995 Dayton Accords, and responded to the terrorist attacks in Nairobi, Kenya, and Dar es Salaam, Tanzania.

The Marines drew significant lessons from these experiences, recognizing that operational environments of the post-Cold War era would challenge 20th-century approaches to expeditionary warfare. The 1996 concept paper *Operational Maneuver from the Sea,* issued under the direction of Marine Corps Commandant General Charles C. Krulak, called for innovation in the "education of leaders, the organization and equipment of units, and the selection and training of Marines" to ensure readiness for the "full spectrum challenges" stemming from ongoing "chaos in the littorals."[17]

In assessing the posture of the Marine Corps before the U.S. Senate Armed Services Committee in 1998, General Krulak acknowledged a shift from nation-state warfare to complex civil conflict when he described the future of conflict not as " 'son of Desert Storm'; it will be the 'stepchild of Chechnya.' "[18] Krulak presciently recognized that in these environments, decisions taken at the level of the small unit can have unforeseen implications: "In the 21st Century, our individual Marines will increasingly operate with sophisticated technology and will be required to make tactical and moral decisions with potentially strategic consequences."[19] Moreover, Krulak pointed out, even decisions taken at the lowest level of rank of the Marines were likely to be "subject to the harsh scrutiny of both the media and the court of public opinion," as new communications technologies facilitated the rapid dissemination of information to an international

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[16]House Committee on Armed Services. 1999. *The State of United States Military Forces,* Hearing before the Committee on Armed Services, House of Representatives, 106th Congress, 1st Session, Publication Number 106-14, January 20, p. 217. Available at http://commdocs.house.gov/committees/security/has020002.000/has020002_0.htm. Accessed October 20, 2011.

[17]Gen Charles C. Krulak, USMC, Commandant of the Marine Corps. 1996. *Operational Maneuver from the Sea,* Foreward and pp. 2-3.

[18]"Statement of General Charles C. Krulak, Commandant of the Marine Corps, United States Marine Corps, Before the Senate Armed Services Committee on 5 February 1998 Concerning the Posture Hearing."

[19]"Statement of General Charles C. Krulak, Commandant of the Marine Corps, United States Marine Corps, Before the Senate Armed Services Committee on 5 February 1998 Concerning the Posture Hearing."

audience.[20] Whether we like it or not, Krulak argued, the United States is entering the era of the "strategic corporal," when individual Marines become the "most conspicuous symbol of American foreign policy. . . . [Their] actions will directly impact the outcome of the larger operation."[21]

To position Marines to address these challenges, Krulak ordered the establishment of the Marine Corps Warfighting Laboratory (MCWL) in 1995 to "study current challenges and analyze future threats affecting the Marine Corps."[22] Located at the Marine Corps Combat Development Command (MCCDC) in Quantico, Virginia, the MCWL was given responsibility for developing and evaluating new operational concepts, including the performance of "Service Oriented Concept-based Experiments" to "test training, organization, and equipment innovations associated with emerging warfighting concepts."[23] As discussed below, the MCWL has played an important role in developing and evaluating new concepts for expeditionary warfare, including "distributed operations" and "enhanced company operations" (ECO), concepts that reflect the significance of Krulak's "strategic corporal" in today's hybrid conflict environments.

The listing above is by no means a complete accounting of assessments or activities that the Marine Corps conducted after the Cold War ended. However, it is fair to say that by the time Al Qaeda executed the attacks on September 11, 2001 (9/11), USMC leadership was already anticipating major enduring changes to established paradigms of conflict and examining how the Marine Corps might best address the resulting challenges. Concepts developed in the 1990s are likely continuing to shape the approach of the Marine Corps to the operational environments of Iraq and Afghanistan today.[24]

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[20]Gen Charles Krulak, USMC, Commandant of the Marine Corps. 1999. "The Strategic Corporal: Leadership in the Three Block War," *Marines Magazine,* January. Available at http://www.au.af.mil/au/awc/awcgate/usmc/strategic_corporal.htm. Accessed October 12, 2011.

[21]Gen Charles Krulak, USMC, Commandant of the Marine Corps. 1999. "The Strategic Corporal: Leadership in the Three Block War," *Marines Magazine,* January. Available at http://www.au.af.mil/au/awc/awcgate/usmc/strategic_corporal.htm. Accessed October 12, 2011.

[22]U.S. Marine Corps, Marine Corps Warfighting Laboratory: see http://www.marines.mil/unit/mcwl/Pages/Overview.aspx. Accessed October 12, 2011.

[23]U.S. Marine Corps, Marine Corps Warfighting Laboratory: see http://www.marines.mil/unit/mcwl/Pages/Overview.aspx. Accessed October 12, 2011.

[24]The conceptual evolution of the USMC is captured in a number of doctrinal publications issued in the late 1990s. Many of the observations and principles included in these publications foreshadow the challenges that the Marine Corps would face on the battlefields of Iraq and Afghanistan. An example appears in the 2001 Marine Corps Doctrinal Publication (MCDP) 1-0, *Marine Corps Operations* (Headquarters Marine Corps, Washington, D.C.). In his foreword to the manual, then-Commandant of the Marine Corps General James L. Jones wrote that MCDP 1-0 "acknowledges that Marine Corps operations are now and will likely continue to be joint and likely multinational . . . the Marine Corps task-organized combined armed forces, flexibility, and rapid deployment apply to the widening spectrum and employment of today's military forces." See also MCDP 6, *Command and Control;* MCDP 3, *Expeditionary Warfare;* Headquarters Marine Corps, Washington, D.C., 1998.

1.1.2 Facing the Long War

Since the inception of conflicts in Afghanistan and Iraq, USMC leadership has continued to assess the operational environment and develop strategies for evolving the Corps to meet the challenges of a "pronounced, irregular threat . . . [that] requires the Marine Corps to make adjustments to the way the Marine Corps organizes its forces to fight our nation's foes."[25] These assessments emphasize that irregular, catastrophic, and disruptive methods have come to comprise a "pattern of complex irregular warfare"[26] that is likely to persist into the future. For example, the 2008 publication *Marine Corps Vision and Strategy 2025* identified hybrid warfare as "the *most likely* form of conflict facing the United States" (emphasis in original),[27] while *The Long War: Send in the Marines* describes a "generational struggle against fanatical extremists; the challenges we face are of global scale and scope."[28]

These and various USMC concept papers detail the evolution of the Marine Corps's foundations and capabilities for ensuring success in the irregular environments of Iraq and Afghanistan. In order to gain a better understanding of how the Marine Corps is positioning itself to address these challenges, the National Research Council's Committee on Improving the Decision Making Abilities of Small Unit Leaders reviewed some of the publicly available literature in which the USMC leadership describes the steps being taken to ensure that Marines can succeed in hybrid environments.

However, before describing some of these changes, it is important to point out that the Marine Corps is not making adjustments in a vacuum; its innovations are better understood as part of a larger, ongoing process through which the Department of Defense and the armed services have been adapting tactics and strategies to ensure effective coordination of combat and stability operations in Iraq and Afghanistan. These changes have implications for the kinds of activities that Marines pursue as part of expeditionary warfare.

For example, until 2004, DOD military planning guidance identified four phases in the continuum of military operations: Phase 1: Deter/Engage; Phase 2: Seize the Initiative; Phase 3: Decisive Operations; and Phase 4: Transition.[29] In

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Many of these doctrinal publications are available at http://www.marines.mil/news/publications/Pages/order_type_doctrine.aspx. Accessed October 10, 2011.

[25]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, p. 3.

[26]See also Marine Corps Intelligence Activity. 2005. *Marine Corps Midrange Threat Estimate 2005-2015,* MCIA-1586-001-05, Quantico, Va., August.

[27]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *Marine Corps Vision and Strategy 2025*, Headquarters Marine Corps, Washington, D.C., January, p. 12.

[28]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January.

[29]Joint Chiefs of Staff. 2001. *Doctrine for Joint Operations*, Joint Publication 3-0, Washington, D.C., September 10, pp. III-19-III-21.

2004, however, the Office of the Secretary of Defense revised this continuum to include two new phases, one at either end of the established continuum. The new "Phase 0: Shape the Environment" emphasized the establishment and solidification of friendly relationships and the deterrence of potential adversaries. At the other end of the expanded continuum, the new "Phase 5: Enable Civil Authority" directed the military to ensure that civil institutions in conflict zones are properly organized and resourced so that civilian populations have access to functioning public services.[30]

As the Government Accountability Office pointed out, this expanded operational guidance is playing an important role in articulating types of operations that the U.S. armed forces will be required to pursue in the context of stability operations. In particular, activities comprising the new phases in the expanded continuum are likely to require careful coordination and "significant unity of effort" among the U.S. armed forces, local security and civilian institutions, other U.S. federal agencies, and international coalition forces and partners.[31] For example, the challenge of "shaping the environment to confront the underlying conditions that are counter to the prospects of winning the ideological struggle"[32] can only be addressed when the U.S. military can work effectively with international coalition partners, international aid groups, other U.S. agencies, and local communities to promote the development of functioning and stable civil institutions in regions of conflict.

Over the past decade, USMC leadership has made a number of changes to ensure that Marines are prepared for these new missions. Among these changes, the Marine Corps has looked to expand force structure, establish new rotation cycles to reduce deployment stress, develop new training programs to provide Marines with theater-relevant skills, and establish new organizations and groups to assist Marines in the field. For example, the Marine Corps evolved some of its core structural elements to enable Marines to pursue new missions and operations. Of particular importance in this regard are innovations in the Marine Air-Ground Task Force, or MAGTF, the organizational structure that is the hallmark of Marine expeditionary warfare. At the battalion level, the MAGTF has traditionally provided "a single commander a combined arms force that can be tailored to the

[30]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, pp. 8-9.

[31]U.S. Government Accountability Office. 2007. *Military Operations: Actions Needed to Improve DoD's Stability Operations Approach and Enhance Interagency Planning,* GAO-07-549, Report to the Ranking Member, Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives, May, pp. 14-17. See also U.S. Department of Defense Joint Forces Command, 2006, *Military Support to Stabilization, Security, Transition, and Reconstruction Operations Joint Operating Concept,* Department of Defense, Washington, D.C., December.

[32]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, p. 1.

situation faced."[33] It is a structure that supports the versatile and rapid deployment of force, because it organizes command, logistics, and ground and aviation combat elements into a single structure that can be rapidly deployed into a range of operational environments, either independently or as part of a larger force.

In 2007, the Marine Corps established a new type of MAGTF, the Security Cooperation Marine Air-Ground Task Force (SC MAGTF). Comprising ground, logistics, and air combat elements, the SC MAGTF is organized according to various tasks in the areas of security cooperation and civil-military operations and can provide a range of capabilities, from operational law to veterinary services, even in remote environments lacking basic infrastructure. To enhance SC MAGTF capabilities further, the Marine Corps Training and Advisor Group was created to be deployed in teams of trained advisers, including as part of an SC MAGTF, to provide ongoing security assistance and training and to establish productive relationships among United States, coalition, and local security forces. SC MAGTF staffing requirements also call for officers and noncommissioned officers (NCOs) with academic area studies and language training appropriate for the region of operations.[34]

Lastly, the Marine Corps has also tried to increase its manpower reserves by growing its number of active-duty Marines. In 2006, the USMC won presidential approval to expand the force structure by 15,000 recruits. This, in turn, enabled the Marine Corps to address the critical problem of deployment fatigue and stress through implementation of a more sustainable deployment cycle, which doubled the ratio of home time to deployment time.[35]

Yet, the extent to which the Marine Corps will be able to maintain an expanded force, not to mention its trajectory of growth and innovation in training and deployment, is unclear. As public opinion shifts in favor of ending conflict in Iraq and Afghanistan, the United States is seeking to reduce its presence in these theaters. In addition, budgetary pressures have driven policy makers to reconsider what is required in order for the United States to maintain a "sustainable" defense capability.[36] In January 2011, the Secretary of Defense announced significant cuts in force size that would reduce the number of active-duty Marines from 202,000

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[33]Gen Charles C. Krulak, USMC, Commandant of the Marine Corps, 1997, *Warfighting*, Marine Corps Doctrinal Publication 1, Washington, D.C., June 20, p. 55; see also Marine Corps Reference Publication (MCRP) 5-12A, *Operational Terms and Graphics;* and MCRP 5-12D, *Organization of Marine Corps Forces.*

[34]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, pp. 7-19.

[35]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, pp. 13-15.

[36]Sustainable Defense Task Force. 2010. *Debt, Deficits, and Defense: A Way Forward*, Project on Defense Alternatives, Washington, D.C., June 11.

to 187,000 as part of a larger package of proposed efficiencies.[37] Reductions in defense spending will undoubtedly continue to impact the Marine Corps.

1.2 DISTRIBUTED OPERATIONS, ENHANCED COMPANY OPERATIONS, AND THE MARINE SMALL UNIT

As the preceding discussion demonstrates, the Marine Corps has been evolving its approach to expeditionary warfare almost continuously since the Cold War drew to a close in the early 1990s.[38] In particular, over the past decade, the Marine Corps has invested significant effort into assessing the requirements and demands of its expanding mission space in order to ensure that Marines are provided with the skills, knowledge, and resources required to conduct a full spectrum of operational activities, kinetic and nonkinetic.

Within this context, the committee was charged with examining the challenges facing small units and their leaders in the hybrid conflict environments of the post-9/11 era. The committee was asked to focus on "small units,"[39] because in the theaters of Iraq and Afghanistan, units below the battalion level have emerged as key players. Although the Marine Corps has traditionally projected expeditionary force through battalions supported by division-sized MAGTFs, the sheer size of Iraq and Afghanistan, coupled with the need to maintain deployed forces for long periods of time during stability operations, led to much wider distribution of Marine forces. For example, in 2003, I Marine Expeditionary Force (IMEF, comprising approximately 65,000 Marines) completed a 17-day march into Iraq, after which it became responsible for stabilizing Al Anbar Province—

> a 53,208 square mile area encompassing more than 1.2 million people living in approximately 40 cities and towns. Marines have had to counter a blend of Sunni insurgents, Al Qaeda terrorists, and local criminal elements in an area which, if it were one of the United States, would rank 26th in geographic size.[40]

Operational experiences like this are not unique in either Iraq or Afghanistan, and as a result, perhaps the most significant lesson learned over the past decade is the

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[37] Robert M. Gates, Secretary of Defense. 2011. "Statement on Department Budget and Efficiencies," Office of the Secretary of Defense, Washington, D.C., January 6; available at http://www.defense.gov/speeches/speech.aspx?speechid=1527. Accessed October 20, 2011.

[38] In a 2009 briefing to the Marine Corps Council, USMC Commandant General James T. Conway identified 10 capabilities and/or organizations that the Marine Corps has created in response to hybrid threats and irregular warfare. See Gen James T. Conway, USMC, Commandant of the Marine Corps, "Marine Corps Vision and Strategy 2025, Commandant's Update to the Marine Corps Council," Powerpoint presentation, April 18, 2009, Slide 21.

[39] The Marine Corps considers small units to be at the company level and below. See Appendix D for the organizational charts and size of a typical USMC rifle company, rifle platoon, and rifle squad.

[40] Marine Corps Combat Development Command. 2009. *Evolving the MAGTF for the 21st Century,* U.S. Marine Corps, Quantico, Va., p. 2.

importance of the Marine small unit. Stabilization operations over large areas in which population centers are widely dispersed necessitate the distribution of a division's forces in smaller units than the battalion—namely, companies, platoons, and squads. In Iraq and Afghanistan, "operations have placed a premium on units with a high degree of mobility and self-sufficiency" while "increasing demand for the ability to employ company-sized task forces in more autonomous roles."[41]

Consequently, small units have assumed responsibilities and have been assigned areas of responsibility that were formerly assigned to battalion-sized units. While these changes enabled the Marine Corps to more easily adapt to the fluid tactics of the enemy and to support the protection of indigenous populations, they also put stress on division- and battalion-level resourcing models. In "standard" expeditionary warfare, "subordinate units rely heavily on higher echelons for most of the coordination necessary to accomplish their individual tasks. This works well in situations where communications are easy and units are in close proximity," but the significant dispersion of forces led to problems with communication, coordination, and mutual unit support.[42] In other words, the distribution of forces in Iraq and Afghanistan strained the MAGTF model of force projection—which leads to the topics of distributed operations and enhanced company operations, concepts that represent an acknowledgment of the stresses described here, as well as an effort to capitalize on the agility and adaptiveness of the small unit.

As previously noted, the Marine Corps Warfighting Laboratory was established by General Krulak in 1995 to look at innovative and unconventional responses to what Krulak had identified as significant changes in future combat environments. Beginning in 2003, in response to conditions in Iraq and Afghanistan, the MCWL developed a concept known as distributed operations, whereby small units would be dispersed across wide geographic areas and connected by robust communications systems.[43] The concept was formally articulated in the 2005 concept paper *A Concept for Distributed Operations,* issued under the direction of Marine Corps Commandant General Michael W. Hagee.[44]

A Concept for Distributed Operations set out a vision for leveraging "the deliberate use of separation and coordinated, interdependent, tactical actions, enabled by increased access to functional support, as well as by enhanced combat

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[41]Marine Corps Combat Development Command. 2009. *Evolving the MAGTF for the 21st Century,* U.S. Marine Corps, Quantico, Va., p. 5.

[42]John D. Jordan. 2011. *Improving the Enhanced Company Operations Fire Support Team,* Master's Thesis, Naval Postgraduate School, Monterey, Calif., p. 3.

[43]Vincent J. Goulding, Jr., Marine Corps Warfighting Laboratory. 2009. "Distributed Operations and Enhanced Company Operations: Experimentation and Marine Corps Capability Development," presentation to the Zvi Meitar Institute for Land Warfare Studies, Latrun, Israel, September 2.

[44]Gen Michael W. Hagee, USMC, Commandant of the Marine Corps. 2005. *A Concept for Distributed Operations*, Headquarters Marine Corps, Washington, D.C., April 25.

capabilities at the small-unit level."[45] Underlying the distributed operations concept was the recognition that "the warriors on the ground, the small units, [are] the prime discriminators, deciders, and actors."[46] Arguably, the concepts presented in *A Concept for Distributed Operations* simply formalized a well-established trend: with resources more widely distributed, and facing a broader range of challenges, Marine small units and their junior leaders (captains, lieutenants, sergeants, and corporals) were in fact assuming responsibility for problems that would otherwise be addressed by more senior officers and NCOs at the company or battalion levels. The concept paper pointed out that multiple deployments in Iraq and Afghanistan had also created a seasoned cadre of junior officers and NCOs who had "proven their critical thinking skills and tactical competence in combat . . . and [were] demonstrating a capacity for small unit leadership. . . ."[47] By "moving authority 'downward' to dramatically increase the speed of command," distributed operations would allow the Marine Corps to leverage this experience to advance maneuver warfare and "achieve tactical successes that will build rapidly to decisive outcomes at the operational level of war."[48]

Yet, as several USMC publications emphasized, the devolution of authority to companies, platoons, squads, and teams would necessitate changes in the preparation and resourcing of these units. Importantly, when small units are distributed, they are "separated beyond the limits of mutual support."[49] Indeed, the distributed operations concept was at first "met with resistance by many due to the vulnerability of small units operating far from supporting units and higher headquarters, and the necessary equipment development and fielding lagged far behind."[50] Yet as MCWL Director Vince Goulding put it, the point of distributed operations was to "enable tactical units to distribute *because* of their training and equipping, not *in spite* of it" (emphasis in original).[51]

As a concept, distributed operations recognized that smaller units, particularly below the company level, needed access to higher-level resources and

[45]Gen Michael W. Hagee, USMC, Commandant of the Marine Corps. 2005. *A Concept for Distributed Operations*, Headquarters Marine Corps, Washington, D.C., April 25.

[46]LtCol Edward Tovar, USMC. 2005. "USMC Distributed Operations," *DARPA Tech,* August 9-11, p. 22.

[47]Gen Michael W. Hagee, USMC, Commandant of the Marine Corps. 2005. *A Concept for Distributed Operations*, Headquarters Marine Corps, Washington, D.C., April 25, p. 2.

[48]Gen Michael W. Hagee, USMC, Commandant of the Marine Corps. 2005. *A Concept for Distributed Operations*, Headquarters Marine Corps, Washington, D.C., April 25, p. 2.

[49]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, pp. 31-32.

[50]Maj Christopher Griffin, USMC. 2009. *Enhanced Company Operations in High Intensity Combat: Can Preparations for Irregular War Enhance Capabilities for High Intensity Combat?* Master's Thesis, U.S. Marine Corps Command and Staff College, Quantico, Va., p. 3.

[51]Vincent J. Goulding, Jr., Marine Corps Warfighting Laboratory. 2009. "Distributed Operations and Enhanced Company Operations: Experimentation and Marine Corps Capability Development," presentation to the Zvi Meitar Institute for Land Warfare Studies, Latrun, Israel, September 2, Slide 4.

capabilities, either to be "called in" when necessary or embedded "organically" at the level of the unit. Additional air and ground mobility, fire-support elements, technology and training for gathering and exploiting actionable intelligence, a responsive and well-resourced supply chain, support for maintenance problems, improved force protection equipment, and robust communications networks: all of these were identified as critical elements needed to link very small units, down to rifle teams, into an operational whole. Moreover, small unit leaders and their Marines would need training to ensure access to at least some of the technical, organizational, medical, and linguistic skills that are normally provided by specialists embedded in higher levels of command.[52]

Under the rubric of distributed operations, the Marine Corps made headway in addressing the types of gaps described above. Training was one important area in which the Corps focused resources, to ensure that small units and their leaders had access to the requisite knowledge and skills to pursue important nonkinetic missions, such as conducting training and professionalization activities with local security forces. In 2005, the USMC Training and Education Command (TECOM) established the Center for Advanced Operational Culture and Learning (CAOCL) at Quantico, Virginia. According to USMC documents, CAOCL activities include education, predeployment training, and regional studies to provide Marines with cultural and communications skills for navigating the "cultural terrain."[53] The Center offers instructor-guided and computer-based language training (using Rosetta Stone) to forces being deployed in both Iraq and Afghanistan. In addition, Tactical Language Kits help Marines develop basic proficiency in new languages, and Tactical Language Training Simulation allows Marines to exercise new communications and language skills in simulated deployment encounters. Faculty at the Marine Corps University have also developed curricula on Operational Culture to support Marines in understanding how cultural dynamics can shape military operations. One significant achievement is the publication in 2008 of the Marine Corps University textbook *Operational Culture for the Warfighter: Principles and Applications,* which integrates historical, economic, political, and social science research with military science and doctrine to help Marines become effective "Cultural Operators."[54] This volume has become a military best-seller, with more than 10,000 copies in print as of this writing.[55]

[52]Gen Michael W. Hagee, USMC, Commandant of the Marine Corps. 2005. *A Concept for Distributed Operations*, Headquarters Marine Corps, Washington, D.C., April 25, pp. VI-IX.

[53]Col George M. Dallas, USMC (Ret.). 2008. "Operational Culture: From the Director," *Operational Culture* 1(1):1.

[54]Barak A. Salmoni and Paula Holmes-Eber. 2008. *Operational Culture for the Warfighter: Principles and Applications,* Marine Corps University Press, Quantico, Va.

[55]Paula Holmes-Eber. 2011. "Teaching Culture at Marine Corps University," pp. 129-142 in Robert A. Albro, George Marcus, Laura McNamara, and Monica Schoch-Spana (eds.), *Anthropologists in the SecurityScape: Ethics, Practice and Professional Identity,* Left Coast Press, Walnut Creek, Calif.

The distributed operations concept also generated other innovations, including the Squad Fires and Combat Hunter training initiatives;[56] the Corps also revised its Infantry Battalion Table of Equipment.[57] Experiments conducted by the MCWL also refined the requirements for successful implementation of the distributed operations plan, including better communications devices, target acquisition and long-range precision fire technologies, improvements in logistics and supply chains, and expanded training.[58] Research programs, including an initiative of the Defense Advanced Research Projects Agency (DARPA), were also pursued.[59]

Yet, in 2008, the Marine Corps announced that the distributed operations concept was "dead." [60] It seems that this decision was made because of the emphasis on increasingly smaller teams being given resources and authority for significant decisions. As one source put it, Marine Commandant General James T. Conway was reportedly " 'not comfortable' with 'six-man [i.e., rifle] teams going out on their own.' "[61] However, the concept was not entirely killed. Instead, distributed operations were reconfigured into enhanced company operations, which addressed the perceived "operating environment's cognitive, physical, and technical limitations that restrained the original [Distributed Operations] concept."[62] The shift from distributed to enhanced company operations was formalized in *A Concept for Enhanced Company Operations,* issued in August 2008 from the office of Marine Corps Commandant General James T. Conway.[63]

In contrasting distributed and enhanced company operations, MCWL Director Vince Goulding described distributed operations as a "bottom up approach" to

[56]Members of the committee were briefed on Combat Hunter during the visit to Camp Pendleton, California, in October 2010, and the topic of Combat Hunter training came up in several of the interviews conducted at Quantico, Virginia, in December 2010. More information on Combat Hunter can be found at http://cognitiveperformancegroup.com/projects/projectch; also see http://www.marines.mil/unit/mcbjapan/Pages/2011/110708-hunters.aspx#.Tuljr0rlE1s. Accessed October 20, 2011.

[57]Vincent J. Goulding, Jr., Marine Corps Warfighting Laboratory. 2009. "Distributed Operations and Enhanced Company Operations: Experimentation and Marine Corps Capability Development," presentation to the Zvi Meitar Institute for Land Warfare Studies, Latrun, Israel, September 2, Slide 4.

[58]Maj Christopher Griffin, USMC. 2009. *Enhanced Company Operations in High Intensity Combat: Can Preparations for Irregular War Enhance Capabilities for High Intensity Combat?* Master's Thesis, United States Marine Corps Command and Staff College, Quantico, Va., p. 4.

[59]LtCol Edward Tovar, USMC. 2005. "USMC Distributed Operations," *DARPA Tech,* August 9-11, p. 22.

[60]Zachary M. Peterson. 2008. "Distributed Ops Concept Evolves into Enhanced Company Operations," *Inside the Navy*, May 19.

[61]Zachary M. Peterson. 2008. "Distributed Ops Concept Evolves into Enhanced Company Operations," *Inside the Navy*, May 19.

[62]Maj Blair J. Sokol, USMC. 2009. *Reframing Marine Corps Operations and Enhanced Company Operations: A Monograph,* U.S. Army Command and General Staff College, Fort Leavenworth, Kans., p. 1.

[63]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *A Concept for Enhanced Company Operations*, Headquarters Marine Corps, Washington, D.C., August 28.

resourcing Marines, recognizing that a "Company is only as good as its platoons, its platoons only as good as its squads, its squads only as good as its Marines." In contrast, Goulding explained, enhanced company operations emphasize the downward movement of battalion-level functions to the company commander, and he sought to ensure adequate institutional support for the many missions of the company.[64]

In other words, enhanced company operations formally recognized that the company—not the platoon, squad, or team—"is the smallest tactical formation capable of sustained independent operations."[65] The USMC thus envisions ECO as "driving the full range of combat development activities towards . . . the company commander." Identified needs include "[facilitating] improved command and control, intelligence, logistics, and fires capabilities" and further changes to "training, manning, and equipping."[66] The concept paper itself identified intelligence, maneuverability, fires, logistics, information operations, command and control, and expanded training, including new simulations for small units to "rehearse" missions prior to execution. Importantly, the Marine Corps has recognized that increased emphasis on the company as an independent operational unit implies significant potential changes to the MAGTF, including the possible development of "company sized MAGTFs."[67] Evolving the MAGTF to address company operations can include "provision of fires, mobility, logistics, communications, intelligence, information operations, foreign internal defense, and civil-military operations capabilities"[68] similar to the capabilities provided at the battalion level, and arguably difficult to source adequately at unit levels much smaller than the company.

To address these challenges, the Marine Corps has redirected effort to pursue the strengthening of company-level capabilities. In particular, the MCWL has conducted several Limited Objective Experiments (LOEs) to evaluate the introduction of critical capabilities to the company level. Prominent innovations that "push" battalion-level capabilities to the company level include the CLIC, or

[64] Vincent J. Goulding, Jr., Marine Corps Warfighting Laboratory. 2008. "Enhanced Company Operations: A Logical Progression to Capability Development," *Marine Corps Gazette* 92(8). Available at http://www.mca-marines.org/gazette/article/enhanced-company-operations. Accessed July 28, 2010.

[65] Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *A Concept for Enhanced Company Operations*, Headquarters Marine Corps, Washington, D.C., August 28, p. 1.

[66] Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *A Concept for Enhanced Company Operations*, Headquarters Marine Corps, Washington, D.C., August 28, p. 2.

[67] Gen James T. Conway, USMC, Commandant of the Marine Corps, 2008, *A Concept for Enhanced Company Operations*, Headquarters Marine Corps, Washington, D.C., August 28, p. 2; see also LtGen G.L. Flynn, USMC, Commanding General, Marine Corps Combat Development Command, 2009, *Evolving the MAGTF for the 21st Century*, U.S. Marine Corps, Quantico, Va., March 20.

[68] LtGen George L. Flynn, USMC, Commanding General, Marine Corps Combat Development Command. 2009. *Evolving the MAGTF for the 21st Century*, U.S. Marine Corps, Quantico, Va., March 20, p. 6.

company-level intelligence cell, as well as the CLOC, the company-level operations cell. Between 2007 and 2009, the MCWL conducted an extensive series of LOEs to assess the feasibility and identify gaps in the CLIC/CLOC concepts in different operational environments. In addition, the Corps has continued to leverage resources developed under distributed operations, such as cultural training and language programs and updated equipment.

1.3 CHALLENGES FOR MARINE SMALL UNITS AND THEIR LEADERS

> The Long War is indeed a small unit leader's fight, and we have to make sure our young warriors, operating sometimes with little sleep and in 120-degree heat, are up to the task of making rapid tactical decisions that may have strategic impact.
>
> —Remarks of the Commandant of the Marine Corps,
> General James T. Conway, USMC,
> "George P. Schultz Lecture Series,"
> San Francisco, California, July 2007

In this chapter, the committee has provided a brief and necessarily incomplete description of how expeditionary warfare in the Marine Corps has evolved over the past two decades. The battlefields of Iraq and Afghanistan have presented Marine small units and their leaders with a daunting array of missions, including the training and professionalization of local police and military forces, the tracking of insurgents in remote areas, the countering of drug trafficking and interdiction of criminals, the evacuation of noncombatants from conflict zones, even the provision of health care to local populations.[69] This diversity is inherent in counterinsurgency (COIN) warfare, which requires Marines to maintain a delicate balance between the use of force and the development of productive relationships with local populations so as to undermine support for insurgency groups (the so-called "hearts and minds"[70] element of COIN operations). In Iraq and Afghanistan, Marines are responsible for pursuing and destroying enemy insurgents, while simultaneously protecting civilians, themselves, and their fellow Marines from harm. They are also frequently coordinating their activities with a range of multinational actors, including the multinational teams of the International Security Assistance Force (ISAF), military and civilian staff from

[69]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January, p. 12.

[70]The committee is aware that the idea of operations to win the hearts and minds of indigenous populations is not a new concept. The phrase was first used by the British Army during the Malayan Emergency in 1948, but the concept has been with us since the time of Alexander. It is mentioned here not because it is new, but because it demands skills and sophistication on the part of the small unit leader not normally called for in combat operations.

the United Nations and NATO, and a range of nongovernmental organizations, not to mention local, regional, and national leaders in Iraq and Afghanistan.

The presence of an observant, intelligent, and adaptive enemy presents additional challenges in an already-complicated mission space, because it means that the environment in which Marine small units are performing their missions is unstable and unpredictable. Tactics, techniques, and procedures (TTPs) that work well one day may be obsolete the next.

As discussed in Chapter 2, Marine small unit leaders must respond to situations that evolve rapidly and unexpectedly from being calm and productive to being kinetic and extremely destructive. The presence of international news media in the battlefield further complicates matters: not only is 24-hour coverage normal, but also the Internet ensures that news stories about Marine engagements with insurgents and reports of collateral damage to civilian populations can rapidly and easily "go viral" with little warning. The second- and third-order effects of such instances can be significant. Moreover, Marine small units are performing their missions across vast expanses of terrain, in environments that can range from dense urban neighborhoods to sparsely populated mountainous areas.

Basic capabilities, including but not limited to command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR), logistics, intelligence, and fire support, can be difficult to maintain at the small unit level when companies are so spread out. And, despite significant national investments in technologies that are aimed at helping the warfighter, not all technology is available to Marines on the ground, and even technology that is available may not be useful for the missions that Marines are conducting. These missions are inherently challenging, and the Marine Corps is working diligently to prepare and equip its Marines to address them. Yet at the same time, the Marine Corps as a whole must "effectively engage in these operations while still *maintaining full spectrum combat capability*" (emphasis added)[71] insofar as the USMC traditional expeditionary, forward-deployed combat role will remain a core element of U.S. military capabilities into the future. At a Corps level, maintaining excellence across such a diverse spectrum of missions is a significant organizational challenge that inevitably involves long-term strategic planning and resource allocation questions, particularly as budgetary pressures complicate investment questions across the U.S. government.

Finally, at the outset of 2012, the Secretary of Defense provided strategic guidance for the DOD—reflecting the President's strategic guidance to the DOD; noted among the primary missions of the U.S. armed forces is the ability to conduct stability and counterinsurgency operations. Specifically, "U.S. forces will retain and continue to refine the lessons learned, expertise, and specialized capabilities that have been developed over the past ten years of counterinsurgency

[71]Gen James T. Conway, USMC, Commandant of the Marine Corps. 2008. *The Long War: Send in the Marines*, Headquarters Marine Corps, Washington, D.C., January.

and stability operations in Iraq and Afghanistan. However, U.S. forces will no longer be sized to conduct large-scale, prolonged stability operations."[72] Moreover, the strategic guidance continues, counterinsurgency remains important although its emphasis appears to be shifting; however, the complexity of environments in which Marines are likely to find themselves will remain, and improving the decision making abilities of small unit leaders is a long-term proposition regardless of the mission emphasis.

The committee recognizes that these two challenges—preparing the small unit leader for the complexities of an expanding, rapidly changing, and highly uncertain mission space while at the same time maintaining the USMC traditional strengths in expeditionary warfare—are interdependent. In response to the terms of reference for the study (see the Preface), this report focuses primarily on the former: ensuring that small unit leaders are selected, prepared, enabled, and sustained as they assume greater responsibility in complex operational environments.

1.4 ORGANIZATION OF THE REPORT

With Chapter 1 setting the context for the challenging operational environment of today's Marine Corps small units, in Chapters 2 through 4, the committee addresses one or more of the topics identified in the terms of reference. Chapter 2 discusses the challenges of the operational environment from the perspective of the small unit leaders. The chapter draws heavily on interviews that a subgroup of the committee conducted in December 2010. The committee had requested permission to conduct these interviews with small unit leaders so that its deliberations could benefit from a fuller understanding of the operational challenges from the perspective of those responsible for carrying out the Corps mission. Coupled with the committee's meetings and review of Marine Corps literature, these interviews provided observations that helped establish the basis for the set of findings presented at the end of Chapter 2.

Chapter 3 then uses the set of six findings to guide a focused review of relevant and specific areas of science and engineering, from neuropsychology to operations research to decision science, for identifying potential "solution spaces" for supporting effective decision making in small units. From this review comes the committee's seventh finding as presented at the end of Chapter 3.

Lastly, Chapter 4 draws on the previous chapters in presenting a set of recommendations for operational and technical approaches to supporting, in the evolving operational environment, small unit leader decision making in the Marine Corps. In making these recommendations, the committee recognizes that the Marine Corps has already invested significant effort and resources in the development, testing, and refining of the operational capabilities of the small

[72]U.S. Department of Defense. 2012. *Sustaining U.S. Global Leadership: Priorities for 21st Century Defense*, Washington, D.C., January.

unit. The committee is very impressed with the progress that the Marine Corps has made in this regard, and offers its comments and recommendations in support of the Marine Corps as it advances its operational capabilities into the future. In addition, the committee was deeply inspired by the professionalism, dedication, and expertise of the Marines whom committee members met, particularly the small unit leaders with whom the committee had the opportunity to interact. As these women and men perceive, adapt, and very effectively shape the dynamics of complex and dangerous adversarial environments, they demonstrate as small unit leaders why the Marine Corps remains the best expeditionary force in the world.

Appendix A presents biographies of the members of the committee. Appendix B provides a summary of committee meetings and site visits. Appendix C contains a list of acronyms and abbreviations used throughout the report. Additional background information on Marine Corps small units, the committee's interview protocol, and biomarkers are provided in Appendixes D through F, respectively. A dissenting opinion to Chapter 3 by two committee members is provided in Appendix G.

2

Challenges of the Operational Environment for the Small Unit Leader: Observations and Findings

2.1 INTRODUCTION

Chapter 1 discussed the evolution of post-Cold War conflict environments and described some of the initiatives that the U.S. Marine Corps (USMC) has undertaken to ensure that Marines can effectively address the complicated challenges of hybrid warfare. To obtain a better understanding of how these trends affect small units and their leaders, the committee decided early in the course of this study to seek input from small unit leaders who had had deployment experience in Iraq and Afghanistan. Both the USMC and National Research Council (NRC) staff were supportive of these efforts and created opportunities for committee members to interact formally and informally with Marine small unit leaders. In September 2010, three Marine captains who had recently returned from deployments as company commanders visited the National Academies in Washington, D.C., and briefed the committee on the changing roles, activities, and challenges facing small units in Iraq and Afghanistan. In October 2010, a subgroup of the committee visited the Infantry Immersion Trainer (IIT) facility at Camp Pendleton, California, to observe activities at the Future Immersive Training Environment (FITE). During this visit, the committee members had an opportunity to observe a training demonstration and to gather information about novel approaches to developing and implementing theater-realistic, scenario-based, predeployment training in the Marine Corps.

2.1.1 Interviews: Purpose and Approach

Although these interactions were helpful in augmenting the materials provided to the committee by the Marine Corps and other Department of Defense

(DOD) offices, several members of the committee expressed concern about not understanding enough with regard to the nature or challenges of decision making from the perspective of the small unit leader. To address this gap, a subgroup of committee members developed an interview protocol to elicit field experiences from Marine small unit leaders with recent deployment experience in Iraq and/or Afghanistan.[1] In December 2010, National Research Council staff made arrangements for 6 committee members to conduct interviews with small unit leaders at the Marine Corps Combat Development Command (MCCDC) in Quantico, Virginia. During this visit, the 6 committee members paired into 3 teams of interviewers, and together these teams conducted a total of 18 hours of interviews and captured experiential narratives from 23 leaders. Each provided committee members with detailed accounts of his or her unit's activities and his or her own leadership challenges.

The day after the interviews, the committee members returned to the National Academies in Washington, D.C., and spent a day working as a group to code and categorize themes from the interview notes. In doing so, the subgroup identified a number of issues that recurred frequently in the accounts of the small unit leaders who were interviewed. The four most salient, overarching themes emphasized the following:

1. The challenges of operating at a significant *geographical distance* from the infantry battalion and from other small units;
2. The *diversity of operational activities,* from kinetics to long-term stabilization and reconstruction operations;
3. The challenge of dealing with an *adaptive and observant adversary* who intermingles with local populations; and
4. Making rapid, high-consequence decisions under *rules of engagement* aimed at supporting an effective counterinsurgency strategy by minimizing unintended consequences of kinetic actions.

In each of these domains, small unit leaders also described how resource gaps in *technology*, *training*, and *personnel* complicated information collection, analysis, and decision making. They also provided examples of decisions taken in the absence of higher-level guidance and support, as well as examples of improvised solutions that enabled them to conduct their missions without easy access to battalion-level resources.

[1] The interview protocol is provided in Appendix E. These interviews with small unit leaders included commissioned and noncommissioned officers. The quotations from and personal experiences of the small unit leaders as related in this chapter were taken from these interviews.

2.1.2 Chapter Organization

This chapter is organized around the four key challenges, listed above, that are faced by the small unit and discussed in the next major section, entitled "2.2 Observations." These challenges are derived from themes identified in the interviews with small unit leaders: geographic dispersion, mission diversity, adaptive adversaries, and rules of engagement. These interview themes are augmented with information that the committee gathered from briefing materials, site visits (see Appendix B for a summary of the committee's meetings and site visits), and the literature reviewed in Chapter 1.

The committee recognizes that the interviews conducted for this study may not be representative of the experiences of all small unit leaders and notes that a compressed information-gathering schedule necessitated quite a small subject sample. In addition, materials provided to the committee by the Marine Corps indicate that USMC leadership, and especially the MCCDC, is aware of and working to address many of the challenges that small unit leaders face. However, the committee considered it important to include specific examples from the experiences of small unit leaders to help the reader better understand the depth and complexity of challenges facing Marines in hybrid, complex environments, such as those encountered in Iraq and Afghanistan. In addition, the committee wanted to call attention to the resourcefulness of small unit leaders in developing strategies to mitigate the effects of resource gaps so as to encourage the Marine Corps to draw on these small unit leaders' experiences as it assesses strategies for supporting and sustaining distributed units.

In discussing the challenges of distributed operations, mission diversity, adaptive adversaries, and rules of engagement, the committee examines how these challenges complicate decision making. Particular attention is devoted to possible gaps in training, technology, and personnel, again with the recognition that the Marine Corps is working hard to identify and address such gaps. To that end, this chapter identifies examples of interventions or "fixes" that the Corps has implemented, developed, or considered.

The chapter concludes with summarizing findings based on the committee's review of enhanced company operations (ECO)-related literature assembled by committee members; the materials that the Marine Corps, the Office of Naval Research (ONR), and other presenters provided the committee; and its compilation of the interview materials. Together, these sources of information are the basis for a set of six findings related to the selection, training, resourcing, and sustainment of small units and their leaders, not just in the battlefields of Iraq and Afghanistan, but also for future hybrid engagements as well.

2.2 OBSERVATIONS

The following observations of the committee are organized according to the four salient, overarching themes, listed above, dealing with challenges that small units face. Each challenge is discussed in a subsection below.

2.2.1 Geographic Dispersion and Resources

The geographic dispersion of small units creates significant challenges for small unit leaders in the Marine Corps. The difficulty of operating autonomously at a significant distance from battalion headquarters was a consistent theme in all 23 of the interviews that the committee conducted with small unit leaders. In Iraq and Afghanistan, a single infantry battalion of approximately 1,100 Marines can be responsible for more than 17,000 square miles of territory.[2] As a result, rifle companies and their constituent platoons, squads, and teams find themselves responsible for territory that may encompass hundreds, if not thousands, of square miles. Operating at significant distances from the infantry battalion, Marine small unit leaders, including company commanders, platoon commanders, and squad leaders, often find themselves planning and executing missions under the same conditions and facing the same decisions that infantry battalions and their leaders might encounter. However, small units are unlikely to have the full complement of equipment and expertise typically available to a battalion.

Geographical dispersion clearly affects unit performance. The small unit leaders interviewed by the committee consistently pointed to significant and frustrating gaps in technology and equipment, including communications and vehicles, as well as logistical support. A Marine lieutenant who led a rifle platoon in Iraq reported that the biggest problem for his unit was ensuring adequate and timely supplies to the rifle squads occupying 12 positions in a remote area. The platoon's table of allowance did not account for his company's being spread into so many positions, and so he had to justify necessary equipment and supplies, from guns to refrigerators.[3] In addition, the remoteness and relative instability of the area made resupply difficult and even dangerous for a platoon, which lacks the full complement of transportation resources that a battalion has. Another Marine described "treacherous" problems for resupplying units in terrain where improvised explosive device (IED) threats are significant, saying that C-130 airdrops were often necessary to get supplies to squads.[4]

In addition, Marine small unit leaders described frustrating problems with communications equipment that was unreliable, broken, or otherwise unavailable to the small unit. One captain reported that his company lacked working NIPRnet (Non-classified Internet Protocol Router Network) and SIPRnet (Secret Internet Protocol Router Network) connections, which led the company to rely

[2] Vincent J. Goulding, Jr., Marine Corps Warfighting Laboratory, "Enhanced Company Operations (ECO) Limited Objective Experiment 4 (LOE4) and Enhanced Marine Air-Ground Task Force Operations (EMO) Way Ahead," presentation to the committee, Washington, D.C., August 5, 2010.

[3] USMC Interviews, Committee on Improving the Decision Making Abilities of Small Unit Leaders, Quantico, Va., December 7, 2010. Hereafter cited as USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[4] USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

exclusively on satellite radios in order to communicate with the battalion.[5] A platoon lieutenant who served in Iraq said that satellite communications were reliable but cumbersome: communicating with battalion command required that he stop his unit, set up the satellite communications unit, point it, and confirm that he had a working signal, which was time-consuming and potentially dangerous in areas where adversaries were active.[6] Another captain described supervising his Marines as they used heavy equipment to move concrete and being frustrated that, despite these Marines being within eyesight of their unit, they were effectively out of communication range.[7]

Personnel gaps, particularly in areas such as intelligence and civil affairs, also complicate the job of the small unit leader. Pursuit of counterinsurgency strategies in hybrid environments means that small units conduct a range of missions, from kinetic engagements to rural development projects. At the battalion level, such efforts would be supported by a complement of personnel with training in intelligence collection and analysis, logistics, civil affairs, and other operational functions. However, these personnel may not be available at the small unit level, which creates problems when those units are operating at a significant distance from the infantry battalion headquarters.

Several of the small unit leaders interviewed by the committee said that they had addressed some of these resource challenges by changing their organizational structure and their tactics, techniques, and procedures (TTPs)[8] in order to make adjustments for conditions on the ground. For example, one small unit leader described revising his platoon's table of organization to reflect the structure and functions of a battalion, with members of the platoon assuming responsibility for intelligence and operations roles.[9] Another small unit leader identified specific administrative, logistics, intelligence, and communications functions that were needed, and then created a team of eight Marines to assume roles that would normally be present at the battalion level.[10] However, as several of the Marines interviewed by the committee at Quantico pointed out, these ad hoc in-theater augmentations would not be necessary if smaller units were provided with trained

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[5]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[6]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[7]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[8]The terms "tactics," "techniques," and "procedures" are often used together, although each term has its own definition: see TRADOC Reg. 25-36 (Department of the Army, Training and Doctrine Command, the TRADOC Doctrinal Literature Program [DLP], Fort Monroe, Va., October 1, 2004; supercedes regulation dated April 5, 2000). Tactics are "the employment and ordered arrangement of forces in relation to each other." Techniques are "non-prescriptive ways or methods used to perform missions, functions, or tasks." Procedures are "standard, detailed steps that prescribe how to perform specific tasks." (See JP 1-02 [Joint Publication 1-02. 2010. *Department of Defense Dictionary of Military and Associated Terms* (as amended through May 15, 2011), November 8; available at http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf. Accessed June 8, 2011.])

[9]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[10]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

personnel who could support basic functions such as intelligence, logistics, and command and control. For example, the ability to communicate reliably and clearly with fellow Marines and with more senior command echelons is extremely important, particularly when small units are operating for long periods of time at significant distances from the forward operating base.

The Marine Corps is aware of the need to provide a fuller complement of both materiel and personnel resources to companies, platoons, and squads operating in a distributed mode. In particular, the Marine Corps Warfighting Laboratory (MCWL) has conducted a number of Limited Objective Experiments (LOEs) examining how new technology and organizational augmentations can support small units in distributed environments. For example, the MCWL's Limited Objective Experiment 4 (LOE4) emphasized the provision of communications and computing technologies to enhance company effectiveness in distributed operations. The technologies tested included the Distributed Tactical Communications System (DTCS), a radio based on the Iridium satellite constellation; TrellisWare radio, a mesh-networked radio; and the Tactical Ground Reporting (TIGR) system, a software program for data management and display.[11] Every Marine in the rifle company was given a radio (usually a company does not have more than one radio per squad).[12] In the experiment, the communications suite provided high-quality on-the-move and out-of-sight communications; however, the MCWL has also indicated that new TTPs are needed to take advantage of this new capability.[13] In addition, the extent to which these advanced communications capabilities are now made regularly available to Marine small units today is unclear.

The MCWL has also developed and experimented with organizational changes at the company level, such as the company-level intelligence cell (CLIC) and the company-level operations cell (CLOC). The CLIC is intended to "standardize the training, manning, and equipping needed for intelligence collection and dissemination" at the company level, and the CLOC will provide company commanders with the ability to coordinate fires and logistics over a large area of operations.[14] To evaluate these innovations, the MCWL has sponsored LOEs and pursued limited in-theater deployment of CLIC and CLOC units. Data gathered on CLIC and CLOC impact validated the need and usefulness of changes to the

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[11] Vincent J. Goulding, Jr., Marine Corps Warfighting Laboratory, "Enhanced Company Operations (ECO) Limited Objective Experiment 4 (LOE4) and Enhanced Marine Air-Ground Task Force Operations (EMO) Way Ahead," presentation to the committee, Washington, D.C., August 5, 2010.

[12] Grace V. Jean. 2010. "Radios for Every Infantryman: Marine Company Tests Experimental Communications Gear," *National Defense*, October.

[13] Vincent J. Goulding, Jr., Marine Corps Warfighting Laboratory, "Enhanced Company Operations (ECO) Limited Objective Experiment 4 (LOE4) and Enhanced Marine Air-Ground Task Force Operations (EMO) Way Ahead," presentation to the committee, Washington, D.C., August 5, 2010.

[14] Kimberly Johnson, 2008, "Marine Companies Win Praise, But Also More Responsibility," *National Defense,* December; Vincent J. Goulding, Jr., Marine Corps Warfighting Laboratory, 2008, "Enhanced Company Operations: A Logical Progression to Capability Development," *Marine Corps Gazette* 92(8).

company's organization; in particular, the presence of the CLIC improved situational awareness, reduced intelligence processing time, and mitigated uncertainty for the company commander.[15,16]

Lastly, the committee is aware that the Marine Corps is developing and implementing training that will prepare Marines to deal with the specific needs of their deployment location and mission. Such training may help small units cope with the resource challenges that they face with distributed operations. For example, one Marine captain deployed in a very remote and mountainous area told the committee that the vehicles provided in-theater were old and prone to breaking down. He felt fortunate to have taken a driving course that gave him skills in preventative vehicle maintenance and repair. This was not a course that most Marine officers are required to take, but it was critically important to the success of his unit's deployment.[17]

2.2.2 Mission Diversity

In Iraq and Afghanistan, combat operations have represented only one element of the USMC mission. In listening to Marine small unit leaders describe their experiences in Iraq and Afghanistan, the committee gained appreciation for the complexity of the small unit leader's job. Effective stabilization and reconstruction efforts are critical in counterinsurgency warfare, which posits that functioning civil institutions and economic opportunity serve as a powerful inoculation against social instability and violence. The small unit leaders interviewed by the committee described a diversity of missions, including securing a village decimated by Taliban fighters to enable people to rebuild their homes, interdicting border incursions, professionalizing national military forces, building an urban police force, collecting intelligence, coordinating medical care for local female populations, sweeping for IEDs, and locating and interdicting insurgents. This list is not exhaustive, but it does illustrate the range of responsibilities that small unit leaders face when deployed.

To complicate matters, Marines who are engaged in stabilization-and-reconstruction-type missions are also likely to encounter situations in which the use of force becomes necessary. In a volatile operational environment, apparently calm situations can degrade into full combat with little warning. In such situations, an optimal course of action may not be immediately apparent, given that immediate actions can have longer-term second- and third-order effects. One small unit

[15]The development of doctrine for CLICs is a top priority for the Marine Corps. See http://www.marines.mil/news/messages/Pages/MARADMIN628-10.aspx. Accessed December 3, 2011. The status of the concept of CLOCs is uncertain.

[16]Vincent J. Goulding, Jr., Marine Corps Warfighting Laboratory, "Enhanced Company Operations (ECO) Limited Objective Experiment 4 (LOE4) and Enhanced Marine Air-Ground Task Force Operations (EMO) Way Ahead," presentation to the committee, Washington, D.C., August 5, 2010.

[17]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

leader involved in a firefight when insurgents attacked a village had to decide whether to help a village elder who had been shot by insurgents or to pursue and destroy the insurgents. He chose to provide emergency medical care for the elder and, in doing so, won the trust of the village but failed to interdict the insurgents. Over the long run, he felt that this was the best outcome, since village residents began to provide the Marines with information on IED emplacements.[18] Another small unit leader told committee interviewers that shifting gears from an aggressive stance to a more "humanitarian" mission and vice versa was difficult. He described having to effect dramatic changes in perspective and attitude for himself and his Marines several times a week, and often on a daily basis.[19] Similarly, a captain with deployment experience in both Iraq and Afghanistan described himself as both "diplomat and warfighter," commenting that successful small unit leaders can move fluidly from one role to another as situations demand.[20]

To complicate matters further, the small unit's adversaries are often members of the very community with which the Marines are trying to build trust relationships. Interdicting adversaries—for example, insurgents who are building and deploying IEDs—is critical for the safety and survival of the Marines. However, identifying adversaries may require actions that are detrimental to trust relationships, such as conducting surprise house searches or arresting village residents. Operations such as these require finesse and nuanced judgment, because Marines may interact with local populations in ways that can easily be perceived as invasive or offensive. These can include entering homes to search for weapons, briefly assuming control of living spaces while conducting patrols to observe street activities without being seen, and even living in homes for short periods of time. Local populations can easily be alienated by overwhelming displays of force. One small unit leader attributed his success in confiscating a prohibited weapon to his positive relationship with a village elder: he was able to purchase the weapon with little fuss. He contrasted this experience with another small unit leader who decided to bring in tanks to threaten a village into surrendering its prohibited weapons. The village emptied, the weapons were never confiscated, and any trust between U.S. forces and the local population was damaged.[21, 22]

Coupled with geographic dispersion, the diversity and volatility of the hybrid environment add even more complexity to small unit decision making and further underscore the importance of training and equipping small units for success. Marine small units and their leaders often interact with and coordinate

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[18]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[19]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[20]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[21]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[22]For one study relating nonviolent counterinsurgency efforts such as the provision of services to successful outcomes, see Eli Berman, Jacob Shapiro, and Joseph Felter, 2011, "Can Hearts and Minds Be Bought? The Economics of Counterinsurgency in Iraq," *Journal of Political Economy* 119(4):766-819; available at http://dss.ucsd.edu/~elib/ham.pdf. Accessed August 26, 2011.

missions and responsibilities with actors from many institutions and countries. Cross-cultural, cross-institutional relationship building in a war zone is no easy task, and success may depend on a mixture of personal disposition toward this kind of work as well as training and experiential learning.

Ideally, such operations would be assigned to experienced and mature military personnel. However, the average age of the Marine Corps in 2010 was 22, and 67 percent of deployed Marines were in their first term of enlistment.[23] The youth and inexperience of the USMC's "strategic corporal" puts a greater burden on company, platoon, and squad leaders to provide effective discipline, guidance, and support to Marines in their unit, while also demonstrating judicious decision making. As one captain told committee interviewers, companies and noncommissioned officers (NCOs) can have strategically significant results depending on their effectiveness in identifying enemies and establishing productive relationships with local populations.[24]

Given the youth of the force, the complexity of hybrid environments, and the diversity of missions, both the selection and the training of small unit leaders and their Marines deserve sustained attention and investment. The Marine Corps currently has no formal policy for directing Marine commands, from the battalion on down, on how to select small unit leaders at the company, platoon, or squad levels.[25] However, the leadership aptitude, style, and qualities of individual small unit leaders become more important as small units shoulder increasingly significant responsibilities in field. For example, one captain who participated in the Quantico interviews enthusiastically described his experience leading an embedded training team in Afghanistan. In relating his experience, he emphasized that an individual's openness to other societies and cultures is critical for the effective pursuit of counterinsurgency operations. To underscore this point, he described a conflict that broke out between the leader of an Afghan "kandak"—roughly the equivalent of an battalion—and a company commander who was assigned to support the professional development of in-country military and civilian security forces in a remote area of Afghanistan. This particular company commander had difficulty adjusting to the region's culture. At one point, he became argumentative with the leader of the kandak, and the two exchanged religious and cultural slurs. This incident quickly scaled the chain of command in both the Afghan and American forces. In recounting this story, the interviewee told committee members that he wished that his superior officers had paid more attention to how small unit

[23]Dennis Judge, Ground Training Division, U.S. Marine Corps Training and Education Command, "USMC Systems Approach to Training," presentation to the committee, Washington, D.C., September 27, 2010.

[24]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[25]MajGen Raymond Fox, USMC, Commanding General, USMC Training and Education Command, personal communication to General Michael Williams, USMC (Ret.), committee co-chair, November 17, 2011.

leaders were selected for particular roles and missions. Some small unit leaders, he said, "have no business being part of an advisory group" in Afghanistan.[26]

Predeployment training and education are also important for small units and their leaders. Considering the diversity of the activities in which Marines are engaged, "core competencies" seem to have evolved beyond the traditional areas of weaponeering, patrolling, conducting offensive and defensive operations, providing fire support, and common combat tasks.[27] In addition to these basics, Marines must be able to assess emerging events and make these decisions in highly unfamiliar cultural, religious, and linguistic contexts, with people who may or may not support U.S. military operations in their country. For example, skilled interpreters are critically important in any mission that requires effective communication and partnership with local communities. However, one small unit leader pointed out that effectively working with a native language interpreter is not a straightforward process. He thought that it required training and wished he had been provided more thorough preparation in the mechanics of communicating with local populations through an interpreter.[28]

The Marine Corps recognizes the importance of developing new approaches to training small units and their leaders to be successful in the volatile settings in which hybrid warfare occurs. Both the MCWL and the Training and Education Command (TECOM) are pursuing new approaches to equipping and training Marines for hybrid warfare. The Corps is using its Systems Approach to Training (SAT) to ensure that Marines receive battlefield-relevant preparation. The SAT paradigm calls for ongoing analysis, design, development, implementation, and evaluation of training programs. In this model, training and readiness standards are updated on approximately a 2-year cycle to incorporate information from operational after-action reviews and lessons learned.[29] In addition, the Corps encourages ongoing training, after-action reviews, and critiques at the unit level in order to promote unit cohesion and learning.

To ensure that training curricula and structures are preparing Marine small units for the diverse demands of hybrid warfare, TECOM is working to identify and define the competencies needed by both enlisted Marines and officers at all grades. In addition to the traditional warfighting skills, emerging training approaches are focused on developing cognitive, psychomotor, and affective skills in small unit leaders, with an emphasis on cultivating intuitive decision making in

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[26]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[27]Dennis Judge, Ground Training Division, U.S. Marine Corps Training and Education Command, "USMC Systems Approach to Training," presentation to the committee, Washington, D.C., September 27, 2010.

[28]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[29]Dennis Judge, Ground Training Division, U.S. Marine Corps Training and Education Command, "USMC Systems Approach to Training," presentation to the committee, Washington, D.C., September 27, 2010.

company commanders and their constituent small units.[30] The USMC approach has been strongly influenced by the Recognition Primed Decision-making model, to which both the Marine Corps and the U.S. Navy have subscribed for more than two decades. TECOM has recently identified intuitive decision making as an important set of skills for small unit leaders in particular.

Implementing novel approaches to training is challenging for a number of reasons, however. First, and perhaps most importantly, Marine units must already undergo a great deal of training, and time for additional training is already limited. Secondly, the Marine Corps lacks a coordinating responsible organization to unify efforts around training oriented toward decision making.[31] In addition, as of the summer of 2010, TECOM had defined neither requirements nor standards for the cognitive, social, or relational skills desired in company commanders and other small unit leaders.[32]

Nonetheless, the Marine Corps is investing in education and training to develop skills that support cross-cultural interaction for diverse missions. It is also providing Marines with predeployment education and training in both language and cultural interactions. As discussed in Chapter 1, the Center for Advanced Operational Culture and Learning (CAOCL) provides both language and cultural training to help Marines engage productively with local populations. Two Marine small unit leaders who received CAOCL training said that it helped them "get past the barriers, jump in, and gain trust quickly."[33] Even so, personnel gaps in small unit-level capabilities may not be fully resolved by predeployment language and cross-cultural interaction training. For example, despite having received some training in local languages, several small unit leaders told the committee that they would have preferred working with a skilled interpreter to support interactions with local populations.[34] Unfortunately, skilled interpreters are scarce below the company level.

The committee is aware that the Department of Defense is investing in research and development (R&D) to support better understanding of the sociocultural and behavioral factors that may influence human behavior for a diversity of missions. Such projects fall under the broader Office of the Secretary of Defense (OSD) Office of the Director of Defense Research and Engineering (DDR&E)

[30]Dennis Judge, Ground Training Division, U.S. Marine Corps Training and Education Command, "USMC Systems Approach to Training," presentation to the committee, Washington, D.C., September 27, 2010.

[31]Dennis Judge, Ground Training Division, U.S. Marine Corps Training and Education Command, "USMC Systems Approach to Training," presentation to the committee, Washington, D.C., September 27, 2010.

[32]Dennis Judge, Ground Training Division, U.S. Marine Corps Training and Education Command, "USMC Systems Approach to Training," presentation to the committee, Washington, D.C., September 27, 2010.

[33]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[34]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

rubric of Human Social Behavioral Cultural R&D, which emphasizes computational modeling and simulation as an analytical methodology and a deployment vehicle. These R&D projects, many of which are managed by the ONR, seek to "provide analysis methods and computational models to support course of action decisions and operational planning."[35] Such technologies may eventually benefit Marines, but persistent challenges exist for developing, evaluating, and deploying computational models in the sociocultural and behavioral areas.[36] In particular, there is a well-recognized need to develop "processes, procedures, and training to ensure appropriate use" of modeling and simulation technologies for in-theater decision making.[37] Regardless of how computational methodologies evolve in this domain, the historical, political, economic, and cultural knowledge acquired as part of computational social modeling and simulation research may be useful in enhancing the content of Marine Corps training.

2.2.3 The Adaptive Adversary

Stabilization, reconstruction, and other nonkinetic projects would require intense cognitive work, even if Marine small units were not operating at significant geographic distances from one another, and even if they were not taking place in the context of an insurgency. However, Marines in Iraq and Afghanistan are also fighting an intelligent, determined, and adaptive insurgency for which traditional force-on-force TTPs are poorly suited.[38] In Iraq and Afghanistan, traditional warfare is the exception, insurgency is the norm, and IEDs can inflict tremendous damage on U.S. forces. Because insurgents are members of local populations, it can be difficult for Marines to distinguish adversaries from neutral members of a population, and insurgent activities may not be easily discriminable from the normal patterns of life in a region.

ONR's George Solhan observed to the committee that "irregular threats are exceptionally difficult to template."[39] Indeed, the fact that adversaries in Iraq and Afghanistan are observant, adaptive, and easily embedded in local populations presents tremendous challenges for "sensemaking" among small units and their leaders. As discussed in Chapter 3, "sensemaking" is a term used by organiza-

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[35]Ivy Estabrooke, Office of Naval Research, "Social Cultural Knowledge for Decision Making," presentation to the committee, Washington, D.C., August 5, 2010.

[36]Computational models are discussed further in Chapter 3, in the section titled "3.3 Engineering Approaches to Support Decision Making."

[37]Ivy Estabrooke, Office of Naval Research, "Social Cultural Knowledge for Decision Making," presentation to the committee, Washington, D.C., August 5, 2010.

[38]For a review of terrorism research using economic analysis including game theory based on the adaptive enemy, see Todd Sandler, 2009, "The Past and Future of Terrorism Research," *Revista de Economia Aplicada* XVII(50):5-25. Available at http://www.utdallas.edu/~tms063000/website/Future_Terrorism_REA2009.pdf. Accessed August 26, 2011.

[39]George Solhan, Office of Naval Research, "ONR Portfolio, Overview on Operational Adaptation," presentation to the committee, Washington, D.C., August 5, 2010.

tional researchers and decision scientists to describe how humans develop, assess, negotiate, and evolve frames of reference that provide meaning and structure to otherwise-ambiguous events. Both the ability to establish a working sense of "what's going on here" and the ability to communicate effectively about how events are unfolding in relation to that working narrative are critical if small units and their leaders are to assess and respond effectively to threatening situations.[40]

As several small unit leaders pointed out, adversaries have the advantage of operating relatively fluently in linguistic, cultural, and geographical territories and can hide their activities in plain sight. One Marine captain described how an insurgent could almost invisibly plant an IED in a public square in an urban area of Iraq by walking through a crowded intersection during a busy time of day, dragging the device into place using a thin cord attached to his or her body; when the device was in place, the insurgent would surreptitiously cut the cord and walk away. Not only was it difficult to see the cord from the observation post, but the Marines could not easily distinguish the individual performing the placement from the scores of other people walking through the streets.[41]

Moreover, as members of local populations, insurgent adversaries can unobtrusively observe unit operations, analyze them for vulnerabilities, and then adjust their own strategies to undermine Marine TTPs.[42] This means that even when Marines do manage to "decode" adversary strategies and implement countermeasures, the efficacy of the countermeasures may be time-limited. The small unit leaders interviewed by the committee at Quantico mentioned numerous examples of this kind of adaptation. For example, one Marine squad leader told the committee how Taliban fighters in a remote area of Afghanistan observed his Marine patrol using a metal detector to search for IEDs located along footpaths. Within a few days, the Taliban fighters had changed tactics, burying pressure plates under pieces of wood to defeat the metal detector. As a consequence, this sergeant lost one of his squad members during a routine patrol when the metal detector did not signal the presence of a pressure plate.[43] Another Marine described a standard defensive strategy of stopping his unit about 300 meters from a suspected IED before attempting to investigate it so as to maintain a minimum safe distance from a possible explosion. Observing this defensive tactic, the local insurgents began setting out fake IEDs in public areas to "lure" the Marines to investigate. The real IED was actually located at the expected 300-meter stopping point so that when

[40]See Gary A. Klein, Brian Moon, and Robert R. Hoffman, 2006, "Making Sense of Sensemaking 1: Alternative Perspectives," *IEEE Intelligent Systems* 21(4):70-73; also Karl Weick, 1988, "Enacted Sensemaking in Crisis Situations," *Journal of Management Studies* 25:305-317; and Karl Weick, 1993, "The Collapse of Sensemaking in Organizations: The Mann Gulch Disaster," *Administrative Science Quarterly* 3:628-652.

[41]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[42]George Solhan, Office of Naval Research, "ONR Portfolio, Overview on Operational Adaptation," presentation to the committee, Washington, D.C., August 5, 2010.

[43]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

the patrol had dismounted, the insurgents would remotely detonate the explosive in close proximity to the patrol.[44]

Anticipating and countering the evolution of adversary tactics require a great deal of support for sensemaking among small units and their leaders. The quality, timeliness, and accuracy of information that can support the development and evaluation of frames of reference is critical if Marines are to identify and respond to novel threat patterns.

Over the past decade, the Marine Corps has employed established protocols and procedures to collect, process, and disseminate information about emerging trends and events on the battlefields of Iraq and Afghanistan. For example, one protocol outlines procedures for transferring authority to incoming units and conducting intelligence operations. Such information can help Marines develop the frames of reference required to effectively assess and respond to events in their area of responsibility (AOR). For example, Marine small unit leaders pointed out that the basic procedures governing the transfer of authority were a critical starting point for developing situational awareness during the early days of a deployment. When Marine units rotate into a new area, the unit that is leaving typically provides extensive information and lessons learned to the small unit leaders and personnel who will be taking over responsibility. Several of the small unit leaders who met with the committee indicated that this "right seat-left seat" transfer of authority provides critical and up-to-date information about the history, people, sites, and status of the new unit's AOR.[45] To the degree that such mechanisms facilitate the accurate transfer of information about patterns of life in an area, they can help new units establish a basic sense of what is normal and what requires attention.

However, as several Marine small unit leaders explained, members of insurgency groups are not unaware of this transfer and can leverage it to their tactical advantage. One Marine small unit leader dryly observed that Afghan insurgents "like to test" new units.[46] He described how an insurgent group in his company's AOR radically changed its TTPs for emplacing and detonating IEDs just as the Marines in his company were becoming familiar with patterns of life in the region.

To counter adversary operations successfully, small unit leaders must remain a step ahead of the adversaries' learning curve. This entails recognizing when adversary tactics have changed and developing appropriate countermeasures, and/or devising ways to keep the adversary from being able to predict the actions that a unit will take.[47] For example, one small unit leader emphasized the importance

[44]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[45]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[46]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[47]For recommendations on basic research needs for countering IEDs that note the importance of "recognizing that insurgents/terrorists will change their behavior," see National Research Council, 2007, *Countering the Threat of Improvised Explosive Devices: Basic Research Opportunities (Abbreviated Version)*, The National Academies Press, Washington, D.C.

of "mixing things up"[48] when conducting IED sweeps.[49] Another squad leader described being deployed to a remote village where the insurgency was very active. IEDs were a near-daily threat, and he recognized that his unit was having difficulty getting accustomed to dealing with the prevalence of IEDs and the rapid changes in adversarial tactics for placing them. He worked with his team leaders to develop an in-field "training" exercise so that his Marines practiced IED encounters using pressure plates that detonated a small explosive charge at a safe distance from the simulated patrol. He believed that this exercise improved both the reaction time and the quality of his Marines' response to IED threats, although he noted, "You never become accustomed to it."[50]

Gaining access to timely and relevant intelligence improves the small unit's ability to assess and address insurgency activities in its AORs. Timely and relevant information about local trends and events is critically important for the efficacy of small units.[51] However, problems with communications equipment, coupled with the relative scarcity of trained intelligence personnel below the battalion level, present significant challenges to developing actionable and relevant intelligence.

Even when small units can access battalion or coalition intelligence assets, the available information may not be relevant to a unit's AOR. For example, when asked to assess the quality of intelligence provided by coalition forces in Iraq, one small unit leader told the committee: "Ninety percent of the time, nothing came from coalition forces. Anything worth a damn came from the locals."[52] Another sergeant described insufficient intelligence from his battalion command and the lack of embedded intelligence functions as particularly frustrating problems. This was particularly the case in regard to knowledge of adversaries' IED-related TTPs, which evolved on a weekly basis. Realizing that intelligence from his command was unlikely to help him keep track of trends in IED emplacements, he learned to rely on the explosive ordnance device clearing teams for information about evolving adversary tactics. One squad leader related his unit's philosophy of intelligence: waiting for good intelligence to arrive, he said, was a bit like waiting for cold beer to deliver itself. "Beer won't come out of the refrigerator to you, and we realized that intelligence wasn't going to deliver itself either. We decided that we should just go and get the intelligence we needed ourselves."[53]

A number of the interventions described above, including immersive, scenario-based training and CAOCL culture and language resources, may be important in helping small units prepare for the dynamic threat environments

[48]For a classic example of "mixed strategy," see R.S. Beresford and M.H. Peston, 1955, "A Mixed Strategy in Action," *Journal of the Operational Research Society* 6(4):173-176.

[49]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[50]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[51]Gen Charles C. Krulak, USMC, Commandant of the Marine Corps. 1997. *Intelligence*, Marine Corps Doctrinal Publication 2, Headquarters Marine Corps, Washington, D.C., June 7, p. 5.

[52]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[53]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

and adaptive adversaries in hybrid warfare. For example, as discussed above, the Marine Corps Warfighting Laboratory has developed a number of concepts to support Marine small units in gathering and making sense of information about trends and events in their areas of operation. Both company-level operational cells and company-level intelligence cells acknowledge the importance of approximating at least some battalion-level functions among smaller units. Although MCWL LOE activities indicated significant benefits from incorporating CLOC and CLIC functions into companies, the committee was unable to determine whether these resources are now a "normal" part of deployment. Nor did the committee attempt to evaluate the impact of CLOC and CLIC functions in real-world theater situations, although it was provided with MCWL assessments of the impact of CLOC and CLIC on LOE outcomes.[54]

Novel predeployment training is also providing Marines with the skills necessary to operate in Iraq and Afghanistan. For example, several small unit leaders described how Combat Hunter training taught them to identify physical evidence and particular patterns of behavior indicative of IED-related activities. In addition, immersive scenario-based training, such as that offered during Mojave-Viper training and at the Infantry Immersion Trainer (IIT) facility at Camp Pendleton, California, can afford Marines an opportunity to experience situations that closely resemble what they are likely to encounter in-theater. However, ensuring that theater-specific skills and scenario-based training are relevant to the environments that Marines are likely to encounter is challenging because the environment is changing so quickly. Maintaining realism and relevance depends on the regular and consistent debriefing of small unit leaders and their Marines to ensure that scenarios approximate what units are likely to encounter in-theater.

At least some immersive training curricula incorporate the recent experiences of Marines in Iraq and Afghanistan. For example, when members of the committee visited the IIT facility at Camp Pendleton in October 2010 to observe the FITE Joint Capability Technology Demonstration (JCTD), the IIT's leadership told the committee members that they had conducted extensive interviews with recently deployed Marines to gather information on the kinds of decision making situations that small units face in-theater. They said that they used this information to develop training scenarios that can be varied across units and from training session to training session so that Marine small units have some exposure to the kind of ambiguous and unpredictable environments that they are likely to encounter when deployed. In addition, the units that went through the FITE scenario were required to conduct an immediate and extensive after-action review in which the squad leader reviewed the events with his Marines and the unit discussed strategies to improve its overall performance in similar situations. Such training can expose

[54] Vincent J. Goulding, Jr., Marine Corps Warfighting Laboratory, "Enhanced Company Operations (ECO) Limited Objective Experiment 4 (LOE4) and Enhanced Marine Air-Ground Task Force Operations (EMO) Way Ahead," presentation to the committee, Washington, D.C., August 5, 2010.

small units to the kind of complex, rapid sensemaking that insurgency warfare demands by providing Marines with predeployment immersive, scenario-based training and encouraging constructive after-action reviews.

Yet the extent to which all small units have access to such immersive predeployment training is not clear. Moreover, established Marine Corps knowledge management approaches, such as lessons learned, may not move quickly enough to support the development of effective scenario-based training. For example, the Marine Corps Center for Lessons Learned does develop and disseminate reports derived from theater experience. As noted above, the System Approach to Training used by TECOM calls for the incorporation of lessons learned into predeployment training, as well as reviews and updates of training curricula on a biennial basis. However, developing and validating lessons learned products can take well over a year: in one interview with the committee, a small unit leader referred to a 35-page document reporting what he believed were critically important lessons derived from his unit's deployment in Afghanistan. Although the events had taken place in 2009, the lessons learned after-action report was not released to the Corps until nearly a year later.[55]

The committee heard from multiple presenters about R&D activities that are aimed at augmenting situational awareness among Marines so that they might more effectively anticipate the insurgency's evolution, counter it, and minimize casualties along the way. Some of these technologies, such as the TIGR platform, may help to capture and communicate unit experiences across the Marine Corps, although the committee did not evaluate any specific research effort or technology.[56] However, technologies that are pushed onto Marines without thorough evaluation and feedback from the operational users can be burdensome to deployed units if they do not work properly. For example, one small unit leader described a very high frequency communications package that would support long-range communication among squads and with company command. Unfortunately, the system was so cumbersome and uncomfortable that the sergeant's squad members rarely used it, choosing to rely instead on personal radios despite the radios' limited range.[57]

2.2.4 Rules of Engagement

The topic of rules of engagement (ROE) is a complicated one; it has received a great deal of media, congressional, and public attention. The committee did not review current ROE, and evaluation of ROE was not included in its terms of reference. However, this topic came up several times in committee interactions

[55]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

[56]Mari Maeda, Defense Advanced Research Projects Agency, "TIGR: Tactical Ground Reporting System," presentation to the committee, Washington, D.C., November 15, 2010.

[57]USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

with small unit leaders, who often described situations in which the ROE had entered into their decision making process and had affected their operational success in-theater.

The committee recognizes that ROE are intended to ensure the responsible and judicious use of force. In some situations, the decisions supported by the ROE are quite clear. One small unit leader described how his company came under fire in an urban residential area, an event that rapidly escalated into a major firefight. The unit positively identified a hostile act and needed to defend itself, which made it relatively easy to justify the use of force. He did not believe that the ROE were an issue in this situation and felt comfortable escalating the fight.[58]

However, several of the Marines interviewed described having to request permission to perform actions that they considered necessary for their mission. One small unit leader said, "We talk about decentralized command, but nobody trusted us with anything . . . we couldn't go from one area of the area of operation to another without submitting a convoy plan."[59] Another small unit leader described needing thorough justification to engage in offensive actions, including multiple intelligence sources about a target, mission briefs several days in advance of the operation, and approval from theater-level command. While he acknowledged that this was for the benefit of the larger military effort, he said that "this caused fire missions to be cancelled or denied during an engagement."[60] Not only do such requirements make rapid response to intelligence difficult, but small units may have a difficult time pulling together all the elements required to justify an offensive mission.

Situations in which the ROE require Marines to get approval for using force can complicate decision making. One small unit leader described coming under intense fire while patrolling a local market. The shots were being fired from buildings with thick walls that made it impossible to hit any of the insurgents firing on the patrol. As the small unit was creating a casualty collection point, a mobile weapons platoon came along with a 50-caliber automatic weapon capable of penetrating the wall. However, the ROE required approval from higher-level authorities to fire the 50-caliber automatic weapon. Four minutes after the unit leader had made his request, the unit continued to take heavy fire, so he told the unit: "Just use the weapon. I'll take the hit." Approval to use the 50-caliber automatic weapon came 10 minutes later, nearly 5 minutes after the firefight was over. Later, the unit leader said, he was asked why he had decided to escalate force and was told that the locals were now afraid to enter the marketplace.[61]

[58] USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.
[59] USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.
[60] USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.
[61] USMC interviews with committee subgroup members, Quantico, Va., December 7, 2010.

This story illustrates the trade-offs inherent in the ROE between near-term personal and unit safety and the long-term success of the deployment as a whole. Also, in this case, command response time proved to be a challenge. ROE restrict the use of force to specific circumstances as a way of mitigating disastrous second- and third-order effects that can quickly emerge in the wake of firefights, particularly when civilians are injured or killed. In terms of the above unit's safety, the best course of action was to use the 50-caliber automatic weapon to gain a decisive tactical advantage over the people shooting at the unit. From a long-term perspective, however, the use of a heavy weapon in a public marketplace gave rise to a number of second- and third-order effects, including undoing progress that the unit had made in cultivating trust with the local population.

In this regard, it is difficult to separate the issue of ROE from the presence of the media. The 24-hour news channels and the Internet ensure that a constant flow of information about U.S. military activities is reaching audiences around the world. As a result, tactical decisions that make sense in one context can have negative strategic effects that influence the success of military operations locally, regionally, and internationally. For example, a firefight that leaves numerous civilians injured or dead can have tremendous ramifications for Marine and other U.S. military operations. Presumably, the Marines were following the ROE and acting morally in such a situation, but the amplifying effect of the media means that Marine "decisions will be subject to the harsh scrutiny of both the media and the court of public opinion."[62]

2.3 FINDINGS

Based on the committee's expertise and experience, along with its data-gathering efforts over the course of this study—including the limited interviews that it conducted with some Marine small unit leaders who had recently returned from deployment to Iraq and Afghanistan—the following are the committee's findings.

FINDING 1: The U.S. Marine Corps lacks up-to-date descriptions and requirements that define the job responsibilities of small unit leaders (company commanders, platoon leaders, and squad leaders), making it difficult to provide job-appropriate training and preparation for them. It is also difficult to assess the small unit leader's effectiveness in the operational environment. Furthermore, despite the fact that small unit leaders are assuming significant responsibilities, the Marine Corps has not established an institutional selection process for the positions of company commander and squad leader.[63]

[62]Gen Charles C. Krulak, USMC, Commandant of the Marine Corps. 1999. "Cultivating Intuitive Decision Making," *Marine Corps Gazette*, May, p. 18.

[63]A Corps-wide selection process for platoon leaders already exists. All Marine officers attend the Basic School, a 6-month, officers' school that equips them with the skills needed to serve as second

FINDING 2: The Marine Corps has invested in a number of novel approaches to training and education, such as Mojave-Viper, Combat Hunter, the Future Immersive Training Environment (FITE) of the Infantry Immersion Trainer facility, and the Center for Advanced Operational Culture and Learning. However, it is not clear whether novel training and educational opportunities are available to all small units and their leaders, nor has the Corps developed a formal training and development sequence which ensures that Marines are provided access to new training and educational opportunities at appropriate points in their careers. In addition, at the time that the committee was conducting its review, the Corps had not identified a responsible organization to ensure that such training and education programs are properly developed, staffed, operated, and evaluated for their efficacy.

FINDING 3: Training must evolve in tandem with the rapidly changing combat environment. However, the Systems Approach to Training relies on a 2-year cycle for evaluating and restructuring formal training practices. Given the rapid evolution of the combat environment, the penetration of knowledge from the battlefield into predeployment training is much too slow. In addition, the traditional mechanisms of the Marine Corps for capturing and transferring experiential knowledge, such as lessons learned, cannot keep pace with the evolution of operations. Marine small units are addressing this problem in-theater by developing training scenarios that exercise skills deemed necessary for the battlefield.

FINDING 4: Marine companies and their constituent small units are assuming responsibilities analogous to those of a battalion but are not provided adequate personnel or material support for critical functions, including logistics, intelligence, communications, and information technology.

FINDING 5: Small unit leaders lack adequate information and analytic support for the cognitive work of sensemaking and situational assessment. In particular, problems with intelligence collection and dissemination, coupled with the paucity of working communications equipment, inadequate bandwidth, and delays in response times from higher levels of command, are detrimental to both decision making and morale at the small unit level. In addition, delays associated with the formal capture, recording, and transfer of theater-related experiential knowledge (such as through lessons learned) make it difficult for deployed units to benefit from the recent experiences of other Marines.

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lieutenants. After completing their training at the Basic School, infantry officers attend the Infantry Officers School, and other officers attend schools of varying length in their occupational specialties. Their standing in these schools serves as the criteria for their selection as platoon leaders, since they have no operational experience.

FINDING 6: Marine small units and their leaders have spent the past decade conducting distributed operations in hybrid environments, facing a determined and observant insurgency while conducting a range of humanitarian, stabilization, and reconstruction activities. Not only have these units and their leaders become extremely adept at making do with limited resources, but they have also developed unique skills, understanding, and insights related to the conduct of hybrid operations in counterinsurgency warfare in Iraq and Afghanistan. As they return to garrison, small units and their leaders bring with them a wealth of knowledge about these environments, as well as key insights into what tools, technologies, training, and other support elements are most important for the successful conduct of operations. Without mechanisms to capture and build on the unique experiential knowledge of small unit leaders, the Marine Corps could easily lose this tremendous resource.

Finally, as discussed above, Marine small unit leaders are dealing with considerable challenges related to the conduct of hybrid, counterinsurgency warfare that involves complicated stabilization and reconstruction operations and the building of political and cultural rapport with local populations while also facing an intelligent and adaptive adversary. Marine small unit leaders are addressing such challenges while dispersed in small units across broad geographical areas and are often minimally resourced for the situations that they are likely to encounter.

The committee commends Marine Corps leadership for recognizing that small units are assuming new levels of responsibility for the success of counterinsurgency efforts in hybrid environments. These missions require a great deal of intense cognitive work, problem solving, and decision making under conditions of uncertainty and ambiguity. Accordingly, in Chapter 3, the report focuses on the scientific and engineering research related to individual and team cognition, sensemaking, and decision making. In doing so, the committee has attempted to identify both established and emerging approaches to understanding human cognitive processing and decision making, with the goal of helping the Marine Corps leverage scientific and engineering R&D to support small unit leaders.

3

Scientific Basis and Engineering Approaches for Improving Small Unit Decision Making

The topic of decision making has been studied in a number of fields, and each offers possibilities for improving the decision making abilities of small unit leaders given the operational and technical challenges facing small unit leaders in today's operational environment, the existing abilities of the Marine Corps, and the findings presented in Chapter 2. The breadth of material related to decision making is substantial and beyond the scope of this report. What follows is a selective review based on the knowledge and experience of the committee members who were particularly interested in reviewing theories and perspectives that could address the operational gaps identified in the previous chapter and that would lead to actionable recommendations. This is an area where committee members are not in unanimous agreement. While the material in this chapter represents the majority opinion, a dissent can be found in Appendix G.

No single theory of decision making or human performance can account for the complex and diverse decisions that small unit leaders must make. The nature of the decision and the context in which it occurs will instead have an effect on which theories (and associated interventions) best support improved decision making performance. The committee focused on two areas: the scientific basis for decision making (cognitive psychology, cognitive neuroscience), and engineering support for decision making (engineering approaches to support decision making, physiological monitoring, and augmented cognition).

Philosophers and historians of science, most notably Thomas Kuhn, describe the evolution of scientific inquiry in any field of knowledge according to phases. Fields that have developed a scientific approach are said to have "paradigms,"[1]

[1]Thomas S. Kuhn. 1977. *The Essential Tension: Selected Studies in Scientific Tradition and Change,* University of Chicago Press, Chicago, Ill., p. 294.

which are shared commitments to a certain understanding of the real world among members of a scientific group. Paradigms are used to guide the collection of data through normal science.[2] Those efforts produce results that are often consistent with (and at times anomalous with respect to) the group's accepted rules. Those in the group who are bothered by anomalies eventually instigate research efforts to challenge, not to reinforce, the paradigm.[3] This perceived failure of the existing rules creates a prelude to the search for new rules. The revolutionary science that ensues strives to develop a new set of rules that will better fit both the accepted and the anomalous data. This effort often involves the pursuit of a new language to represent the new model.[4] After the acceptance and adoption of a new paradigm, normal science resumes.

Regarding the stages of evolution among the fields of knowledge that this report considers, naturalistic decision making (NDM) has evolved into normal science since its inception in the late 1980s. However, other fields that the chapter refers to are in earlier stages of evolution and have potential to change accepted models of thought. Cognitive neuroscience is an example of a field that may provide a deeper understanding of decision making over the longer term.

This chapter is organized in three major sections and closes with a brief summary and the committee's seventh and final finding. The first major section, "3.1 Cognitive Psychology," summarizes one aspect of the scientific basis for understanding decision making: the broad field of cognitive psychology, including prescriptive and descriptive approaches, and the emerging field of resilience theory. The next major section, "3.2 Cognitive Neuroscience," summarizes a second aspect: the emerging field of cognitive neuroscience and its potential for understanding the fundamental neurophysiological mechanisms underlying human decision making. The last major section, "3.3 Engineering Approaches to Support Decision Making," provides a broad overview of existing and potential engineering approaches to aiding the decision maker, including approaches to information integration, tactical decision aiding, human-computer interface (HCI) design, and physiological monitoring and augmented cognition. Also included in that section is a brief discussion of human-centered design methods that can help develop promising concepts related to decision aiding into *useful* and *usable* decision aids for the small unit leader.

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[2]Thomas S. Kuhn. 1970. *The Structure of Scientific Revolutions,* 2nd ed., University of Chicago Press, Chicago, Ill., pp. 25, 68.

[3]Gary A. Klein. 1997. "An Overview of Naturalistic Decision Making Applications," p. 141 in C.E. Zsambok and Gary A. Klein (eds.), *Naturalistic Decision Making,* Lawrence Erlbaum, Mahwah, N.J.

[4]Thomas S. Kuhn. 2000. *The Road Since Structure: Philosophical Essays, 1970-1993,* University of Chicago Press, Chicago, Ill., p. 30.

3.1 COGNITIVE PSYCHOLOGY

Approaches to modeling human decision making behavior have evolved through various phases, as Figure 3.1 shows. According to *prescriptive theories,* such as economic theory[5] and expected utility theory,[6] humans consider available options in a formal and systematic way and then "choose the one with the highest expected return."[7] "Specifying principles and contraints derived from formal or mathematical systems such as deductive logic, Bayesian probability theory, and decision theory," normative research explores "how people *ought* to make decisions"; in this vein, "the need to improve decision making arises because human decision makers systematically violate normative constraints."[8] That is, people often do not behave in a manner that is consistent with what is prescribed by rational, optimized models. These normative approaches are described below.

In contrast, *descriptive models* were built to capture specific decision making processes based on the actual behavior of individuals and teams, typically within natural settings. Six cognitive approaches to descriptive modeling of decision making are reviewed below.

Finally, this section on cognitive psychology concludes with a discussion of *resilience,* what it means for decision makers operating in uncertain environments, and how resilience engineering can help improve decision outcomes in uncertain and rapidly changing situations.

3.1.1 Prescriptive Theories

3.1.1.1 Subjective Expected Utility[9]

Subjective expected utility (SEU) is a mathematical model regarding choice that is at the foundation of most contemporary economics, theoretical statistics, and operations research (OR). Blume and Easley consider SEU as one class of

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[5]John von Neumann and Oskar Morgenstern. 1947. (2007, 60th Anniversary Edition). *Theory of Games and Economic Behavior,* Princeton University Press, Princeton, N.J.

[6]Ralph L. Keeney and Howard Raiffa. 1993. *Decisions with Multiple Objectives: Preferences and Value Tradeoffs,* Cambridge University Press, New York.

[7]Christopher Nemeth and Gary A. Klein. 2011. "The Naturalistic Decision Making Perspective," in James J. Cochran (ed.), *Wiley Encyclopedia of Operations Research and Management Science,* Wiley, New York.

[8]Raanan Lipshitz and Marvin S. Cohen. 2005. "Warrants for Prescription: Analytically and Empirically Based Approaches to Improving Decision Making," *Human Factors* 47(1):102-120. See also Jonathan Baron, 2007, *Thinking and Deciding*, Cambridge University Press, New York.

[9]This section is taken in large part from: Herbert A. Simon, George B. Dantzig, Robin Hogarth, Charles R. Piott, Howard Raiffa, Thomas C. Schelling, Kenneth A. Shepsle, Richard Thaier, Amos Tversky, and Sidney Winter, 1986, *Research Briefings 1986: Report of the Research Briefing Panel on Decision Making and Problem Solving,* National Academy of Sciences, National Academy of Engineering, Institute of Medicine, National Academy Press, Washington, D.C.

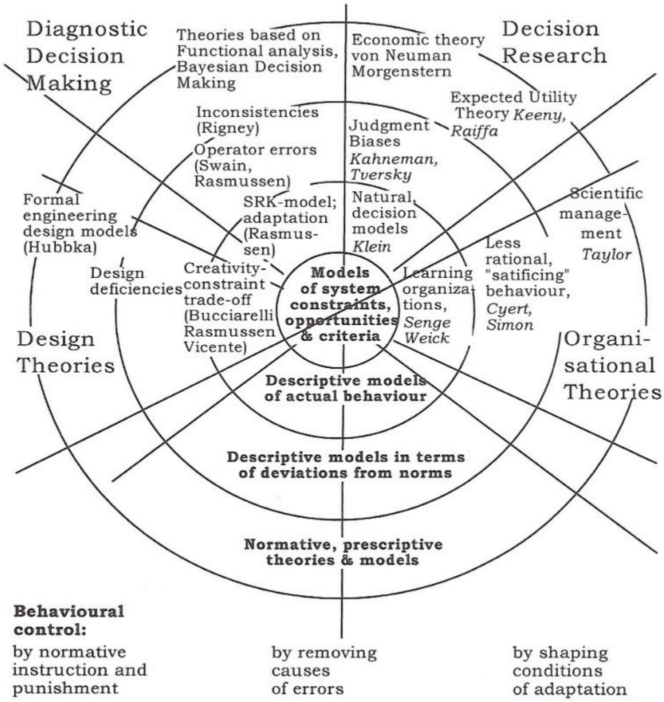

FIGURE 3.1 Behavioral modeling methods. SOURCE: © Ashgate Publishing. Reprinted with permission from: Jens Rasmussen. 1997. Figure 2 of Chapter 5, "Merging Paradigms: Decision Making, Management, and Cognitive Control," in Rhona Flin, Eduardo Salas, Michael Strub, and Lynne Martin (eds.), *Decision Making Under Stress: Emerging Themes and Applications,* Ashgate Publishing Company, Brookfield, Vt., p. 75.

decision models for choice under uncertainty, and its dominance was understandable at a time when few alternatives were available.[10]

SEU assumes that a decision maker has what is termed a "utility function"—an ordering, by subjective preference, among all of the possible outcomes of a choice. In SEU, all of the alternatives are known among which a choice can be made, and the consequences of choosing each alternative can be determined.

SEU theory makes it possible to assign probabilities subjectively, which opens the way to combining subjective opinions with objective data. SEU can also be used in systems that aid human decision making. In the probabilistic version of SEU, Bayes's rule prescribes how people *should* take account of new information and respond to incomplete information. Many of the modern approaches to

[10]Lawrence E. Blume and David Easley. 2007. "Rationality," in Lawrence E. Blume and Steven N. Durlauf (eds.), *The New Palgrave Dictionary of Economics,* June. Available at http://www.dictionaryofeconomics.com/dictionary. Accessed September 9, 2011.

optimizing operations research use assumptions of SEU theory, the major ones being that (1) maximizing the achievement of some goal is desired, (2) this can be done under specified constraints, and (3) all alternatives and consequences (or their probability distributions) are known. Satisfying these assumptions is often difficult or impossible in real-world situations.

3.1.1.2 Economic Model

Becker contends that "all human behavior can be viewed as involving participants who maximize their utility from a stable set of preferences and accumulate an optimal amount of information and other inputs in a variety of markets."[11] The economic, or rational-choice, approach equates human rational behavior with instrumentalist (especially economic) rationality. The rational-choice approach applies this concept to all rational activity and explains human behavior as economic rationality.[12]

3.1.1.3 Rational Actor

The rational-actor (also rational-choice) theory is used to understand economic and social behavior. In this instance, "rational" signals the desire for more of a good rather than less of it, under the presumption of some cost for obtaining it. Models used in rational-choice theory assume that "individuals choose the best action according to unchanging and stable preference functions and constraints."[13] These assumptions, however, are often violated under real-world conditions in which models are not rich enough to capture all of the behaviors that one might want to examine,[14] and actual behavior is not available for observation in the model.

According to Hedström and Stern, rational-choice sociologists typically "use explanatory models in which [individuals] . . . are assumed to act rationally . . . as conscious decision makers whose actions are significantly influenced by the costs and benefits of different action alternatives."[15] Rather than focusing on the actions of single individuals, most rational-choice sociologists seek to explain

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[11] Gary S. Becker. 1976. *The Economic Approach to Human Behavior,* University of Chicago Press, Chicago, Ill., p. 14.

[12] Milan Zafirovski. 2003. "Human Rational Behavior and Economic Rationality," *Electronic Journal of Sociology.* Available at http://www.sociology.org/content/vol7.2/02_zafirovski.html. Accessed September 2, 2011.

[13] See an entry title "Rational Choice Theory" at http://en.wikipedia.org/wiki/Rational_choice_theory.

[14] Lawrence E. Blume and David Easley. 2007. "Rationality," in Lawrence E. Blume and Steven N. Durlauf (eds.), *The New Palgrave Dictionary of Economics,* June. Available at http://www.dictionaryofeconomics.com/dictionary. Accessed September 9, 2011.

[15] Peter Hedström and Charlotte Stern. 2007. "Rational Choice and Sociology," in Lawrence E. Blume and Steven N. Durlauf (eds.), *The New Palgrave Dictionary of Economics,* June. Available at http://www.dictionaryofeconomics.com/dictionary. September 9, 2011.

"macro-level or aggregate outcomes such as the emergence of norms, segregation patterns, or various forms of collective action . . . [by studying] the actions and interactions that brought them about."[16]

3.1.1.4 Behavioral Decision Theory

In decision theory, making effective decisions relies on "understanding the facts of a choice and the implications of [making that choice] . . . well enough to identify [and carry through with] the option in one's own best interests" from among the available options.[17] As Fischhoff explains, choices are described in terms of the following:

- *Options:* "actions that an individual might [or might not] take";
- *Outcomes:* "valued consequences that might follow from those actions";
- *Values:* "the relative importance of those outcomes"; and
- *Uncertainties:* "regarding which outcomes will be experienced."[18]

These four elements are synthesized in decision rules that enable a choice among options. As a normative analysis, decision theory "can [help to] clarify the structure of complex choices" by identifying the best courses of action in light of the values that a decision maker holds.[19] Fischhoff also suggests that descriptive studies and prescriptive research complement normative analysis and should be used iteratively, because (1) "descriptive research [such as approaches described in the next subsection] is needed to reveal the facts and values that normative analysis must consider," and (2) "prescriptive interventions are needed to assess whether descriptive accounts provide the insight that is needed in order to improve decision making."[20]

3.1.2 Descriptive Models of Human Behavior

A significant limitation of much of the early work in decision making theory is that training methods and decision aiding systems that were developed from formal, prescriptive systems (including SEU, economic model, rational-actor, and behavioral decision approaches) neither improved decision quality nor were

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[16]Peter Hedström and Charlotte Stern. 2007. "Rational Choice and Sociology," in Lawrence E. Blume and Steven N. Durlauf (eds.), *The New Palgrave Dictionary of Economics,* June. Available at http://www.dictionaryofeconomics.com/dictionary. September 9, 2011.

[17]Baruch Fischhoff. 2005. "Decision Research Strategies," *Health Psychology* 24(4):S9-S16.

[18]Baruch Fischhoff. 2005. "Decision Research Strategies," *Health Psychology* 24(4):S9-S16.

[19]Baruch Fischhoff. 2005. "Decision Research Strategies," *Health Psychology* 24(4):S9-S16.

[20]Baruch Fischhoff. 2010. "Judgment and Decision Making," *WIREs Cognitive Science* 1:724-735.

adopted in field settings.[21] Researchers in human behavior and performance found the tools and prescribed methods difficult to use in their own work.[22] This is because field settings are typically complex, emergent, poorly defined, and strongly influenced by context. While they were academically appealing, prescriptive theories of decision making were rarely the basis for practical changes that improved decision making.[23] As a result, newer approaches began to be developed in the 1980s that have been found to be better suited to understanding and improving decision making behavior in the real world, such as that carried out by Marine Corps small unit leaders. A discussion of these newer approaches is presented in the following sections.

3.1.2.1 Heuristics and Biases

The heuristics and biases (HB) approach contends that people do not use strategies in the form of algorithms in order to follow principles of optimal performance. Instead, individuals rely on rules of thumb to make decisions under conditions of uncertainty and employ them even when expected utility theory, probability laws, and statistics suggest that an individual is likely to choose certain optimal courses of behavior. These heuristics include representativeness ("in which probabilities are evaluated by the degree to which A is representative of B"), availability of instances or scenarios ("in which people assess the frequency of a class or the probability of an event by the ease with which instances of occurrences can be brought to mind"), and adjustment from an anchor (in which "people make estimates by starting from an initial value that is adjusted to yield the final answer").[24] Although heuristics can be "highly economical and usually effective," their use can also lead to biases resulting in "systematic and predict-

[21] One potential explanation is simply that the prescriptive "models" of human behavior do not, in fact, model human behavior and thus are incompatible with how a human accomplishes the unaided task. A more complete discussion of how decision theory models and game theory models in particular fail in representing human behavior in the "real world" can be found in a recent study: National Research Council, 2008, Greg L. Zacharias, Jean Macmillan, and Susan B. Van Hemel (eds.), *Behavioral Modeling and Simulation: From Individuals to Societies*, The National Academies Press, Washington, D.C., pp. 195-206.

[22] J. Frank Yates, Elizabeth S. Veinott, and Andrea L. Patalano. 2003. "Hard Decisions, Bad Decisions: On Decision Quality and Decision Aiding," pp. 13-63 in Sandra L. Schneider and James Shanteau (eds.), *Emerging Perspectives on Judgment and Decision Research,* Cambridge University Press, New York.

[23] Although the constrained optimization methods that underlie many of the prescriptive theories have found significant application in the development of tactical decision aids, as described below in the section titled "3.3.3 Tactical Decision Aids for Course of Action Development and Planning."

[24] Amos Tversky and Daniel Kahneman. 1974. "Judgment Under Uncertainty: Heuristics and Biases," *Science* 185(4157):1124-1131.

able errors."[25] The HB approach can benefit activities such as training by enabling decision makers to anticipate and avoid such errors.

3.1.2.2 Naturalistic Decision Making[26]

The naturalistic decision making approach seeks to understand human cognitive performance by studying how individuals and teams actually make decisions in real-world settings rather than in a laboratory. NDM researchers typically focus on mental activities such as decision making and sensemaking strategies, while also trying to be sensitive to the context of a situation. Three major criteria have appeared in the literature to describe research that counts as NDM study: such research (1) focuses on expertise, (2) takes place in field (not laboratory) settings, and (3) reflects the conditions such as complexity and uncertainty that complicate our lives. Marine Corps small unit leaders operate in the kind of complex, uncertain environment for which the NDM approach is a good fit.

NDM has focused on the importance of intuition, as well as on two key models: recognition-primed decision making (RPD) and the data-frame theory (DFT) of sensemaking.

3.1.2.3 Intuition

The lay person routinely thinks of intuition as knowledge or belief that is obtained by some means other than reason or perception. In fact, intuition is tacit knowledge, or expertise, that comes from experience. Intuition relies on experience to recognize key patterns that indicate the dynamics of a situation.[27] NDM research has helped to "demystify intuition by identifying the cues that experts use to make their judgments, even if those cues involve tacit knowledge and are difficult for the expert to articulate."[28] Intuition-based models account for how people use their experience to rapidly categorize situations, relying on "some kind of synthesis of their experience to make . . . judgments." [29] These situation categories, implicitly or explicitly, then suggest appropriate courses of action.[30]

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[25] Amos Tversky and Daniel Kahneman. 1974. "Judgment Under Uncertainty: Heuristics and Biases," *Science* 185(4157):1124-1131.

[26] This section is taken nearly verbatim from: Christopher Nemeth and Gary A. Klein, 2011, "The Naturalistic Decision Making Perspective," in James J. Cochran (ed.), *Wiley Encyclopedia of Operations Research and Management Science,* Wiley, New York.

[27] Gary A. Klein. 1999. *Sources of Power,* MIT Press, Cambridge, Mass.

[28] Daniel Kahneman and Gary A. Klein. 2009. "Conditions for Intuitive Expertise: A Failure to Disagree," *American Psychologist* 64(6):515-526.

[29] Christopher Nemeth and Gary A. Klein. 2011. "The Naturalistic Decision Making Perspective," in James J. Cochran (ed.), *Wiley Encyclopedia of Operations Research and Management Science,* Wiley, New York.

[30] Raanan Lipshitz and Marvin S. Cohen. 2005. "Warrants for Prescription: Analytically and Empirically Based Approaches to Improving Decision Making," *Human Factors* 47(1):102-120.

3.1.2.4 Recognition-Primed Decision Making

For the past two decades, the Marine Corps has subscribed in varying degrees to the recognition-primed decision making model of human decision making. Given the changing nature of small unit operations as described in Chapters 1 and 2, the use of this model is worth reconsidering.

Developed from NDM research, the RPD model (Figure 3.2) "describes how people use their experience in the form of a repertoire of patterns. The patterns highlight the most relevant cues [in a situation], provide expectancies, identify plausible goals, and suggest typical types of reactions."[31] The decision maker relies on specific content expertise and experience.[32] The RPD model blends pattern matching (intuition as described above) and analysis (specifically, by means of mental simulation).[33]

In the RPD model, people who "need to make a decision . . . can quickly match the situation [that they confront] to the patterns they have learned. If they find a clear match [between the situation and a learned pattern], they can carry out the most typical course of action. They do not evaluate an option by comparing it to others, but instead imagine—mentally simulate—how [the action] might be carried out, . . . [making it possible to] successfully make very rapid decisions . . . [I]n-depth interviews with fire ground commanders about recent and challenging incidents . . . [have shown] that the percentage of [times that] RPD strategies [were used] generally ranged from 80% to 90%."[34, 35]

3.1.2.5 Data-Frame Theory of Sensemaking

Sensemaking is the exploitation of information under conditions of uncertainty, complexity, and time pressure in order to support awareness, understanding, planning, and decision making. Individuals and teams with superior sensemaking abilities can be expected to handle situations better in spite of uncertainty and information overload, to make faster and better decisions with regard to an

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[31] Christopher Nemeth and Gary A. Klein. 2011. "The Naturalistic Decision Making Perspective," in James J. Cochran (ed.), *Wiley Encyclopedia of Operations Research and Management Science,* Wiley, New York; Gary A. Klein. 2008. "Naturalistic Decision Making," *Human Factors* 50(3):456-460.

[32] Terry Connolly and Ken Koput. 1997. "Naturalistic Decision Making and the New Organizational Context," pp. 285-303 in Zur Shapira (ed.), *Organizational Decision Making,* Cambridge University Press, Cambridge, U.K.

[33] Gary A. Klein. 1993. "Recognition-Primed Decision (RPD) Model of Rapid Decision Making," pp. 138-147 in Gary A. Klein, Judith Orasanu, Roberta Calderwood, and Caroline E. Zsambok (eds.), *Decision Making in Action,* Wiley, Norwood, N.J.

[34] Christopher Nemeth and Gary A. Klein. 2011. "The Naturalistic Decision Making Perspective," in James J. Cochran (ed.), *Wiley Encyclopedia of Operations Research and Management Science,* Wiley, New York; Gary A. Klein. 2008. "Naturalistic Decision Making," *Human Factors* 50(3):456-460.

[35] Gary A. Klein. 1998. *Sources of Power: How People Make Decisions*, MIT Press, Cambridge, Mass.

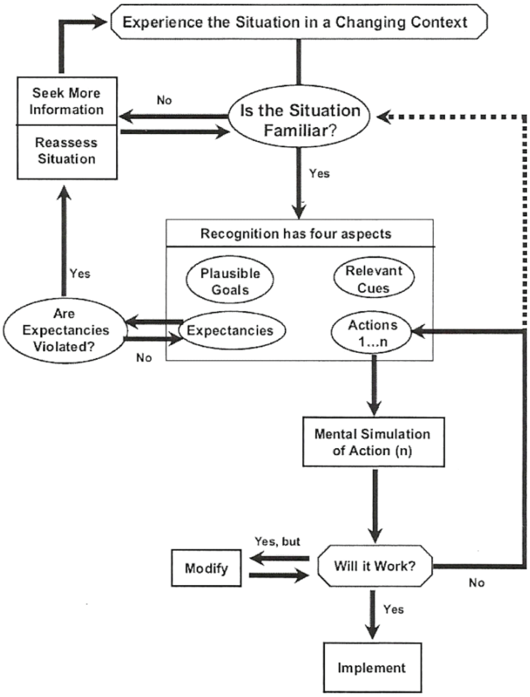

FIGURE 3.2 Recognition-primed decision making model. SOURCE: Gary A. Klein. 1989. "Recognition-Primed Decisions," pp. 47-92 in *Advances in Man-Machine Systems Research,* W.B. Rouse (ed.), Vol. 5, JAI Press, Greenwich, Conn.

adversary, and to prevent fundamental surprise.[36] Success in seeking and using information is essential to sensemaking because this behavior responds to, and is mandated by, changing situational conditions.[37]

The data-frame theory of sensemaking (Figure 3.3) describes the process of fitting data into a frame (a story, script, map, or plan) and fitting a frame around the data.[38] Context informs how an individual views and handles new information. A frame provides cues, goals, and expectancies and guides attention toward data that are of interest to the frame. Experience-based knowledge helps to create

[36]Gary A. Klein, David Snowden, Chew Lock Pin, and Cheryl A. Teh. 2007. "A Sense Making Experiment—Enhanced Reasoning Techniques to Achieve Cognitive Precision," paper presented at 12th International Command and Control Research and Technology Symposium, Singapore.

[37]Brenda Derwin. 1983. "An Overview of Sense-Making Research: Concepts, Methods, and Results to Date," paper presented at International Communication Association Annual Meeting, Dallas, Tex., May.

[38]Gary A. Klein, Jennifer K. Phillips, Erica L. Rall, and Deborah A. Battaglia. 2003. "A Summary of the Data/Frame Model of Sensemaking," *Proceedings of Human Factors of Decision Making in Complex Systems,* University of Abertay, Dundee, Scotland.

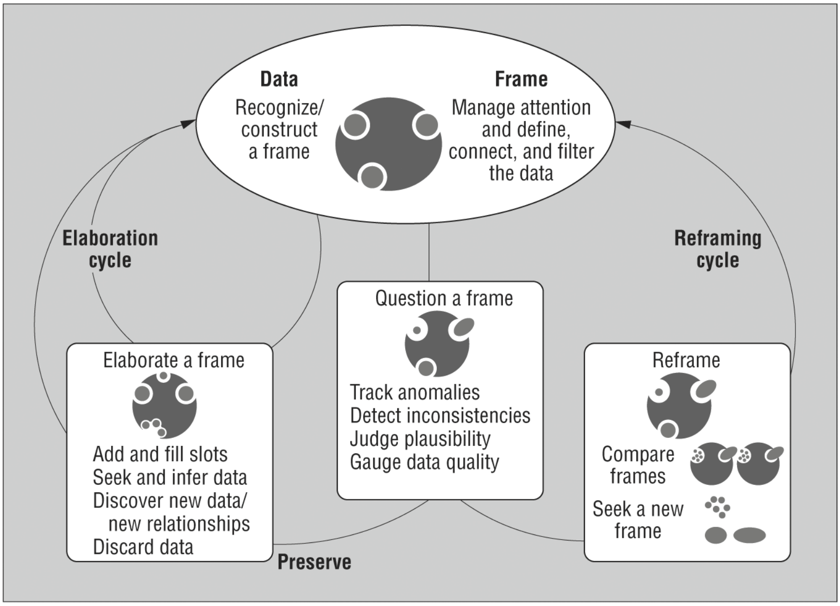

FIGURE 3.3 The data-frame theory of sensemaking. SOURCE: © IEEE. Reprinted with permission from: Gary A. Klein, Brian Moon, and Robert R. Hoffman. 2006. "Making Sense of Sensemaking, 2: A Macrocognitive Model," *IEEE Intelligent Systems* 21(5):89.

an emergent frame, which in turn informs the significance of new information. The frame becomes a sort of dynamic filter that can be questioned, compared to other frames, or elaborated and enriched, as an individual continuously seeks to assess the situation.

The deliberate construction and use of information in sensemaking find parallels in Revans's action learning, in which individuals learn with and from others by studying their own actions and experience in order to improve performance. The action learning approach includes four activities: (1) encountering changes in perceptions of the world (hearing); (2) the exchange of information, advice, criticisms, and other forms of influence (counseling); (3) taking action in the world with deliberately designed plans (managing); and (4) following the five stages of the scientific method (authentication).[39]

3.1.2.6 Team Cognition

The notion that team members must share knowledge about their task and each other has been studied for more than 20 years. "Team cognition," or shared

[39]David Botham. 1998. "The Context of Action Learning," in Wojciech Gasparski and David Botham (eds.), *Action Learning. Praxiology, The International Annual of Practical Philosophy and Methodology* 6:33-61, Transaction Publishers, New Brunswick, N.J.

mental models as some have labeled it, refers to the knowledge that must be shared among team members so that sophisticated, coordinated performance can occur even under extreme conditions such as time pressure or danger.[40] Taking a sports example, the "no-look" or "blind pass" in basketball aptly illustrates how team members can perform a fairly complex sequence of behaviors with little or no overt communication. In such cases, the team members are relying on shared knowledge about the task (e.g., how much time is left in the game, how good the opponent is, etc.) and each other (e.g., the skill level of their teammates, how likely it is that a teammate will anticipate the pass, etc.) in order to coordinate effectively. This degree of shared knowledge must be developed over time as the team members perform together. In addition, research has shown that shared knowledge can be increased with targeted team-level training interventions.[41]

Team researchers have studied a number of other team-level competencies in addition to shared knowledge that are important for team functioning; these include communication, coordination, compensatory behavior, mutual performance monitoring, intrateam feedback, and collective orientation.[42] Over the past 20 years, investigations into how to improve team decision making have revealed several useful strategies.[43] In most cases, successful team training involves exposing the team to realistic scenarios that represent the types of problems that it will encounter in the operational environment. Such scenarios, when appropriately designed and paired with effective feedback and debriefing mechanisms, help teams to develop the repertoire of instances necessary to support adaptive team performance.[44]

[40] Janis A. Cannon-Bowers, Eduardo Salas, and Sharolyn Converse. 1993. "Shared Mental Models in Expert Team Decision-Making," pp. 221-246 in N. John Castellan, Jr. (ed.), *Individual and Group Decision Making: Current Issues,* Lawrence Erlbaum Associates, Hillsdale, N.J.

[41] Kimberly A. Smith-Jentsch, Janis A. Cannon-Bowers, Scott I. Tannenbaum, and Eduardo Salas. 2008. "Guided Team Self-Correction: Impacts on Team Mental Models, Processes, and Effectiveness," *Small Group Research* 39(3):303-327.

[42] Janis A. Cannon-Bowers, Scott I. Tannenbaum, Eduardo Salas, and Catherine E. Volpe. 1997. "Defining Competencies and Establishing Team Training Requirements," pp. 333-380 in Richard A. Guzzo and Eduardo Salas (eds.), *Team Effectiveness and Decision-Making in Organizations,* Jossey-Bass, San Francisco, Calif.

[43] Eduardo Salas, Diana R. Nichols, and James E. Driskell, 2007, "Testing Three Team Training Strategies in Intact Teams: A Meta-Analysis," *Small Group Research* 38(4):471-488; Eduardo Salas and Janis A. Cannon-Bowers, 2000, "The Anatomy of Team Training," pp. 312-335 in Sigmund Tobias and J.D. Fletcher (eds.), *Training and Retraining: A Handbook for Businesses, Industry, Government and Military,* Macmillan, Farmington Hills, Mich. Also see Janis A. Cannon-Bowers and Clint A. Bowers, 2010, "Team Development and Functioning," in Sheldon Zedeck (ed.), *Handbook of Industrial and Organizational Psychology*, American Psychological Association, Washington, D.C., for a summary.

[44] Steve W.J. Kozlowski, Rebecca J. Toney, Morell E. Mullins, Daniel A. Weissbein, Kenneth G. Brown, and Bradford S. Bell, 2001, "Developing Adaptability: A Theory for the Design of Integrated-Embedded Training Systems," pp. 59-123 in *Advances in Human Performance and Cognitive Engineering Research,* US: Elsevier Science/JAI Press; Janis A. Cannon-Bowers and Clint A. Bowers, 2009, "Synthetic Learning Environments: On Developing a Science of Simulation, Games and Virtual

3.1.3 Resilience

Resilience is the ability either "to mount a robust response to unforeseen, unpredicted and unexpected demands and to resume normal operations, or to develop new ways to achieve operational objectives."[45] The ability to realize that potential, however, relies on understanding change and having the ability to adapt. Any number of factors can lead to systems that are brittle,[46] or unable to change in response to circumstances. A system that is resilient "can maintain the ability to adapt when demands go beyond an organization's customary operating boundary."[47]

Individuals, groups, and systems all have the potential to be resilient, and "human operators can be a source of resilience as a result of initiatives to create safety under resource and performance pressure."[48] However, operators alone cannot be expected to ensure resilience. The systems of which they are a part also need the ability to adapt. Resilience engineering (RE) can make it possible to cope with and recover from unexpected developments. RE provides the tools to develop and manage systems that can anticipate the need for change, because no organization or system can be designed to anticipate all the variability in the real world. Research approaches such as cognitive systems engineering (CSE)[49] make it possible to learn how to avoid brittleness in the face of uncertainty and unanticipated variability.

3.1.4 Implications from Cognitive Psychology

Cognitive psychology brings to bear time-tested knowledge based on scientific inquiry that can address each of the findings in Chapter 2 and support the committee's recommendations in Chapter 4.

Worlds for Training," pp. 229-261 in Steve W.J. Kozlowski and Eduardo Salas (eds.), *Learning, Training and Development in Organizations,* Routledge, New York.

[45]Christopher Nemeth. 2011. "Adapting to Change and Uncertainty," *Cognition, Technology & Work* December 28; Erik Hollnagel, David D. Woods, and Nancy Leveson (eds.). 2006. *Resilience Engineering: Concepts and Precepts,* Ashgate Publishing, Aldershot, U.K.

[46]Nadine B. Sarter, David D. Woods, and Charles E. Billings. 1997. "Automation Surprises," pp. 1926-1943 in Gavriel Salvendy (ed.), *Handbook of Human Factors and Ergonomics,* 2d Ed., Wiley, Hoboken, N.J.

[47]Christopher Nemeth. 2011. "Adapting to Change and Uncertainty," *Cognition, Technology & Work* December 28; Christopher Nemeth, Robert Wears, David D. Woods, Erik Hollnagel, and Richard I. Cook. 2008. "Minding the Gaps: Creating Resilience in Healthcare," in Kerm Henricksen, James B. Battles, Margaret A. Keyes, and Mary L. Grady (eds.), *Advances in Patient Safety: New Directions and Alternative Approaches, Vol. 3, Performance and Tools,* AHRQ Publication No. 08-0034-3, Agency for Healthcare Research and Quality, Rockville, Md.

[48]Christopher Nemeth. 2011. "Adapting to Change and Uncertainty," *Cognition, Technology & Work* December 28; Richard I. Cook and David D. Woods. 1994. "Operating at the Sharp End: The Complexity of Human Error," pp. 255-310 in Marilyn Sue Bogner (ed.), *Human Error in Medicine.* Lawrence Erlbaum, Hilllsdale, N.J.

[49]David D. Woods and Emilie M. Roth. 1988. "Cognitive Systems Engineering," pp. 3-43 in M. Helander (ed.), *Handbook of Human-Computer Interaction,* North-Holland, Amsterdam.

Methods that are inherent in cognitive psychology research approaches such as cognitive task analysis (CTA) and cognitive systems engineering—both described in more detail below in the section titled "3.3.1 Decision Aid Design Methodologies"—reveal the key characteristics of uncertain, risky, hazardous work settings. They also reveal actual behaviors of small unit leaders as they overcome obstacles in the pursuit of the goals that their missions dictate. Data from studies of individual and team performance enable the Marine Corps to understand how Marines actually perform cognitive and metacognitive work, from problem detection, naturalistic decision making, sensemaking, planning, and replanning, to adaptation, coordination, attention management, the maintaining of common ground, management of uncertainty and risk, and more. Findings can be used to create new processes, facilities, and information systems and aids to support cognitive work.

The use of cognitive psychology methods ensures that models and solutions based on those data are valid, accurate reflections of the true nature of that world. For example, the close match of the recognition-primed decision making model to *actual* decision making behavior observed in the field led to its adoption by the Marine Corps. This scientific rigor makes it possible for cognitive psychology to develop solutions that gain traction in actual applications. Cognitive psychology can be used to derive requirements for tasks that form the basis for job design and selection criteria. It can be used to create training content, scenarios, and means to evaluate performance before and after training. It can provide approaches to elicit expertise and transfer it to others efficiently, or use it to develop cognitive aids to assist decision making in any number of applications.

Descriptive approaches to decision making will continue as the foundation of contributions to small unit leader decision making behavior that includes sensemaking, situational assessment, problem detection, planning, and coordination and collaboration. Cognitive psychology methods used in field research can reveal individual and group initiatives that Marines develop to perform new missions in new settings. These methods can then be used to provide the basis for the design and development of useful and usable information systems, the next generation of lessons learned, and tactical decision aids (TDAs). Shedding light on team behaviors can support new approaches to team training, rapid-response training capabilities that allow faster reaction to the evolution of enemy tactics and techniques, courses of instruction that are scaled to the company level, and, finally, training systems that respond to field experience, to incorporate and convey lessons learned more quickly. Cognitive psychology can continue to be used to discover and to learn about new challenges that small unit leaders face as the missions and role of the Marine Corps evolve.

3.2 COGNITIVE NEUROSCIENCE

Following is a summary of recent work in cognitive neuroscience, which seeks to use insight from functional neuroanatomy to extend theoretical models of decision making, as well as to explain individual differences in decision making performance.

3.2.1 Overview of Cognitive Neuroscience

Cognitive neuroscience is an emerging academic area that uses measures of brain function to examine decision making in a way that complements cognitive psychology, with its primary focus on overt behaviors and associated internal mental processes. Using functional magnetic resonance imaging (fMRI) and electroencephalographic measures of brain activity, the science aims to uncover specific brain-behavior relationships that could explain behavior and performance in decision making. The approach is only beginning to examine what cognitive factors might lead to successful decision making, with recent experiments drawing mainly on tasks involving economic exchange. Clearly, these are relatively constrained compared to the complex decision making environment of the small unit leader (e.g., adaptive decision making in the face of an adversary). Initial results demonstrate that it is possible to separate decision making into distinct cognitive components that are supported by separable brain systems.[50] A consistent observation across studies is that a particular decision depends on (1) the way that a person integrates available evidence and (2) the way that he or she estimates the expected value placed on the decision.[51]

Much of the research in cognitive neuroscience related to decision making examines the influences that determine the estimated value of one choice over another. In this framework, valuation is an individual's determination of the possible risks, rewards, and costs, and also the way in which the person's value is shaped by societal influences. Functional magnetic resonance imaging studies demonstrate that different sources of reward, costs, and societal influences are processed in distinct networks of the brain.[52] Furthermore, reward networks can be distinguished from networks that track the relative risk of a decision.[53] This dissociation of brain networks for reward and risk raises a fundamental question

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[50] Vinod Venkatraman, John W. Payne, James R. Bettman, Mary Francis Luce, and Scott A. Huettel, 2009, "Separate Neural Mechanisms Underlie Choices and Strategic Preferences in Risky Decision Making," *Neuron* 62:593-602; Joseph W. Kable and Paul W. Glimcher, 2009, "The Neurobiology of Decision: Consensus and Controversy," *Neuron* 63(6):733-745.

[51] Jan Peters and Christian Büchel, 2009, "Overlapping and Distinct Neural Systems Code for Subjective Value During Intertemporal and Risky Decision Making," *Journal of Neuroscience* 29(50):15727-15734; David V. Smith, Benjamin Y. Hayden, Trong-Kha Truong, Allen W. Song, Michael L. Platt, and Scott A. Huettel, 2010, "Distinct Value Signals in Anterior and Posterior Ventromedial Prefrontal Cortex," *Journal of Neuroscience* 30(7):2490-2495.

[52] Jamil Zaki and Jason P. Mitchell. 2011. "Equitable Decision Making Is Associated with Neural Markers of Intrinsic Value," *Proceedings of the National Academy of Sciences of the United States of America* 108(49):19761-19766.

[53] Peter N.C. Mohr, Guido Biele, and Hauke R. Heekeren, 2010, "Neural Processing of Risk," *Journal of Neuroscience* 30(19):6613-6619; Gui Xue, Zhong-Lin Lu, Irwin P. Levin, and Antoine

about how the brain reconciles competing influences. There is growing consensus that the brain uses another network to perform a mental calculus that combines different rewards and risks into a common valuation.[54] It is this calculation of value across many inputs rather than a single reward or risk that ultimately directly shapes a decision. These distinctions can be used to explain why decisions may often appear to be "irrational" if all factors influencing an internalized valuation (and subsequent externalized and observed decision) are not considered.

3.2.2 Implications from Cognitive Neuroscience

Cognitive processes used for estimating value and evaluating evidence are potential sources of individual variation that could explain differences in how people make decisions. This possibility has been supported by neuroscience research using fMRI experiments to study tasks that are specifically associated with risk taking,[55] avoiding uncertainty,[56] and expending effort.[57] These studies are particularly important because they provide objective metrics of decision making that could—the word *could* is emphasized here—be applied in the assessment of small unit leader decision making "style" or "biases" (e.g., toward or away from risk). One potential application could be in the selection process: if cognitive neuroscience techniques eventually prove useful in the identification of objective metrics of decision making performance by "good" small unit leaders, for example, then such techniques might be applied to the screening of potential small unit leader candidates. Recent research also suggests that some of the processes influencing decision making performance can be modified through training to account for individual differences seen across populations. For example, reward-sensitive individuals can be trained to increase working memory and increase performance on tasks that do not include a reward.[58] Thus, another

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Bechara, 2010, "The Impact of Prior Risk Experiences on Subsequent Risky Decision-Making: The Role of the Insula," *Neuroimage* 50:709-716.

[54]Joseph W. Kable and Paul W. Glimcher, 2010, "An 'As Soon As Possible' Effect in Human Intertemporal Decision Making: Behavioral Evidence and Neural Mechanisms," *Journal of Neurophysiology* 103(5):2513-2531; Guillaume Sescousse, Jérǒme Redouté, and Jean-Claude Dreher, 2010, "The Architecture of Reward Value Coding in the Human Orbitofrontal Cortex," *Journal of Neuroscience* 30:13095-13104.

[55]Jan B. Engelmann and Diana Tamir. 2009. "Individual Differences in Risk Preference Predict Neural Responses During Financial Decision-Making," *Brain Research* 1290:28-51.

[56]Koji Jimura, Hannah S. Locke, and Todd S. Braver. 2010. "Prefrontal Cortex Mediation of Cognitive Enhancement in Rewarding Motivational Contexts," *Proceedings of the National Academy of Sciences of the United States of America* 107:8871-8876.

[57]Joseph T. McGuire and Matthew M. Botvinick. 2010. "Prefrontal Cortex, Cognitive Control, and the Registration of Decision Costs," *Proceedings of the National Academy of Sciences of the United States of America* 107:7922-7926.

[58]Koji Jimura, Hannah S. Locke, and Todd S. Braver. 2010. "Prefrontal Cortex Mediation of Cognitive Enhancement in Rewarding Motivational Contexts," *Proceedings of the National Academy of Sciences of the United States of America* 107:8871-8876.

potential application is to assess the progress of an individual's decision making effectiveness during training.

Cognitive neuroscience is still in its infancy and is far from being a validated and proven practical means for selection and/or training assessment. However, it should be recognized that the methodology is evolving rapidly, with new techniques emerging to map the strength of connections between brain regions based on either structural information (diffusion tensor and diffusion spectrum imaging)[59] or functional information (resting-state fMRI).[60] It remains to be seen if these methods could be used to select for or assess the decision making performance of small unit leaders.

3.3 ENGINEERING APPROACHES TO SUPPORT DECISION MAKING

There is a long history of the leveraging of methods from engineering to enhance decision making, through the development of what are called decision aids, and a complete review is beyond the scope of this report.[61] Here, the focus is on five areas of opportunity that the committee considered to be the most relevant to the development of decision aids for small unit leaders: (1) design methodology, (2) information integration, (3) algorithmic decision aids, (4) human-computer interaction, and (5) physiologic monitoring and augmented cognition.

3.3.1 Decision Aid Design Methodologies

Engineering "solutions" oftentimes start with what the engineer thinks should be the solution, rather than with an assessment of what the end user is trying to accomplish. As a result, fielded decision aids may not only fail to satisfy the fundamental goal of aiding the user—in this case the small unit leader—but may actually hinder the user in any number of ways (e.g., by being so cumbersome to use that user's workload ends up being increased rather than reduced by the aid; by being used outside the bounds for which they were designed; by being sufficiently complex so as to obfuscate their inner workings, thereby reducing trustworthiness; and so on).[62,63] As a result, designers in the systems engineering and human

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[59]Danielle S. Bassett, Jesse A. Brown, Vibhas Deshpande, Jean M. Carlson, and Scott T. Grafton. 2011. "Conserved and Variable Architecture of Human White Matter Connectivity," *Neuroimage* 54(2):1262-1279.

[60]Gagan S. Wig, Bradley L. Schlaggar, and Steven E. Petersen. 2011. "Concepts and Principles in the Analysis of Brain Networks," *Annals of the New York Academy of Sciences* 1224(1):126-146.

[61]An early example is the more than 2,000-year-old astrolabe, an aid for the analog calculation of the locations of celestial bodies, and later, an aid for navigation.

[62]See, for example, Steven Casey, 1998, *Set Phasers on Stun: And Other True Tales of Design, Technology, and Human Error,* Agean Publishing Company, Santa Barbara, Calif.

[63]Thomas B. Sheridan. 2002. *Humans and Automation: System Design and Research Issues,* Wiley, New York.

factors community have come together and identified general approaches to the design and development of systems that account for user needs while recognizing the capabilities and limitations of both the user and the decision aid being developed. Rather than a summary of the extensive literature in this area, what follows is a very brief overview of two methodologies introduced in the discussion above: cognitive task analysis and cognitive systems engineering.

3.3.1.1 Cognitive Task Analysis

Researchers cannot expect decision makers to explain accurately why they have made decisions,[64] and so researchers have developed methods to learn from experts. Cognitive task analysis[65] is a set of methods, such as semi-structured interviews and observations, that are used to discover the cues and context that influence how people make decisions. These methods reveal the actual demands and obstacles that practitioners confront in their work and serve as a basis to make inferences about the judgment and decision process. Results of CTA research are used to develop representations that include descriptions, diagrams, and models. Although the committee did not perform a complete CTA, the interviews that the committee conducted at Quantico, Virginia, among combat-experienced Marines relied on a CTA approach to elicit their expert knowledge (see Appendix E for the interview protocol).

3.3.1.2 Cognitive Systems Engineering

The science base described in this report is critical to the improvement of small unit leader decision making. However, as noted in a 2007 study from the National Research Council (NRC),[66] it is not sufficient in itself to ensure the successful development, acquisition, deployment, operation, and maintenance of effective human-centered systems to support that decision making. Cognitive systems engineering[67,68] extends CTA methods to the development of tools, processes, and facilities to support cognitive work. Although there are many different approaches to the analysis components of CSE (e.g., cognitive task

[64]Richard E. Nisbett and Timothy D. Wilson. 1977. "Telling More Than We Can Know: Verbal Reports on Mental Processes," *Psychological Review* 84(3):231-259.

[65]Beth Crandall, Gary A. Klein, and Robert R. Hoffman. 2006. *Working Minds: A Practitioner's Guide to Cognitive Task Analysis,* MIT Press, Cambridge, Mass.

[66]National Research Council. 2007. Richard W. Pew and Anne S. Mavor (eds.), *Human-System Integration in the System Development Process,* The National Academies Press, Washington, D.C.

[67]David D. Woods and Emilie M. Roth. 1988. "Cognitive Systems Engineering," pp. 3-43 in M. Helander (ed.), *Handbook of Human-Computer Interaction,* North-Holland (Elsevier Science Publishers), New York.

[68]Erik Hollnagel and David D. Woods. 2005. *Joint Cognitive Systems: Foundations of Cognitive Systems Engineering,* Taylor and Francis, Boca Raton, Fla.

analysis,[69] cognitive work analysis,[70] work-centered support systems,[71] applied cognitive task analysis[72]) they share a common view of system development as being human-centered. The incorporation of CSE into the Department of Defense (DOD) systems acquisition process will account for the complex individual and team cognitive activity that Marines perform. It will also ensure that systems involving decision support will incorporate human-centered design into initial requirements specification, and then to development, evaluation, and eventual fielded systems.

3.3.2 Information Integration: Collection, Fusion, and Assessment

Good decision making requires an accurate assessment of the current and evolving situation, as well as a clear understanding of the options available for dealing with a given situation. Here the opportunities for improving the assessment half of the problem are discussed, and the next section addresses opportunities for improving associated option-generation and option-selection activities.

As discussed in an extensive literature reaching back to the late 1980s[73] and recently documented in a collection of [critical] essays,[74] situational awareness (SA) entails "the perception of the critical elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future."[75]

SA enables decision makers to assess the state of the world, important features in a scene, estimates for progress against plan, and adversaries' intentions. Given the explosion of air- and ground-based sensors, providing adequate SA to the Marine may seem a solved problem. However, four significant challenges exist:

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[69] Jan Maarten Schraagen, Susan F. Chipman, and Valerie L. Shalin (eds). 2000. *Cognitive Task Analysis (Expertise: Research and Application Series),* Lawrence Erlbaum Associates, Mahwah, N.J.

[70] Kim J. Vicente. 1999. *Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work,* CRC Press, Boca Raton, Fla.

[71] Robert G. Eggleston, Emilie M. Roth, and Ronald Scott. 2003. "A Framework for Work-Centered Product Evaluation," pp. 503-507 in *Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting,* Human Factors and Ergonomics Society, Santa Monica, Calif.

[72] Laura G. Militello and Robert J.B. Hutton. 1998. "Applied Cognitive Analysis (ACTA): A Practitioner's Toolkit for Understanding Cognitive Task Demands," *Ergonomics* 41(11):1618-1641.

[73] Martin L. Fracker. 1988. "A Theory of Situational Assessment: Implications for Measuring Situation Assessment," pp. 102-106 in *Proceedings of the Human Factors Society 32nd Annual Meeting,* Santa Monica, Calif.

[74] Eduardo Salas and Aaron S. Dietz. 2011. *Situational Awareness,* Ashgate Publishing Co, Burlington, Vt.

[75] Mica Endlsey. 1995. "Toward a Theory of Situation Awareness in Dynamic Systems," *Human Factors* 37(1):32-64.

1. Perceiving key elements[76] requires properly emplaced sensors, be they human eyes on a target, or unmanned aerial vehicles (UAVs) with electro-optical/forward-looking infrared sensors onboard.

2. The collected sensor data must be processed to provide a *perception* of the elements. Humans can do this with relative ease, but machine sensors must be augmented with sophisticated processing systems.

3. *Perceived* elements must be aggregated to define a situation that is operationally relevant to the Marine charged with making decisions, at whatever echelon is being considered. Humans do this quite well, particularly with training and practice, but reliable machine-based "situation assessors" have yet to be developed.

4. The assessment of dynamic situations requires some form of extrapolation in order to anticipate how events might unfold. Although computational analysis can support human judgment, reliable predictive "situational forecasters" simply do not exist.

Shortcomings at all levels of the SA-chain have been exacerbated by the rapid proliferation of sensor feeds that are generating petabytes of data.[77] However, considerable effort is being put into new sensor-management, data-processing, and information-integration capabilities, all of which may significantly benefit small unit decision making in the following areas:

- *Collection management (CM) to provide capabilities for sensor selection, planning, and placement are more common in upper echelons of the military than among small units*. However, the provision of appropriate sensor systems and CM capabilities could enhance the small unit's ability to develop SA. For example, simple "apps" (applications) that employ novel optimization algorithms can help small unit leaders deploy static and dynamic sensor systems so as to maximize information gains.
- *Sensor signal processing to convert collected data into higher-order elements (objects, events, relationships) will be critical in addressing the data deluge*. For example, the explosive growth of UAV-supplied full-motion video (FMV) will overwhelm exploitation methodologies that rely on human processing.[78] Data fusion, feature detection and identification, pattern recognition, and anomaly detection can support human analysts by aggregating large amounts of

[76]Critical elements vary from situation to situation: in a "kinetic" situation this could be a small adversary group waiting in ambush; in a "nonkinetic" situation, the banker funding a bomb maker, and so forth. Elements can be objects (e.g., individual adversaries, weapons systems, etc.), relationships (parts of a formation, members of a terrorist cell, etc.), or events (explosions, IED emplacements, food riots, etc.).

[77]Comment by Lt Gen David A. Deptula, USAF, in Stew Magnuson, 2010, "Military 'Swimming in Sensors and Drowning in Data,'" *National Defense Magazine,* January.

[78]That is, detecting the *elements* of interest to the decision maker.

raw data into elements of interest—not just for FMV streams but for other sensor systems as well. The fusion of different classes of data (e.g., imagery and acoustic streams) is quite difficult, requiring not only the georegistration of separately emplaced sensors and their fields of sensitivity, but also an understanding of how each "registers" different elements (e.g., a truck). Although both single-sensor and multisensor data fusion technologies are still under development, emerging methods and technologies are likely to play an important role in augmenting the efficiency and accuracy of human analysts.

- *Estimation of the current situation is primarily a manual process.*[79] Little support exists for small units, especially in hybrid engagements calling for "non-kinetic" situational assessment (e.g., "What is the sentiment of the village toward our presence here?"). However, two related NRC reports[80,81] have recently suggested that methodologies such as expert systems[82] and case-based reasoning[83] might be used to integrate disparate elements into situational assessments to support small unit decision making in complex hybrid engagements. More sophisticated probabilistic methodologies, including Bayesian Belief Networks,[84,85] Dynamic Bayesian Belief Networks, and Probabilistic Relational Models,[86] bear investigation, as do network models that support the visualization of social relationships, communication pathways, and information dissemination. Moreover, machine learning techniques[87,88] may enable knowledge capture and reuse: for example, encoding information about recent events to support Marines in assess-

[79]Typically accomplished with simple "laydown" maps showing blue and red forces. More advanced displays could be envisioned that used sensor data on enemy movements and fires, fused with terrain features and blue force information, to serve as the basis for a probabilistic threat assessment, visually displayed by "heat maps" or threat-density maps, showing relative concentration densities.

[80]National Research Council. 1998. "Situation Awareness," pp. 172-202 in Richard Pew and Anne Mavor (eds.), *Modeling Human and Organizational Behavior,* National Academy Press, Washington, D.C.

[81]National Research Council. 2008. Greg L. Zacharias, Jean MacMillan, and Susan B. Van Hemel (eds.), *Behavioral Modeling and Simulation: From Individuals to Societies,* The National Academies Press, Washington, D.C.

[82]Peter Jackson. 1998. *Introduction to Expert Systems,* Addison Wesley, Boston, Mass.

[83]Agnar Aamodt and Enric Plaza. 1994. "Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches," *AI Communications* 7(1):39-59.

[84]Gregory F. Cooper. 1990. "The Computational Complexity of Probabilistic Inference Using Bayesian Belief Networks," in *Artificial Intelligence* 42(2-3).

[85]Ann E. Nicholson and J. Michael Brady. 1994. "Dynamic Belief Networks for Discrete Monitoring," in *IEEE Systems, Man, and Cybernetics Society* 24(11).

[86]Lise Getoor, Nir Friedman, Daphne Koller, and Avi Pfeffer. 2001. "Learning Probabilistic Relational Models," pp. 307-338 in Sašo Džeroski and Lavrac Nada (eds.), *Relational Data Mining,* Springer, New York.

[87]Dimitri P. Bertsekas and John Tsitsiklis. 1996. *Neuro-Dynamic Programming,* Athena Scientific, Nashua, N.H.

[88]Pieter Abbeel and Andrew Y. Ng. 2004. "Apprenticeship Learning Via Inverse Reinforcement Learning," in *Proceedings of the Twenty-first International Conference on Machine Learning,* ACM, New York.

ing adversarial intentions and objectives. Finally, the DOD is investing in new methods and techniques to support nonkinetic SA; for example, in the Human Socio-Cultural Behavior (HSCB) modeling program managed by the Office of Naval Research.[89] It must be recognized, however, that weakly constrained "non-kinetic" situations present immense methodological and technical challenges for modeling and simulation that must be addressed if programs such as HSCB are to be successful.

- *Forecasting may benefit from the development of computational models and simulations that have a sound theoretical basis and have undergone rigorous verification and validation in the intended operational scenario*. Forecasting also requires that systems exploit up-to-date information in order to ensure operational relevance and accuracy. Many "kinetic" red force (adversary) tracking and projection models have been designed with these capabilities, but providing the same level of reliability in less constrained, "nonkinetic" situations is an immensely more difficult problem.

In summary, accurate SA enables the decision maker to monitor events, to determine if the objectives and constraints of a current operational plan or solution are being followed, and perhaps to detect unforeseen opportunities that support additional goals or objectives. The decision maker may choose to pursue the current plan, or create a new plan to accommodate emerging problems, or capitalize on new opportunities (regarding replanning, see below). Given today's high-resolution sensors, low-cost flight control and guidance systems, and computing power, such aids are not unrealistic, although they require significant development, testing, and verification and validation.

3.3.3 Tactical Decision Aids for Course-of-Action Development and Planning

Marine Corps Doctrinal Publication One (MCDP1) states:

> Decision making may be an intuitive process based on experience. This will likely be the case at lower levels and in fluid, uncertain situations. Alternatively, decision making may be a more analytical process based on comparing several

[89] See http://www.onr.navy.mil/Science-Technology/Departments/Code-30/All-Programs/Human-Behavioral-Sciences.aspx. Accessed December 3, 2011. The HSCB program seeks to understand the human, social, cultural, and behavioral factors that influence human behavior; improve the ability to model these influences and understand their impact on human behavior at the individual, group, and society level of analysis; improve computational modeling and simulation capabilities, visualization software tool sets, and training and mission rehearsal systems that provide forecasting capabilities for sociocultural responses; and develop and demonstrate an integrated set of model description data (metadata), information systems, and procedures that will facilitate assessment of the software engineering quality of sociocultural behavior models, their theoretical foundation, and the translation of theory into model constructs.

options. This will more likely be the case at higher levels or in deliberate planning situations.[90]

Tactical decision aids (TDAs) have been used to support military decision making for many years. For example, some TDAs have employed case-based reasoning to generate potential courses of action (COAs); examples are BattlePlanner,[91] JADE (Joint Assistant for Deployment and Execution),[92] and HICAP (Hierarchical Interactive Case-based Architecture for Planning).[93] Others use high-level modeling and simulation, including qualitative reasoning, to help decision makers evaluate COAs.[94,95] Such technologies, however, are geared for situations that afford deliberative information processing and assessment—for example, to support decision makers at higher command echelons in assessing order of battle. In contrast, small units engage in both deliberative planning and rapid, high-consequence decision making in real time. The former affords time and resources for deliberate information collection and processing, but the latter does not. Small units may benefit from TDAs that support both modes and which provide small unit leaders with a "playbook" of cues and frameworks to support the accurate and efficient assessment of incoming information, as discussed above in the description of RPD models of decision making.

Inexpensive and powerful computers, coupled with the development of efficient algorithms,[96] mean that portable TDAs may provide small unit leaders with access to efficient and useful optimization techniques. Methods from operations research,[97] including optimization formulations (e.g., mathematical programming, dynamic programming) and associated algorithms (e.g., the many variants of the simplex method, branch-and-bound, interior point methods, approximate dynamic programming) have been incorporated into TDAs to identify and evaluate near-best solutions, given constraints such as task scheduling, resource availability, and

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[90]Gen Charles C. Krulak, USMC, Commandant of the Marine Corps. 1997. *Warfighting*, Marine Corps Doctrinal Publication One, Washington, D.C., June 20, pp. 85-86.

[91]Marc Goodman. 1989. "CBR in Battle Planning," in *Proceedings of the Second Workshop on Case-Based Reasoning*, Pensacola Beach, Fla.

[92]Alice M. Mulvehill and Joseph A. Caroli. 1999. "JADE: A Tool for Rapid Crisis Action Planning," in *Proceedings of the 4th International Command and Control Research and Technology Symposium*, Providence, R.I.

[93]Hector Muñoz-Avila, David W. Aha, Leonard A. Breslow, and Dana S. Nau. 1999. "HICAP: An Interactive Case-Based Planning Architecture and Its Application to Noncombatant Evacuation Operations," in *Proceedings of the Ninth Conference on Innovative Applications of Artificial Intelligence,* AIAA Press, Orlando, Fla.

[94]Johan de Kleer and Brian C. Williams (eds.). 1991. *Artificial Intelligence Journal* 51 (Special Issue on Qualitative Reasoning About Physical Systems II).

[95]Benjamin J. Kuipers. 1994. *Qualitative Reasoning: Modeling and Simulation with Incomplete Knowledge*. MIT Press, Cambridge, Mass.

[96]Jorge Nocedal and Stephen J. Wright. 2006. *Numerical Optimization,* Springer, New York.

[97]Wayne Winston. 2004. *Operations Research: Applications and Algorithms,* Duxbury Press, Belmont, Calif.

risk. More recently, genetic and evolutionary algorithms,[98,99,100] as well as distributed agent-based approaches such as market-based optimization,[101] have provided new techniques to support tactical decision making. Aids that incorporate these techniques can generate "satisficing" solutions relatively quickly, but they also allow more optimal solutions to emerge over time. In addition, such methods can be relatively robust to uncertainty, data staleness, and brittleness of the optimum, all of which are problematic for traditional OR-based approaches. Small units may benefit from technologies that incorporate such methods.

Tactical decision aids that incorporate novel optimization algorithms might also be very useful for deliberative planning at the small unit level. For example, the resupply of dispersed units can present significant logistical challenges, but TDAs could be developed to help company commanders ensure that their units have the required materiel. A route-planning TDA could search among possible convoy routes to satisfy traversability constraints, minimize travel time, and maximize protection from possible threats. When the decision maker receives new threat information, the TDA would support modification of the route, just as a vehicle driver might modify a route proposed by Google Maps when learning of a road closure due to, say, flooding.

Similarly, a TDA might help small unit leaders manage sensor arrays and collection assets in order to maximize the probability of interdicting insurgents, or help them in making decisions about distributing improvised explosive device (IED) clearance assets over a road network.[102] In such scenarios, optimization techniques may be useful in helping small unit leaders generate sets of possible actions with estimates of relative "goodness" with respect to mission objectives, as made explicit to the TDA.

TDAs might also have a role in rapidly unfolding situations, such as those encountered by small units when hybrid engagements shift from nonkinetic to kinetic states. As discussed in Chapter 2, many of the difficult decisions faced by Marines are associated with the question of whether to employ fires, given the risk of collateral damage. A very simple TDA could help the small unit leader assess the probability of overall physical damage in a target zone, while a more informative aid could estimate the probability of damage to specific intended targets

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[98] David E. Goldberg. 1989. *Genetic Algorithms in Search, Optimization and Machine Learning,* Kluwer Academic Publishers, Boston, Mass.

[99] David E. Goldberg. 2002. *The Design of Innovation: Lessons from and for Competent Genetic Algorithms,* Addison-Wesley, Reading, Mass.

[100] David B. Fogel. 2006. *Evolutionary Computation: Toward a New Philosophy of Machine Intelligence,* 3d ed., IEEE Press, Piscataway, N.J.

[101] Dan Schrage, Christopher Farnham, and Paul G. Gonsalves. 2006. "A Market-Based Optimization Approach to Sensor and Resource Management," in *Proceedings of SPIE Defense and Security,* Vol. 6229, Orlando, Fla., April.

[102] Alan R. Washburn and P. Lee Ewing. 2011. "Allocation of Clearance Assets in IED Warfare," *Naval Research Logistics* 58(3):180-187.

and associated collateral features. An enhanced map showing relative locations of true and collateral targets, together with damage probability contours, might allow small unit leaders to make more efficient and reliable risk assessments, as opposed to their recalling and mentally processing relevant factors while under stress. In either case, the applicable mathematics are well understood,[103] and the required computations would be easily performed on a handheld or laptop device.

It is not difficult to provide additional examples of TDAs that could be used effectively by the small unit leader. However, there are important caveats:

- As noted earlier, the "front-end" analysis (e.g., CTA, CSE) is required in order to clearly identify the problem being addressed. This *must* be done before any technical formulation or algorithm development. Doing it the other way round, and attempting to make the TDA "user-friendly" after the fact, is a sure route to another discarded tactical tool.
- A TDA designed for COA development or mission planning will only be as good as the assessed-situation data feeding it. If the TDA is "optimizing" for the wrong situation, the aiding that it offers may be worse than none at all.
- Critical attention needs to be paid to what is being "optimized" and what assumptions are being made by the optimization algorithms. If the optimization metric is not the same as that being implicitly held by the user operating the TDA, and/or if the TDA design assumptions are being violated by the actual scenario of use, then the TDA advice is unlikely to be optimal in any sense of the word.
- Consideration should be given to other factors in the design of the TDA besides optimality in some predefined solution space. For example, robustness of the proposed solution[104] may be much more important than optimality if the operating context is fraught with uncertainty. Likewise, if the user cannot understand the solution logic ("Why did it suggest that???"), a simpler but less optimizing technique may be more appropriate. Some decisions may be better supported by explanatory capabilities that enable the user to trace the TDA's "reasoning." In addition, effective visualization modes must be developed. Map-based aids are the most popular, but some situations call for totally novel representations (e.g., influence analysis may call on social network visualization, logistics planning on Gantt charts, etc.). Finally, ease of training on how to use the new TDA[105] and its ease of integration into the existing operations will both be strong determinants of technology adoption.

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[103] Alan R. Washburn and Moshe Kress. 2009. *Combat Modeling* in the International Series in Operations Research and Management Science, Springer, New York.

[104] That is, the sensitivity of the solution payoff to unpredictable or uncontrollable variations in the solution space.

[105] With today's "20-something" users expecting to need no training at all in view of their consumer-electronic experiences, significant "usability" issues need to be addressed by future TDA developers.

3.3.4 Human-Computer Interaction: Displays and Controls

Although the above considerations for successful TDA design and deployment are broad, general, and certainly not exhaustive, there is an extensive, prescriptive, and empirically validated body of specific knowledge that exists under the rubric of what is called human-computer interaction, or HCI. The Association for Computing Machinery defines human-computer interaction as "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them."[106]

Many of the science and technology HCI "products" come in the form of best practices by HCI designers and evaluators (e.g., the guidelines noted above). Many more, however, are summarized in formalized guidelines, textbooks, and handbooks,[107,108,109] which cover topics that range from the "shallow," interfaced-focused topics of how to deal with, in the present case, the TDA interface between human and computer (regarding displays and controls; see below), to the "deep," under-the-hood topics dealing, on the computer side, with issues like opacity of operation, trustworthiness of the computations, and so on, and on the human side with issues like the operator's skill level, that person's mental model of the TDA, and so on.

Interface displays have primarily focused on visual modality, and display guidance has ranged from very early work in the 1940s on the design of good displays for the aircraft cockpit,[110,111] to work in the 1990s focusing on the development of a consistent design framework for visualizing different classes of information,[112,113] to current efforts for displaying high-dimensional data sets with complex relationships between data entities. In this last category, a relevant

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[106] See http://old.sigchi.org/cdg/cdg2.html#2_11. Accessed December 3, 2011.

[107] Andrew Sears and Julie A. Jacko (eds.). 2008. *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications*, 2d Ed., CRC Press, New York.

[108] Christopher D. Wickens, John D. Lee, Yili Liu, and Sallie E. Gordon Becker. 2004. *An Introduction to Human Factors Engineering,* 2d ed., Pearson Prentice Hall, Upper Saddle River, N.J.

[109] See also the Association for Computing Machinery Special Interest Group on Human-Computer Interaction Bibliography: Human-Computer Interaction Resources for links to more than 65,000 related publications. Available at http://hcibib.org. Accessed December 3, 2011.

[110] L.F.E. Coombs, 1990, *The Aircraft Cockpit: From Stick-and-String to Fly-by-Wire,* Patrick Stephens Limited, Wellingborough; see also L.F.E. Coombs, 2005, *Control in the Sky: The Evolution and History of The Aircraft Cockpit*, Pen and Sword Books Limited, Barnsley, U.K.

[111] Mary L. Cummings and Greg L. Zacharias. 2010. "Aircraft Pilot and Operator Interfaces," in Richard Blockley and Wei Shyy (eds.), *Encyclopedia of Aerospace Engineering*, Vol. 8, Wiley, Hoboken, N.J.

[112] Sig Mejdal, Michael E. McCauley, and Dennis B. Beringer. 2001. *Human Factors Design Guidelines for Multifunction Displays,* DOT/FAA/AM-01/17, Office of Aerospace Medicine, Washington, D.C.

[113] Ben Schneiderman. 1996. "The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations," *Proceedings of IEEE Symposium on Visual Languages,* Boulder, Colo.

concern in today's hybrid environment is the presentation of complex information associated with a large social network, consisting of multiple categories of entities (nodes) connected by multiple types of relationships (links). Algorithmic-centric approaches often take the tack of reducing node and link complexity, computing simple social network analysis measures[114] such as node centrality, and displaying abstracted two-dimensional representations of the networks with their associated measures. In contrast, visualization-centric approaches attempt to maintain the full network complexity, and present it in its full richness by means of innovative information-coding schemes (color, luminosity, size, animation, etc.). Examples of this "algorithmic-averse" approach, in which the human does the network parameter extraction, can be found at many web sites.[115] Finally, it is important to note that, in the right operational context, the visual modality may not be the best way to display information (hence, auditory alarms), and other modalities should be considered. Indeed, there is a push toward multimodality displays (combined visual, auditory, haptic, etc.) in certain cases, and there are emerging guidelines for their use and design.[116]

The development of interface controls does not have as rich a history as that of the display side, except perhaps in highly constrained environments like the aircraft cockpit. In the aircraft cockpit, manual controls have evolved from crude direct linkages from hands and feet to the control surfaces, to exquisitely complex fly-by-wire hand controllers augmented by dozens of on-stick switches and buttons, some dedicated to controlling the functionality of others.[117] Transition of interface controls to the ground-based warfighter has happened at a considerably slower pace, but it is happening. As discussed just a few years ago:

> These technologies include spatial auditory displays, skinbased haptic and tactile displays, and automatic speech recognition (ASR) voice input controls. When used by themselves or collectively, displays involving more than one sensory modality (also known as multimodal displays) can enhance soldier safety [and effectiveness] in a wide variety of applications.[118]

Potential clearly exists for improving the controls side of the interface, especially in the demanding environments faced by today's Marines. Right now,

[114]David Knoke and Song Yang. 2008. *Social Network Analysis,* 2d ed., Sage Publications, Thousand Oaks, Calif.

[115]For example, http://socialmediatrader.com/10-amazing-visualizations-of-social-networks. Acessed December 3, 2011.

[116]Leah M. Reeves, Jennifer Lai, James A. Larson, Sharon Oviatt, T.S. Balaji, Stéphanie Buisine, Penny Collings, Phil Cohen, Ben Kraal, Jean-Claude Martin, Michael McTear, T.V. Raman, Kay M. Stanney, Hui Su, and QianYing Wang. 2004. "Guidelines for Multimodal User Interface Design," *Communications of the Association for Computing Machinery* 47(1):57-59.

[117]See, for example, the F-22 controls description, at http://www.f22fighter.com/cockpit.htm#Hands-On%20Throttle%20and%20Stick%20%28HOTAS%29. Accessed December 3, 2011.

[118]Ellen C. Haas. 2007. "Emerging Multimodal Technology," *Professional Safety,* December. Available at http://www.asse.org. Accessed December 3, 2011.

the commercial world is leading the development, replacing the mouse/cursor paradigm that it introduced 30 years ago with direct visual manipulation afforded by touch-sensitive screens and multitouch gestures like "pinch" and "swipe,"[119] and, most recently, by a voice-recognition technology, Siri, introduced by Apple on its iPhone 4S.[120] Significant potential exists in improving the control side of TDAs in the next several years—not only by an improvement in the effectiveness of the operator's control of the TDA and the visualization of its data, but also by a qualitative change in the nature of the interaction. This change, in effect, would move the operator from a "batch" mode of directing algorithmic processing of a given data stream toward a "real-time" mode of interaction whereby the computer and operator mutually inform and interact with each other to arrive at a "solution" to the tactical problem at hand. Improving the control side of the interaction is critical to making this happen.

3.3.5 Physiological Monitoring and Augmented Cognition

3.3.5.1 Physiological Monitoring

As summarized in Chapters 1 and 2, decision making by the small unit leader is executed under extremely challenging physiological states and stresses, including sleep deprivation, fatigue, anxiety, and fear. All of these stressors can have an effect on basic cognitive capacities such as sustained attention.[121] In addition, the maximal tolerated stress will vary with different individuals.[122] Decision making performance could vary both among different individuals and at different times for the same individual. The most prevalent and widely studied stressor in battlefield operations is sleep deprivation or disruption that destructively impacts on the restorative properties of sleep. For example, research has shown that long periods of sleep deprivation (40 hours of sleeplessness) have a profound effect on the ability of a sharpshooter to select out one hostile target as being different from four neutral or friendly targets with minimal effects on single-target marksmanship performance.[123] Other studies have shown that sleep deprivation also impacts moral decision making tasks. After 53 hours of sleep deprivation,

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[119] See http://www.apple.com/macosx/whats-new/gestures.html. Accessed December 3, 2011.

[120] See http://www.apple.com/iphone/features/siri.html. Accessed December 3, 2011.

[121] Peter A. Hancock and Joel S. Warm. 1989. "A Dynamic Model of Stress and Sustained Attention," *Human Factors* 31(5):519-537.

[122] Peter A. Hancock and James L. Szalma. 2008. *Performance Under Stress (Human Factors in Defense),* Ashgate Publishing, Surrey, U.K.

[123] National Research Council. 2009. *Opportunities in Neuroscience for Future Army Applications,* The National Academies Press, Washington, D.C., p. 53.

there is impairment in the ability to integrate emotion and cognition information to guide moral judgments.[124]

Biological markers, or biomarkers, provide an empirical approach to assessing physiological states of the decision maker independent of that person's decision making performance.[125] Several biomarkers can potentially indicate that a small unit leader is at risk for degraded behavioral performance. These biomarkers include peripheral measures of the autonomic nervous system, including changes in the electrical properties of skin (galvanic skin response), changes in the contraction of the heart (reduction of the cardiac QT interval), and increases in pulse and respiratory rate, as shown in Table 3.1. Changes in the central nervous system can be measured by electroencephalography (EEG). There can be a reduction in the alpha (10 Hz) wave of the power spectrum of background activity and reductions in evoked electrical responses to stimuli, such as a reduced positive wave near the visual areas (the P300). Blood levels of essential hormones and proteins (such as serum cortisol and acute-phase serum protein levels) can also change with physiologic stress. Each of these biomarkers measures effects over different timescales. Some are relatively transient (measured in minutes) in their association with performance degradation, others have a somewhat longer half-life (measured in hours to days) associated with loss of performance, and yet others are long-lasting indicators (measured in weeks or longer) of performance shift.

Unfortunately, common interventions such as prescribed or limited work-shift duration that are employed in other professions, including aviation and medicine, are not readily applicable to hybrid warfare. The motivation for using physiologic monitoring is that a dynamic measure of stress or mental state could be used to introduce restorative interventions adaptively, contingent on the task or context. The biomarkers could potentially be used to establish boundary conditions or reasonable physiological states in which decision making is reliable. One outcome of this research would be the measurement of a set of biomarkers in the deployed leader, providing a mechanism to anticipate potential positive and negative responses to threat and thereby to allow mitigation of undesired states, such as poor decision making.

3.3.5.2 Augmented Cognition

As noted above, decision making is critically dependent on an ability to integrate the available evidence. Prior knowledge, experience, the level of uncertainty, and the rate at which new information is acquired during an operation are

[124] William D.S. Kilgore, Desiree B. Kilgore, Lisa M. Day, Gary H. Kamimori, and Thomas J. Balkin. 2007. "The Effects of 53 Hours of Sleep Deprivation on Moral Judgments," *SLEEP* 30(3):345-352.

[125] Additional discussion of the relation of biomarkers to stress and decision making outcomes is presented in Appendix F.

TABLE 3.1 Biomarkers, Stress Indicators, and Device Requirements for Stressors on the Battlefield

Biomarkers	Stress Indicators	Device Requirements
Cardiac QT interval	Decreased QT interval with increased stress	Portable electrocardiogram—two leads with personal digital assistant (PDA)
Pulse and respiratory rates	Increased rates with increased stress	Arm and chest electrodes with PDA
Reduction in slow wave with eyes closed	Reduction in slow wave associated with fatigue or attention loss	Electrodes placed to occipital region with PDA
Change in P300 of visual evoked potential	Marked change associated with fatigue or attention loss	Small light emitter on glasses with two electrode leads and PDA
Cortisol and acute-phase proteins	Marked changes with stress	Transdermal measure

some of the critical factors influencing how evidence is integrated when a person is making a choice.[126] In addition, time-varying internal "states" of the operator, which may be associated with workload, performance anxiety, task stress, and a number of other factors, have been hypothesized to affect information integration and decision making task performance.[127,128] Accordingly, the Defense Advanced Research Projects Agency (DARPA) initiated the Augmented Cognition program in 2001,[129] which at its inception was

> an investigation of the feasibility of using psychophysiological measures of cognitive activity to guide the behavior of human–computer interfaces. The goal is to increase the effectiveness of system operators by managing the information presented to them and the tasks assigned to them based on the available cognitive capacity of the operator.[130]

[126]Philippe Domenech and Jean-Claude Dreher, 2010, "Decision Threshold Modulation in the Human Brain," *Journal of Neuroscience* 30:14305-14317; Emily R. Stern, Richard Gonzalez, Robert C. Welsh, and Steven F. Taylor, 2010, "Updating Beliefs for a Decision: Neural Correlates of Uncertainty and Underconfidence," *Journal of Neuroscience* 30:8032-8041.

[127]See http://www.augmentedcognition.org/history.htm. Accessed December 3, 2011.

[128]Peter A. Hancock and Joel S. Warm, 1989, "A Dynamic Model of Stress and Sustained Attention," *Human Factors* 31(5):519-537; also Peter A. Hancock and James L. Szalma, 2008, *Performance Under Stress (Human Factors in Defense),* Ashgate Publishing, Surrey, U.K.

[129]Leah M. Reeves, Dylan D. Schmorrow, and Kay M. Stanney. 2007. *Augmented Cognition and Cognitive State Assessment Technology—Near-Term, Mid-Term, and Long-Term Research Objectives,* Springer, New York.

[130]Mark St. John, David A. Kobus, and Dylan Schmorrow. 2004. "Overview of the DARPA Augmented Cognition, Technical Integration Experiment," *International Journal of Human–Computer*

At the time, the program focused on

> the evaluation of 20 psychophysiological measures from 11 different research groups, including functional Near Infrared imaging, continuous and event-related electrical encephalography, pupil dilation, mouse pressure, body posture, heart rate, and galvanic skin response.[131]

The first phase of the program demonstrated "a great potential for a number of psychophysiological gauges to sensitively and consistently detect changes in cognitive activity during a relatively complex command and control-type task." It was thought at DARPA that, with sufficient development, several of the sensors could be brought out of the laboratory into the field. The second phase of the program has moved into incorporating these measures into prototypes of operational systems to further demonstrate the utility of measuring cognitive activity as a basis for augmenting that activity.

The Office of Naval Research, the Army Research Office, and the Army Research Laboratory are continuing with components of the Augmented Cognition program that DARPA started, to facilitate information integration, accelerate learning, and increase workload capacity.[132] Emerging research also suggests the potential for fMRI, EEG, and magnetoencephalography (MEG) methods to identify processes that support abstract decision making, including creative thinking.[133] Because of low cost and potential portability, increasing emphasis is given to EEG solutions to augment cognition. Methods involving brain mapping could also lead to the design of behavioral, immersive, or adaptive training algorithms that are applicable to small unit leaders.[134]

3.4 SUMMARY AND FINDING

This report deals with the conduct of enhanced company operations in hybrid environments that are complex, contingent, and variably bounded. It calls for understanding and aiding difficult levels of decision making that span tactical operations, coordination, logistics, cross-cultural negotiation, and more. Deci-

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Interaction 17(2):131-149.

[131] Mark St. John, David A. Kobus, and Dylan Schmorrow. 2004. "Overview of the DARPA Augmented Cognition, Technical Integration Experiment," *International Journal of Human–Computer Interaction* 17(2):131-149.

[132] LCDR Joseph Cohn, USN, "Some Thoughts on Improving the Decision Making Abilities of Small Unit Leaders," presentation to the committee, Washington, D.C., September 28, 2010; COL Steven Chandler, USA, "Human Dimension: Optimizing Individual Performance for More Effective Small Units," presentation to the committee, Washington, D.C., September 28, 2010.

[133] LCDR Joseph Cohn, USN, "Some Thoughts on Improving the Decision Making Abilities of Small Unit Leaders," presentation to the committee, Washington, D.C., September 28, 2010.

[134] Raja Parasuraman, James Christensen, and Scott Grafton (eds.). 2012. "Neuroergonomics: The Human Brain in Action and at Work," *NeuroImage* 59(1):1-153.

sions in that setting are made on a collection of many variables, not just one, and often involve trade-offs based on context, mission, and judgment.

Both science and engineering provide a basis for insights that can improve the decision making abilities of small unit leaders. This chapter has reviewed selected traditional and evolving approaches to cognitive psychology and cognitive neuroscience as the scientific basis for decision making. It has also discussed the roles that information integration, tactical decision aiding, and physiological monitoring can play in engineering support for decision making. The chapter closes with the committee's last finding:

FINDING 7: Established and emerging research in human cognition and decision making is highly relevant to developing approaches and systems that support small unit decision making. Cognitive psychology can provide significant guidance in developing technologies that support the decision maker, including approaches to information integration, tactical decision aids, and physiological monitoring and augmented cognition. However, technologies that do not incorporate human-centered design methods—such as those of cognitive systems engineering—may not generate *useful* and *usable* in-theater decision aids for the small unit leader. Lastly, the emerging field of cognitive neuroscience may have significant potential for developing the understanding of the fundamental neurophysiological mechanisms underlying human decision making. Although research in this area is very new, over the next few decades it may generate a fundamental paradigm change in scientific approaches to understanding human perception, sensemaking, and decision making.

4

Recommendations

The committee is impressed with the progress that the Marine Corps has made in preparing its small unit leaders for operations in Iraq and Afghanistan. Nonetheless, small unit leaders still confront a set of institutional hurdles with respect to the selection, training, and support that they receive. Their role is also changing significantly in response to the complex and evolving nature of their operational environment. This chapter presents the recommendations that the committee proposes to address these challenges. Some of the recommendations are founded on well-reviewed research that could provide near-term solutions; others are based on research, still in the formative stages, that may only have potential in the longer term. This difference is indicated in the recommendations themselves.

The committee realizes that some of its recommendations are beyond the purview of the Commanding General, Marine Corps Combat Development Command (CG, MCCDC).[1] However, the committee anticipates that all of these recommendations will be helpful to the CG, MCCDC, in terms of implementing or advocating changes in these four major areas: selection, training, support, and sustainment. Finally, the committee understands the dynamic nature of the conflict and the operational environment, and realizes that the Marine Corps may be in the process of implementing some of the committee's recommendations even as this report is being published.

[1]The CG, MCCDC, is also the Deputy Commandant for Combat Development and Integration (DC, CD&I).

4.1 SELECTION

During the course of its data gathering, the committee was impressed with the knowledge and professionalism of the small unit leaders whom the committee members had the opportunity to meet and interview. Although it is obvious that the Marine Corps selects superb Marines for these positions, the committee did not find evidence that a consistent approach is used across the Marine Corps to select leaders at the company or squad level.[2] The committee did not formally review the Marine Corps selection processes for small unit leaders, but it recognizes the importance of the selection of leaders to conduct enhanced company operations (ECO) in hybrid engagements. Further, hybrid environments often demand from these leaders "nonkinetic" response options such as the sophisticated judgments that are needed to "win the hearts and minds" of the population and deny the adversary sanctuary.

Leaders in the Marine Corps tend to be identified empirically (by what they do) in their units, rather than scientifically, through tests. However, small unit leaders are more junior in rank and have had less time in the Corps for demonstrating their leadership skills. For this reason, a science-based evaluation of leadership traits may offer some value. Validated psychometric instruments may be a suitable means to adopt immediately, while longer-term research might explore potential contributions of neuroscience-based measures.

RECOMMENDATION 1: Assess the pros and cons of establishing a Corps-wide process for the selection of squad leaders and company commanders. Such a process does not need to be centralized, but any form of implementation should be undertaken consistently across the Marine Corps. Continue to monitor progress in the development and validation of psychometric and physiologically based indicators that may have mid- and long-term potential to enhance selection.

4.2 TRAINING

The Corps has successfully employed a range of technologies to help train small unit leaders. For example, immersive training technology helps small unit leaders develop their decision making skills. But such systems are limited in number and may not be sufficiently available for a long enough period of time to support the development of expertise that is needed to improve decision making. Also, the current rate of lesson plan development and implementation for training is far too slow to be effective against an adaptive enemy: the committee heard

[2]Platoon leaders are not included in Recommendation 1 because a Corps-wide selection process for platoon leaders already exists, as mentioned in Chapter 2.

that it takes 2 years to develop new training courses.[3] Here the committee offers three bases for the training recommendations that follow.

First, training systems should help lessons learned to come alive for *both* individual Marines and small units. Unfortunately, it is not uncommon for some predeployment training, no matter how good it is, to be obsolete by the time the Marine reaches theater. Moreover, most current training systems are difficult to deploy in-theater (to support rapid skill acquisition, for example) and are not flexible enough to allow rapid updates using new scenarios or lessons learned from the field.

Second, Marines must continually observe, learn, and adapt if they are to succeed, but technological support for in-theater knowledge capture and exchange is limited. The current lessons learned program is a memorandum-style submission process that can take up to a year to become available to others, and its products typically require in-depth reading. Rapid changes in hybrid warfare call for a much more responsive, time-sensitive way to contribute and convey small unit insights, and these insights also need to be available in a medium that matches how Marines share such information. This is particularly important when geographic dispersion (e.g., in Iraq and Afghanistan) makes it difficult for small units to share fluidly evolving tactics, techniques, and procedures (TTPs) developed in direct response to an adapting adversary.[4] For example, during the committee's interviews with recently deployed Marines, small unit leaders described in-field training that they had developed for their units to change TTPs to address a specific threat. Small units and their leaders would benefit from some means to capture rapidly and share those insights. The committee was also impressed by the Tactical Ground Reporting (TIGR) system, which the Army has used on the battlefield and the Marine Corps has used in experimental efforts. Technologies such as TIGR may help small units to capture, manage, share, and display data to aid decision making for the small unit level. In addition, adaptive databases might be used in predeployment training systems to create relevant and up-to-date training scenarios that simulate the cognitive and tactical complexity of theater experiences.

Third, the committee notes that even as squad leaders are being asked to engage in a wider range of missions, training and preparation at the squad leader level still emphasize traditional combat skills. Predeployment training may not provide squad leaders with adequate exposure to the types of challenges that they are likely to encounter, particularly for nonkinetic operations.

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[3] Dennis Judge, Ground Training Division, U.S. Marine Corps Training and Education Command, "USMC Systems Approach to Training," presentation to the committee, Washington, D.C., September 27, 2010.

[4] As noted in Chapter 2, small unit leaders routinely evolve new TTPs and engage in in-field training in order to deal with specific threats more effectively.

RECOMMENDATION 2: Continue to develop and implement in-garrison and predeployment team training techniques and opportunities to increase the sensitivity and timeliness of small unit training with respect to rapidly evolving hybrid warfare issues. Specifically:

- Identify a responsible organization to ensure that training and education programs are properly developed, staffed, operated, and evaluated;
- Continue to expand and develop training for squad leaders;
- Support an increase in the availability and realism of individual and team immersive training, with learning objectives similar to programs such as Mojave-Viper and FITE;
- Adopt proven team training techniques to foster unit cohesion and continuous improvement;
- Develop training systems that respond to field experience in order to incorporate and convey lessons learned more quickly; and
- Explore the use of social media to capture and share insights of small unit leaders as a next-generation lessons learned program.

RECOMMENDATION 3: Support small units with in-theater training by adapting training and delivery methods and employing appropriate technologies:

- Develop a rapid-response training capability that allows faster reaction to the evolution of enemy tactics and techniques. For example, computer-based scenarios might be developed, then modified by small unit leaders in reaction to changing missions and tactical circumstances.
- Expand current efforts in cultural and language training to include computer-based courses and on-demand reachback for small unit leaders.

4.3 SUPPORT

Marine small unit leaders will need staffing, field assistance, and technology support to meet the increasing responsibilities of ECO in hybrid engagements and complex environments. As described in Chapter 2, the Marines have informally organized their small units to take on tasks that are similar to those now performed by the battalion-level staff. This is accomplished by appropriating Marines who are either temporarily available or not in immediate demand. Other initiatives at the small unit level during a deployment have provided immediate solutions to genuine challenges. Such ad hoc arrangements show that the need is genuine, but it is clear that these arrangements cannot be sustained over time. Informal arrangements will also tend to result in lowered performance compared with what could be accomplished by Marines who have received training and support for these tasks.

RECOMMENDATION 4: Provide primary or collateral billets at the company level to perform the functions of logistics, civil affairs, and operations and communications. Develop and provide courses of instruction that are scaled to the company level and tailored to these staff functions.

Small unit leaders who conduct distributed operations need support beyond additional billets, particularly in information and communications connectivity, information integration, and decision aiding. All of these areas call for well-tailored, human-centered technology solutions to supplement the small unit's limited manpower.

The Marine Corps is already experimenting with improved communications suites, notably the Distributed Tactical Communications System, the TrellisWare radio, and the TIGR system. All three appear promising. However, as discussed in Chapter 3, simply opening up communications can lead to a data deluge, especially with the exponential growth in the data that are available through sensors. Small unit leaders need mission-focused information integration. In such systems, data would be fused across modalities (e.g., full motion video and unmanned ground sensors), localized and/or filtered for the unit's current area of operations, and, finally, packaged into mission-relevant information products that provide actionable intelligence to the decision maker.

Electronic platforms that support the generation of these products, as well as allowing a free, unmoderated exchange of knowledge about current experience, could help Marines make better decisions for their diverse missions by providing for a free and candid exchange of experiences and new ideas.[5] In summary, a variety of high-level staff planning functions normally found at the battalion level and above may very well be supplied—in limited form—to the company and below, by means of appropriate investment in technology and human-centered engineering.

RECOMMENDATION 5: Provide technical and engineering solutions to support the small unit leader through well-tailored human-centric products for supplementing limited manpower in order to improve connectivity, information integration, and aids to decision making. Specifically:

- Provide increased communications bandwidth for voice, text, graphics, and data to small units, with priority to those in remote locations;
- Develop tactical decision aids (TDAs) designed for small unit leaders in order to support cognitive work such as sensemaking, situational assessment, problem detection, planning, and coordination and collaboration;

[5] As noted in Chapter 3, moderating these exchanges tends to limit the freedom of interactions and inhibits a free exchange of candid ideas. Instead of a moderator, the unit commanders in-theater would be best qualified to add perspective and monitor such exchanges in order to ensure the integrity of what is shared, guarding against the propagation of inaccurate claims or unfounded rumors.

- Enable Marines to use electronic platforms that allow a free, supervised (but not moderated) exchange of current experiences in-theater; and
- Provide small unit leaders with reachback capability to obtain online expertise, data, and software to support their diverse roles.

4.4 SUSTAINMENT

The term "sustainment" traditionally refers to support for the individual Marine. The term can also be applied to the sustainment of science and technology efforts that the Marine Corps and Navy can invest in the future to support the role of the small unit leader in hybrid warfare. The term is used both ways in this section.

Enlisted small unit leaders who have honed their skills to optimum levels during deployment face the prospect of significant change when they return to garrison where their duties involve far less responsibility. The refined skills that they developed to conduct ECO in the hybrid environment stand the real prospect of erosion and, in the worst case, risk being lost to the rest of the Marine Corps. This is particularly true in the case of the corporals and junior sergeants. Developing the means to keep them engaged as leaders would benefit these experienced small unit leaders as well as the Marine Corps. Such practices not only would recognize and capture junior enlisted expertise but also would make these Marines a continuing leadership resource beyond their deployment.

As noted in Chapter 3, it is now possible to measure various biomarkers of brain function (e.g., cardiac interval, pulse/respiratory rates, and electroencephalogram and functional magnetic resonance imaging activity) and bodily function (e.g., blood chemistry, stress hormones, blood pressure) reliably and noninvasively to provide a better understanding of the state of the individual. A number of these measures can be done with simple apparatus that can be used in a field environment. Therefore, it may be possible to acquire considerable data about the state of the leader on the battlefield and to make adjustments accordingly to maintain a high level of decision making performance.

RECOMMENDATION 6: Consider ways to engage experienced junior enlisted leaders so that they can continue in a leadership role and the Marine Corps can benefit from their leadership expertise. For example, include junior enlisted leaders with hybrid ECO deployed experience to support the following:

- "Schoolhouse" programs in the Marine Corps dealing with hybrid warfare, ECO, and leadership;
- The design and development of future technologies and systems (e.g., social media) to enhance the small unit's ability to successfully engage in distributed operations; and
- The design and development of immersive training and educational programs to prepare Marines for future hybrid engagements.

RECOMMENDATION 7: Continue to invest in and leverage promising areas of science and technology research in the near term, midterm, and far term to enhance the decision making performance of small unit leaders.

- In the near term:

—Invest in means to capture and disseminate or share knowledge across the Marine Corps, accompanied by good but easy-to-manage measures for tracking the effect of the capture of new knowledge and of training initiatives;

—Incorporate human systems integration into the Navy/Marine Corps acquisition process in order to ensure that decision-support systems such as communications technologies, information integration systems, tactical decision aids (TDAs), and physiological monitoring systems are based on Marine missions and operator needs; and

—Develop single-purpose applications ("apps") for smartphones and tablets to support sensor collection management, sensor signal processing, situational assessment and forecasting, and TDAs in planning and course-of-action evaluation.

- In the midterm, develop and implement the following:

—Team training and leadership training, applying the principles of resilience engineering as described in Chapter 3 of this report, in order to build small units and small unit leaders that are more resilient;

—Deployable training simulators that can be used in-theater and that can be modified by Marines, not programmers, to adapt to their current situation; and

—Training and mission-rehearsal systems, visualization aids, and TDAs for nonkinetic operations that build on current applied research in the DOD's program in Human Social Cultural Behavior.

- In the far term, explore the future potential for the following:

—Physiological identification of stress and fatigue levels, the use of biomarkers, and real-time physiological monitoring for "state" assessment to determine the possible effect of factors that might contribute to poor judgment;

—Research on state assessment and trait identification to explore the potential to identify and select good candidates for the small unit leader in hybrid warfare situations; and

—Innovative training techniques such as intelligent tutoring and adaptive learning.

Appendixes

A

Biographies of Committee Members

Robert L. Popp, *Co-Chair,* is the founder, president, and chief executive officer of NSI, Inc., a small business composed of a premier group of nationally recognized scientists, methodologists, and analysts that specializes in providing innovative social science solutions to complex problems for clients predominantly in the defense, intelligence, and national security realm. Prior to founding NSI, Dr. Popp served for 5 years as a senior government executive within the Department of Defense: 1 year at the Office of the Secretary of Defense as Assistant Deputy Undersecretary of Defense for Advanced Systems and Concepts, where he oversaw a portfolio of Advanced Concept Technology Demonstration programs focused on information assurance, multilevel security, C4ISR (command, control, communications, computers, intelligence, surveillance, and reconnaissance), and homeland security; and 4 years at the Defense Advanced Research Projects Agency (DARPA) as Deputy of the Information Exploitation Office (IXO) and Information Awareness Office (IAO). At DARPA/IAO, he oversaw a portfolio of research and development (R&D) programs focused on information technology solutions for counterterrorism and foreign intelligence. At DARPA/IXO, he established a novel R&D thrust focused on applying quantitative and computational social science models and methods to do root-cause analysis of instability and conflict within weak and failing states. Dr. Popp has served on the Defense Science Board and the Army Science Board and is a senior associate for the Center for Strategic and International Studies. He also served as an unpaid consultant to the National Research Council (NRC) Committee on Organizational Modeling: From Individuals to Societies. Dr. Popp has held senior positions with several defense prime contractors, including BBN Technologies, Aptima, and

ALPHATECH (now BAE). He holds two patents, has published many scholarly papers, and is an editor of *Emergent Information Technologies and Enabling Policies for Counter-Terrorism,* published in 2006 by Wiley-IEEE Press. He served on active duty in the U.S. Air Force in the 1980s as an aircraft maintenance technician of F-106 fighters and B-52 bombers. He received his Ph.D. in electrical engineering from the University of Connecticut.

Michael J. Williams, Gen, USMC (Ret.), *Co-Chair,* is currently an independent consultant, having retired from the U.S. Marine Corps after 35 years of service. In his last position, he served as Assistant Commandant of the Marine Corps. His previous assignments include Deputy Chief of Staff, Programs and Resources, Headquarters, Marine Corps; Commander, Marine Corps Systems Command; Commanding General, Joint Task Force 160, a humanitarian relief effort for Haitian and Cuban migrants at Guantanamo Naval Base, Cuba; Commander, 2d Force Service Support Group; Vice Director for Operational Plans and Interoperability, J-7; and Vice Director, Joint Staff for Military Education, The Joint Staff. General Williams was Commander, Marine Aircraft Group 26, and deployed to Saudi Arabia to participate in Operations Desert Shield and Desert Storm. His personal decorations include the Defense Superior Service Medal with gold star; Legion of Merit with gold star; Bronze Star Medal with Combat "V"; Meritorious Service Medal; Air Medal with Strike Flight Numerals "25" and bronze star; and Navy Commendation Medal with gold star and Combat "V." General Williams is a former member of the Defense Science Board (DSB) and served as co-chair of the DSB Task Force on Deployment of Members of the National Guard and Reserves in the Global War on Terror. He holds master's degrees from the University of Southern California and the College of Naval Warfare.

Peter A. Beling is an associate professor in the Department of Systems and Information Engineering at the University of Virginia, having joined the faculty there in 1993. Previously, he held positions at the Center for Naval Analyses, where he worked primarily on analyses of Marine Corps operations, and at IBM Almaden Research, where he studied algorithms for parallel and distributed optimization. Dr. Beling's research interests are in the area of decision making in complex systems, with emphasis on Bayesian scoring models, machine learning, and mathematical optimization. His research has found application in a variety of domains, including reconnaissance and surveillance, education and training, and lender and consumer-credit decision making. Dr. Beling is the founder of the Financial Engineering Research Group at the University of Virginia, which is a focal point for research on the mathematical modeling and risk management aspects of consumer and retail credit. He is also active in the University of Virginia site of the Wireless Internet Center for Advanced Technology, which is an Industry-University Cooperative Research Center sponsored by the National Science Foundation. He has served as reviewer or editor for a number of academic journals. Dr. Beling received his Ph.D. in industrial engineering and operations research from the University of California, Berkeley.

Janis A. Cannon-Bowers is a research professor of the Institute for Simulation and Training at the University of Central Florida. She is currently the principal investigator on several efforts involved with the application of technology to the training for and execution of complex tasks. These efforts include developing and testing videogame technologies that will teach fundamental knowledge and skills to Navy recruits; investigating command decision making and teamwork on Navy submarines in order to make recommendations for enhanced training, information architecture, and displays; and investigating intelligent tutoring and scenario-based training strategies for Navy surface-ship training. Dr. Cannon-Bowers previously held the position of senior scientist for training systems for the U.S. Navy in a senior executive-level scientist position and reported directly to the Chief of Naval Operations. In this position, she provided advice to senior Navy leadership on how to best restructure the entire training enterprise and transform the Navy into a learning organization. Dr. Cannon-Bowers is an active researcher, with more than 125 scholarly publications and presentations. She serves on the editorial boards of several research journals, and is currently a member of the NRC Committee on Learning Science: Computer Games, Simulations, and Education. She earned both her M.A. and her Ph.D. degrees in industrial/organizational psychology at the University of South Florida.

Scott T. Grafton is a professor of psychology and director of the Brain Imaging Center at the University of California, Santa Barbara, where he joined the faculty in 2006. The center uses functional magnetic resonance imaging (fMRI), magnetic stimulation, and high-density electroencephalography (EEG) to characterize the neural basis of goal-directed behavior. Dr. Grafton's recent research projects include an initiative co-funded by the Army Research Office to develop fMRI methods of human expertise, individual subject differences, and learning. He was previously a research fellow in neuroimaging at the University of California, Los Angeles, where he developed methods for mapping human brain activity using positron emission tomography. With these methods he focused on brain plasticity during motor learning and the reorganization of the nervous system in the face of injury or neurodegeneration. He went on to develop brain imaging programs at the University of Southern California, Emory University, and Dartmouth College. He received his M.D. from the University of Southern California and completed a neurology residency at the University of Washington and a residency in nuclear medicine at the University of California, Los Angeles.

Susan Hackwood is currently the executive director of the California Council on Science and Technology (CCST) and professor of electrical engineering at the University of California, Riverside, where her research interests include electrical engineering, signal processing, and cellular robotic systems, to name just a few. CCST is a not-for-profit corporation composed of 200 top science and technology leaders sponsored by the key academic and federal research institutions in California; it advises the state on all aspects of science and technology, including nanotechnology, stem cell research, intellectual property, climate change, energy, information technology, biotechnology, and technical workforce development and education. Dr. Hackwood has worked extensively with industry, academic, and government partnerships to identify policy issues of importance and is active in regional and state economic development. She is currently a member of the NRC's Naval Studies Board and has served on other scientific boards and advisory committees. Dr. Hackwood is a fellow of the Institute of Electrical and Electronics Engineers and the American Association for the Advancement of Science. She received a Ph.D. in solid state ionics in 1979 from De Montfort University.

Stephan Kolitz, a distinguished member of the technical staff in the Mission Systems Division, has been on the technical staff at the Charles Stark Draper Laboratory since 1989. He continues to be the lead for the development of new technologies and for their implementation into practice to solve operational problems for complex systems across a wide range of domains, including C2 (command and control), ISR (intelligence, surveillance, and reconnaissance), irregular warfare, transportation and logistics, sensor data fusion, information exploitation, reliability and safety analysis, and autonomous mission planning. His recent and current projects include the following: command and control of large-scale sensor systems; force protection against an asymmetric threat; modeling, risk-aware planning and scheduling for transportation and logistics operations; and research into human-computer collaborative decision making under uncertainty. He is an associate fellow of the American Institute of Aeronautics and Astronautics (AIAA) and is on the AIAA Intelligent Systems Committee. Dr. Kolitz has provided leadership in Draper's collaboration with the academic world, supervising more than 25 graduate students from the Massachusetts Institute of Technology (MIT), both master's and Ph.D. candidates doing their thesis and dissertation research at Draper. He is a lecturer in extension at Harvard University and has been a lecturer at MIT. He has been an author on more than 55 papers during his time at Draper. He holds a Ph.D. in operations research from Northwestern University.

Steven Kornguth is the director of the Center for Strategic and Innovative Technologies at the University of Texas at Austin, as well as the director of biological and chemical defenses at the Institute for Advanced Technology for the identification of critical technologies, and a research professor of pharmacy. His current research efforts relate to sustaining the high-tempo operations performance of soldiers and developing technologies for defense against biological threats. Dr. Kornguth was previously a professor of neurology and biomolecular chemistry at the University of Wisconsin, Madison, and is currently professor emeritus. He is editor of *Neurocognitive and Physiological Factors During High-Tempo Operations,* published in 2010 by Ashgate. Dr. Kornguth is a current member of the Army Science Board and a former member of the NRC Committee on Opportunities in Neuroscience for Future Army Applications. He is also a member of the Biological Security Experts Group. He earned his Ph.D. in biochemistry from the University of Wisconsin, Madison.

Frederick R. Lopez, BrigGen, USMCR (Ret.), is an independent consultant, having retired from the U.S. Marine Corps Reserve after 28 years and having served 3 years on active duty. He also had a 36-year career as an engineer with McDonnell Douglas Aircraft Company and Raytheon Company. In his last position, he was the director of engineering for Raytheon Electronic Warfare Systems in Goleta, California. General Lopez was responsible for the management of all engineering personnel in support of operational and support programs in electronic warfare systems and for the implementation of engineering processes and process improvement activities within the engineering discipline. Highlights in General Lopez's Marine Corps career include a tour of duty in Vietnam, service as an Infantry Officer with Master Parachutist Qualification, and a secondary Military Occupational Specialty of Forward Air Controller (FAC). He has held billets as company executive officer, company commander, battalion executive officer, battalion commander, FAC, naval gunfire team leader, brigade platoon leader, Air/Naval Gunfire Liaison Company operations officer, regimental operations officer, assistant division commander and Commanding General of the 4th Marine Division, and Deputy Commanding General of the lst Marine Expeditionary Force. His medals and decorations include the Distinguished Service Medal and Bronze Star Medal with Combat "V." General Lopez was a member of the NRC Standing Committee for Technology Insight—Gauge, Evaluate, Review, and the NRC Committee on Avoiding Technology Surprise for Tomorrow's Warfighter. He received a B.S. degree in mathematics from California State Polytechnic College and his M.S. in computer science from West Coast University.

Laura A. McNamara is a principal member of technical staff in the Exploratory Simulation Technologies Organization at the Sandia National Laboratories. Trained in cultural anthropology, Dr. McNamara conducts field studies in national security environments to assess barriers and opportunities for new technology development and adoption. She has worked with nuclear weapons experts, intelligence analysts, and cybersecurity experts, focusing on issues of expert knowledge elicitation and representation, verification and validation in computational social science, uncertainty quantification, user-centered design strategies, innovation adoption, and software evaluation. As the human factors team lead for Sandia's Networks Grand Challenge, she is currently working on evaluation strategies to determine how novel information visualization techniques impact knowledge production in intelligence organizations. Dr. McNamara is a fellow of the Society for Applied Anthropology and was appointed to a second term on the American Anthropological Association's Commission on the Engagement of Anthropology with the U.S. Security and Intelligence Communities. She received her Ph.D. in cultural anthropology from the University of New Mexico.

Christopher Nemeth is a principal scientist at Applied Research Associates, Inc., Cognitive Solutions Division. He is group leader for Cognitive Systems Engineering and performs research to understand and support human cognitive performance in high-hazard work domains. Dr. Nemeth has served for more than 20 years as an adjunct member of the faculty at the Illinois Institute of Technology. As principal of Nemeth Design/Human Factors, he has provided design and human factors consulting, writing on human performance and system design, and has provided expert witness services for litigation related to human performance. Dr. Nemeth served in the U.S. Navy and Naval Reserve and retired at the rank of captain after 30 years of service. In his last assignment, he served as the Public Affairs Officer for the Naval Surface Reserve Force, headquartered in New Orleans, Louisiana. His personal decorations include the Legion of Merit, Defense Meritorious Service Medal, Meritorious Service Medal, Navy Commendation Medal (second award), and Navy Achievement Medal (second award). He also earned qualifications as a Navy diver (scuba) and Navy/Marine Corps parachutist. Dr. Nemeth received his Ph.D. in human factors/ergonomics from the Union Institute and University.

Michael I. Posner is currently an emeritus professor of psychology at the University of Oregon in the Department of Psychology and the Institute of Cognitive and Decision Sciences. He is also an adjunct professor at the Sackler Institute for Developmental Psychobiology at Weill Medical College of Cornell University. Dr. Posner is an eminent researcher in the field of attention and has studied the role of attention in high-level human tasks such as visual search, reading, and number processing. More recently, he has investigated the development of attentional networks in infants and young children. Dr. Posner is a fellow of the American Psychological Association, the Association for Psychological Science, the Society of Experimental Psychologists, the American Academy of Arts and Sciences, and the American Association for the Advancement of Science. He was elected to the National Academy of Sciences in 1981 and the Institute of Medicine in 1988. He is currently a member of the NRC's Board on Behavioral, Cognitive, and Sensory Sciences and was a member of the NRC Committee on Human Factors (currently known as the Committee on Human-Systems Integration). For his contributions to the field of cognitive neuroscience, Dr. Posner was awarded the 2008 National Medal of Science. He earned his Ph.D. in psychology from the University of Michigan.

Alan R. Washburn, distinguished professor emeritus of operations research at the Naval Postgraduate School, has served as chair of the Operations Research Department. His work has spanned the fields of electrical engineering, physics, mathematics, and operations research. Dr. Washburn is the recipient of many awards including the 2005 Clayton J. Thomas Award from the Military Operations Research Society and the 2009 Navy Distinguished Civilian Service Medal awarded by the Secretary of the Navy. His research results in applied probability, search and detection, optimization, combat models, game theory, and undersea warfare have been applied by the military services. Dr. Washburn was elected to the National Academy of Engineering in 2009 for his analytical contributions to search theory and military operations research and their application to antisubmarine, mine, and information warfare. He earned his Ph.D. in electrical engineering from Carnegie Mellon University.

Gerold Yonas joined the Mind Research Network in 2009 as the director of neurosystems engineering. In his current work, he is dedicated to creating the new field of neurosystems engineering that links the advances in neuroscience with systems engineering through interdisciplinary teams that focus on the development of solutions to complex system problems that involve behavior, cognition, and neurotechnology. Previously, Dr. Yonas worked at the Sandia National Laboratories, where he served as vice president of Systems, Science, and Technology and later became Sandia's principal scientist and initiated Sandia's Advanced Concepts Group. He is a fellow of the American Physical Society and a fellow of the American Institute of Aeronautics and Astronautics. He has received several honors, including the U.S. Air Force Medal for Meritorious Civilian Service and the Secretary of Defense Medal for Outstanding Public Service. Dr. Yonas participates in several defense boards and is an adjunct professor in the Department of Electrical and Computer Engineering at the University of New Mexico. He has published extensively in the fields of intense particle beams, inertial confinement fusion, strategic defense technologies, technology transfer, and "wicked engineering." He received his Ph.D. in engineering science and physics at the California Institute of Technology.

Greg L. Zacharias is the president and senior principal scientist of Charles River Analytics, Inc. In this position, he provides strategic direction for the Government Services and Commercial Solutions Divisions, while contributing to efforts in cognitive systems engineering and advanced decision-support systems. Before co-founding Charles River Analytics, he was a senior scientist at BBN Technologies, a research engineer at Charles Stark Draper Laboratory, and a U.S. Air Force attaché for the Space Shuttle program at NASA's Johnson Space Center. Dr. Zacharias has been a member of the NRC's Committee on Human Factors (currently the Committee on Human-Systems Integration), co-chaired the NRC

Committee on Organizational Modeling: From Individuals to Societies, and recently was a member of the NRC's Committee for a Review of the En Route Air Traffic Control Complexity and Workload Model reviewing an En Route Air Traffic Control Workload Model for the Federal Aviation Administration. He has served on the Air Force Scientific Advisory Board as an outside peer reviewer of the Air Force Research Laboratory and recently chaired a study in advanced command and control of remotely piloted aircraft for future operations. Dr. Zacharias is currently the founding chair of the Human Systems Division of the National Defense Industrial Association. He earned a Ph.D. in aeronautics and astronautics from the Massachusetts Institute of Technology.

B

Summary of Committee Meetings and Site Visits

The Committee on Improving the Decision Making Abilities of Small Unit Leaders was first convened in August 2010. Over a period of 6 months, the committee held numerous meetings and conducted site visits both to gather input from the relevant communities and then to discuss the committee's findings and recommendations. The meetings consisted of a combination of presentations from outside experts and discussion and debate among the committee. A summary of the committee's meetings and site visits is provided below:

- *August 5-6, 2010, in Washington, D.C.* First full committee meeting. Briefings on enhanced company operations and small unit decision making from the Marine Corps Combat Development Command (MCCDC); Marine Corps Warfighting Laboratory, MCCDC; Training and Education Command (TECOM), MCCDC; and the Office of Naval Research, Expeditionary Maneuver Warfare and Combating Terrorism Science and Technology Department (ONR Code 30).
- *September 27-28, 2010, in Washington, D.C.* Second full committee meeting. Briefings on small unit decision making from U.S. Army Special Forces, Special Operations Command; Training and Doctrine Command, U.S. Army; and Ground Training Division, TECOM, MCCDC. Additionally, the committee hosted a panel of small unit leaders (i.e., Marine Corps captains) from the Basic School to hear their personal experiences and recommendations and a panel of government and industry scientists from the following organizations: Office of Naval Research; the Center for Advanced Operational and Culture Learning, TECOM, MCCDC; NSI, Inc.; and Personal Decisions Research Institutes.
- *October 6-7, 2010, in Camp Pendleton, California.* Site visit and small group data-gathering session. Briefings on the Future Immersive Training Environment, Joint Capability Technology Demonstration.

- *November 15-16, 2010, in Washington, D.C.* Third full committee meeting. Briefings on decision-support systems, expert performance, and training in adaptive thinking from the Defense Advanced Research Projects Agency, Naval Research Laboratory, Army Research Laboratory, Air Force Research Laboratory, Army Research Institute for the Behavioral and Social Sciences, and Florida State University.
- *December 7-8, 2010, in Quantico, Virginia.* Site visit and small group data-gathering session. Committee interviews with Marine Corps small unit leaders.
- *December 9-10, 2010, in Washington, D.C.* Fourth full committee meeting. Committee deliberations and report drafting.
- *January 10-14, 2011, in Irvine, California.* Fifth full committee meeting. Committee deliberations and report drafting.

C

Acronyms and Abbreviations

AOR	area of responsibility
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CAOCL	Center for Advanced Operational Culture and Learning
CG	commanding general
CLIC	company-level intelligence cell
CLOC	company-level operations cell
CM	collection management
COA	course of action
COIN	counterinsurgency
CSE	cognitive systems engineering
CTA	cognitive task analysis
DARPA	Defense Advanced Research Projects Agency
DDR&E	Director of Defense Research and Engineering
DFT	data-frame theory
DOD	Department of Defense
DTCS	Distributed Tactical Communications System
ECO	enhanced company operations
EEG	electroencephalography
EMO	enhanced Marine Air-Ground Task Force operations

FITE	Future Immersive Training Environment
fMRI	functional magnetic resonance imaging
FMV	full-motion video
GAO	Government Accountability Office
HB	heuristics and biases
HCI	human-computer interface
HSCB	human socio-cultural behavior
IED	improvised explosive device
IIT	Infantry Immersion Trainer
IMEF	I Marine Expeditionary Force
ISAF	International Security Assistance Force
ISR	intelligence, surveillance, and reconnaissance
JCTD	Joint Capability Technology Demonstration
LOE	Limited Objective Experiment
MAGTF	Marine Air-Ground Task Force
MCCDC	Marine Corps Combat Development Command
MCDP	Marine Corps Doctrinal Publication
MCWL	Marine Corps Warfighting Laboratory
MTT	Mobile Training Team
NATO	North Atlantic Treaty Organization
NCO	noncommissioned officer
NDM	naturalistic decision making
NIPRnet	Non-classified Internet Protocol Router Network
NRC	National Research Council
NSB	Naval Studies Board
ONR	Office of Naval Research
OR	operations research
OSD	Office of the Secretary of Defense
PDA	personal digital assistant
R&D	research and development
RE	resilience engineering
ROE	rules of engagement
RPD	recognition-primed decision making

SA	situational awareness
SAT	Systems Approach to Training
SC MAGTF	Security Cooperation Marine Air-Ground Task Force
SEU	subjective expected utility
SIPRnet	Secret Internet Protocol Router Network
TDA	tactical decision aid
TECOM	Training and Education Command
TIGR	Tactical Ground Reporting
TTPs	tactics, techniques, and procedures
UAV	unmanned aerial vehicle
USMC	U.S. Marine Corps

D

Marine Corps Small Units

The Marine Corps considers small units to be at the company level and below. Of these small units, the committee focused on the leaders of companies, platoons, and squads. Although the actual size and organization of these units depend on the type of unit and mission, Figures D.1, D.2, and D.3 provide the organizational diagrams of a typical rifle company, rifle platoon, and rifle squad, respectively.

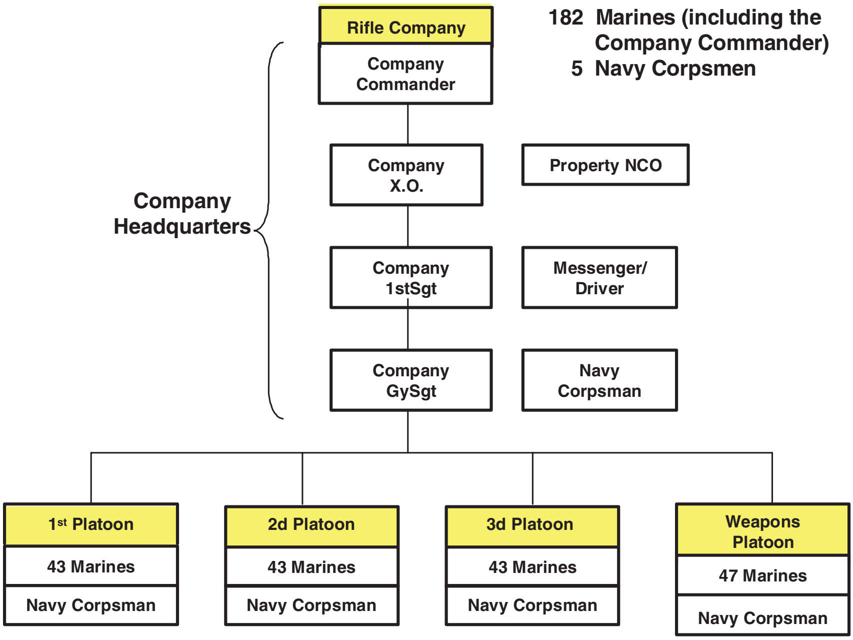

FIGURE D.1 Organizational diagram of a typical U.S. Marine Corps rifle company. The company commander is usually a captain.

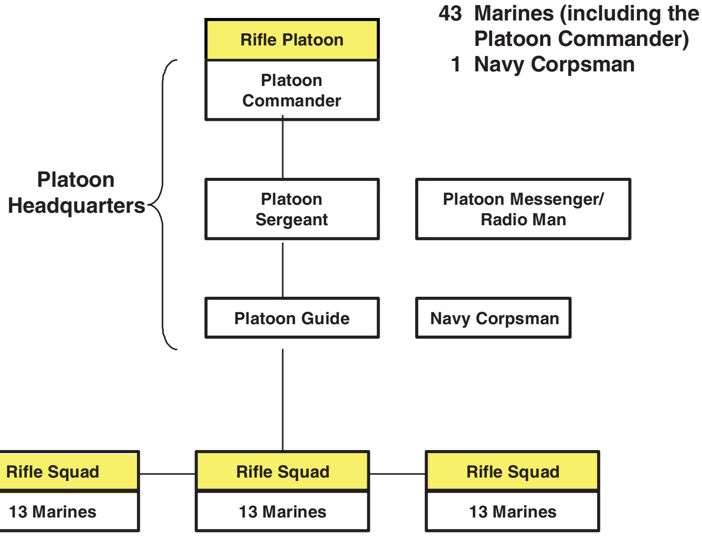

FIGURE D.2 Organizational diagram of a typical U.S. Marine Corps rifle platoon. The platoon leader is usually a second lieutenant.

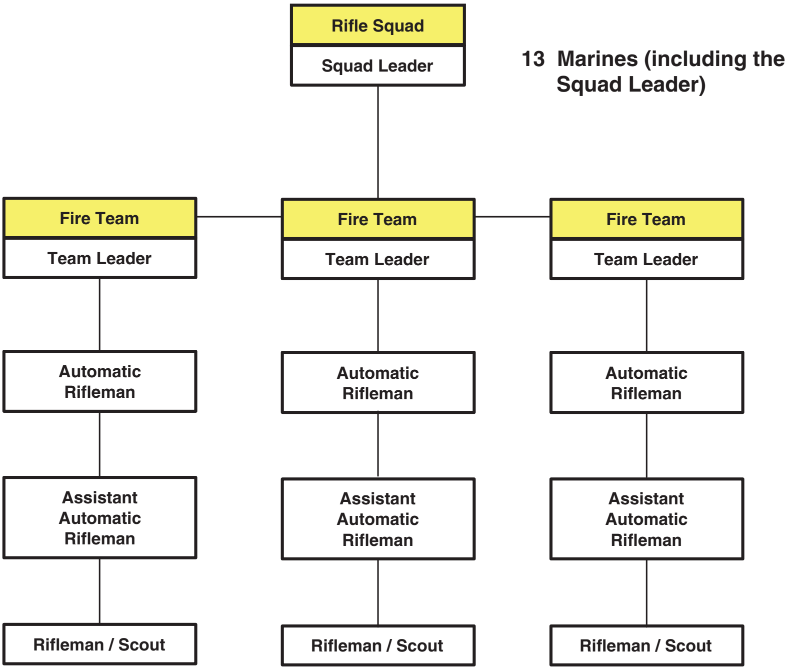

FIGURE D.3 Organizational diagram of a typical U.S. Marine Corps rifle squad. The squad leader is usually a sergeant or corporal.

E

Interview Protocol

A subgroup consisting of six members of the National Research Council's Committee on Improving the Decision Making Abilities of Small Unit Leaders conducted a 1-day, interview activity at the Marine Corps Combat Development Command (MCCDC) in Quantico, Virginia, on December 7, 2010, to gather data on the characteristics of decision challenges that Marine small unit leaders face in Iraq and Afghanistan. The goal of these interviews was to gather data on the types of decisions faced by small unit leaders conducting enhanced company operations and distributed operations in Iraq and Afghanistan.

Members of the committee subgroup asked the interview participants to describe and comment on the kinds of decisions that they had made while conducting kinetic and nonkinetic operations in the field. The subgroup agreed to keep the interview responses anonymous and did not collect any identifying information from the interviewees, except for rank and deployment experience.

Members of the subgroup designed an efficient, team interviewing approach so as to maximize the amount of information gathered while minimizing the burden on MCCDC staff. The interview protocol that was followed is summarized below.

PARTICIPANTS

The subgroup interviewed junior officers and noncommissioned officers with recent deployment experience in Iraq or Afghanistan in leadership positions at the company, platoon, and squad levels. The interview pool, selected by MCCDC, included captains, lieutenants, sergeants, and one corporal. Twenty-four small unit leaders were selected for the interviews.

SCHEDULE

Three interview teams of two committee members each scheduled interviews with two small unit leaders per session, for a total of 24 interviews.[1] Each interview lasted approximately 90 minutes.

INTERVIEW QUESTIONS

Each session began with interviewees being asked to give oral consent with respect to the following points of procedure:

- Individuals were welcome to participate in the interview at their own choice.
- Whether an individual participated was to have no effect on that person's status or performance evaluation.
- Participants could choose to withdraw from the interview at any time.
- No identifying information was recorded.
- No risks were anticipated.

For background information, the interviewees were asked to provide a brief description of their assignments in the Marine Corps so far, their deployments over the past couple of years, and their role during their most recent deployment. Each Marine was also asked to describe his or her recent experience in distributed operations, including the major tasks for which the interviewee was responsible and that person's experiences with intelligence, logistics, and command and control. Then, each Marine was asked to share a particularly challenging event that he or she had experienced as a key participant when deployed. The interviewee was also asked to describe what he or she thought would be the most challenging event or situation that he or she could face on a combat assignment. Each Marine was also given the chance to discuss anything that he or she wanted to share before concluding the interview.

RESULTS

After the interviews were complete, the subgroup performed iterative qualitative coding on the interview responses to identify key themes in the interviewees' accounts. No evaluation of the individuals was undertaken.

[1]One of the Marines was unable to participate, and so in the end, 23 Marines were interviewed.

F

Biomarkers

Specific biomarkers can be measured to indicate performance capability. For instance, individuals exhibiting extensive neural connectivities between major brain areas (as determined by increased fractional anisotropy on diffusion tensor imaging, a magnetic resonance imaging technique) tend as a group to sustain attention for longer periods of time than those with fewer such connectivities. Subsequently, those individuals exhibiting extensive connectivities will perform at a sustained level for longer time periods than those will with fewer connectivities.[1] As another example, the marked reduction in the slow wave from visual cortex recordings following eye closure is indicative of fatigue and loss of vigilance.[2]

[1]Matthew D. Rocklage, Victoria Williams, Jennifer Pacheco, and David M. Schnyer, 2009, "White Matter Differences Predict Cognitive Vulnerability to Sleep Deprivation," *Sleep* 32(8):1100-1103; Matthew D. Rocklage, W. Todd Maddox, Logan T. Trujillo, and David M. Schnyer, 2010, "Individual Differences to Sleep Deprivation Vulnerability and the Neural Connection with Task Strategy, Metacognition, Visual Spatial Attention, and White Matter Differences," pp. 75-92 in Steven Kornguth, Rebecca Steinberg, and Michael D. Matthews (eds.), *Neurocognitive and Physiological Factors During High-Temp Operations,* Ashgate Publishing, Burlington, Vt.

[2]Christian Cajochen, Daniel P. Brunner, Kurt Kräuchi, Peter Graw, and Anna Wirz-Justice, 1995, "Power Density in Theta/Alpha Frequencies of the Waking EEG Progressively Increases During Sustained Wakefulness," *Sleep* 18:890-894; Christian Cajochen, Rosalba Di Biase, and Makoto Imai, 2008, "Interhemospheric EEG Asymmetries During Unilateral Bright-Light Exposure and Subsequent Sleep in Humans," *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology* 294:R1053-1060; Julian Lim and David F. Dinges, 2008, "Sleep Deprivation and Vigilant Attention," pp. 149-173 in *Annals of the New York Academy of Sciences* 1129:305-322; Ernst Niedermeyer, 1999, "The /Normal EEG of the Waking Adult," in Ernst Niedermeyer and Fernando Lopes Da Silva (eds.), *Electroencephalography: Basic Principles, Clinical Applications and Related Fields* (4th ed.), Williams and Wilkens, Philadelphia, Pa.

Certain biomarkers can be measured quantitatively in an operational setting as shown in Chapter 3, Table 3.1. By monitoring multiple indicators, it may be possible to provide a signature of probable performance degradation. The measurement of these biomarkers in the deployed leader could then provide a mechanism for anticipating potential positive and negative responses to threat and thereby allow mitigation of undesired states. One possibility then would be for extensive data sets of individual performance versus stress curves to be developed for the leaders.

One challenge would be to develop better estimates of an individual's state (e.g., Is an individual in a rational, decision making mode versus an anger-response mode, or in a state to detect the presence of a threat rapidly versus lacking focus?). Objective assessments of individual states performed in a quantitative and reproducible manner would require individual-based correlates of biomarker measurements with performance capability. The varied experiences of individual Marines suggest that biomarker outputs required for the assessment of logistics leaders may differ from those needed by infantry leaders who may also have a different set of critical markers from those for Marines involved in negotiations with a local council leader.

Stress is coupled to performance in general as a U-shaped function: at very low stress levels and at very high stress levels, performance degrades (see Figure F.1). For example, performance can degrade either because of boredom (very low stress) or because of overload (high stress). The maximum level of stress conducive to high performance varies by individual.[3] In studying individual differences, it would be ideal to develop for each unit leader a plot of stress susceptibility versus performance under high-tempo operations. The stresses assessed could include sleep deprivation, fatigue, anxiety, isolation, and fear. Such a set of curves could predict changes in the ability to make decisions and maintain vigilance, situational awareness, and communication skills.

DECISION SPACE

Decision making in conducting enhanced company operations in hybrid engagement, complex environments is carried out in a context of complexity, the time duration of the mission, and geographical distribution. The complexity of decision making is confounded by the conflicting goals of kinetic combat conducted simultaneously with nonkinetic interactions involving noncombatants with a strategic mission to "win the hearts and minds of the population." The time element can range from tactical issues that last for minutes to long-term strategic issues that may last for weeks and months. The geographic distribution can range from the local issues in a neighborhood of a small village to the large-scale inter-

[3] Peter A. Hancock and James L. Szalma. 2008. *Performance Under Stress (Human Factors in Defense),* Ashgate Publishing, Surrey, U.K.

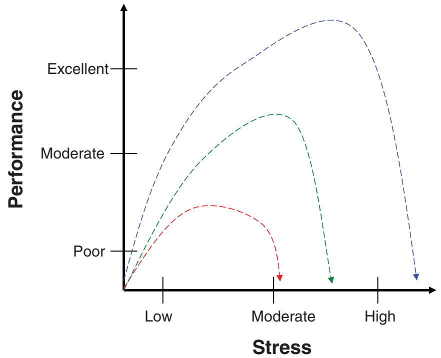

FIGURE F.1 Performance versus stress. SOURCE: Adapted from data by Peter A. Hancock and Joel S. Warm, 1989, "A Dynamic Model of Stress and Sustained Attention," Human Factors 31(5):519-537.

actions in a state or a region. These three variables (complexity, time, and space) that characterize decision making can be plotted together. This plot in Figure F.2 can be thought of as the "decision space."

The decision space also includes many coupled dependencies, such as the impact of noncombatant and combatant casualties on psychological stress, time urgency as a function of rapidly changing conditions, the logistics of supplying needed support over a great distance, and the quantity and validity of the data that contribute to situational awareness. And, of course, all of these interactions are

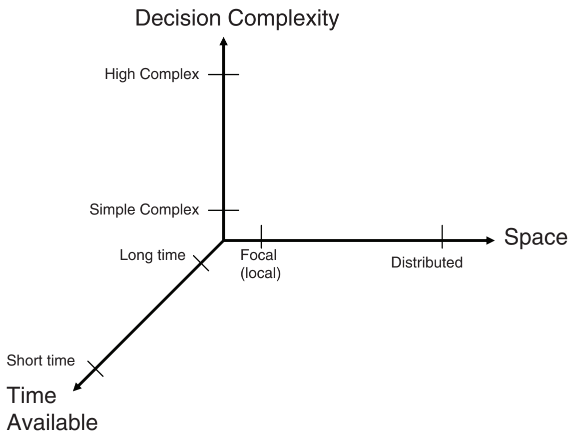

FIGURE F.2 The decision space, involving complexity, time, and space. The farther one is from the origin, the more stressful and difficult the decision making task becomes, with a higher likelihood of negative outcomes; the closer to the origin, the more manageable the decision making is.

compounded by the various uncertainties associated with each of the decisional factors (i.e., the *real* state of the world, the uncertainty associated with a weapon's effect and the associated collateral damage, etc.). As a result of these multiple interacting variables, the outcome of any action will have high variability with often-unexpected and sometimes undesirable outcomes.

A PROBABILISTIC APPROACH

Because precise predictions of the outcomes of various decisions are not possible, a probabilistic risk management approach to decision making could be applied. This probabilistic or engineering approach should include the expected performance of individual decision makers at various points in the decision space. In particular, the biomarkers of the individual making the decision could be a particularly vital source of data that could be monitored and used to reduce the risk involved in military operational decisions.

"Risk" is defined here as the product of the consequence of an outcome and the probability of that outcome occurring. The desired outcome from improving the decision making capability of small unit leaders is to minimize the risk involved in their decisions. Risk can be reduced by changing either the consequence of an action or its probability of occurrence, or both. Improvements could be achieved in decision making performance by using biomarkers to monitor the physiological characteristics of individuals and providing mitigation to reduce the probability or consequence of a particular suboptimal decision process. Figure F.3 illustrates how lowering the consequences and lowering the probability lowers the risk.

Because of the inherent complexity of hybrid warfare, particularly in situations involving combatants and noncombatants, the consequences of an action may be significant and the probability of an undesirable outcome may be high. An example would be a patrol that has a high probability of noncombatant casualties as a result of the co-location of noncombatants.

In all cases, the risk management approach requires the ability to make decisions involving an analysis of a situation and an evaluation of the risk involved. The performance of the decision maker will depend on such factors as perceived rewards, cost, and social influences. Individual differences include intelligence, adaptability, specific situational awareness, and training. It is well known that the effectiveness of the decision maker is particularly impacted by chronic and acute stressors as a function of time.[4]

Individual characteristics of adaptability can result in different levels of continuing performance over a broad level of stress and over an extended period, but for each individual there is a cumulative effect of chronic stress punctuated

[4]Peter A. Hancock and James L. Szalma. 2008. Performance Under Stress (Human Factors in Defense), Ashgate Publishing, Surrey, U.K.

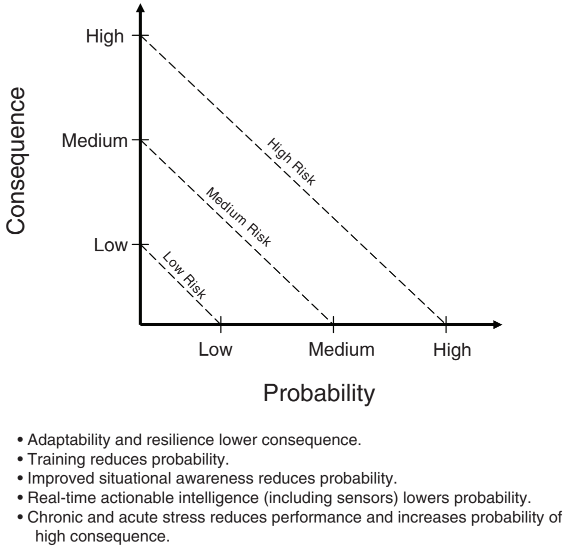

FIGURE F.3 Risk management. (The scales of the axes are logarithmic.)

by acute incidents that can lead to a certain point at which the performance can rapidly decline (based on the Yerkes-Dodson law illustrated earlier in Figure F.1). In addition to the widely used methods of behavioral modeling, the data from biomarkers on the physiological status of the decision maker could also be used to anticipate or avoid this decrease in performance.

The critical technical issue that needs to be resolved is whether physiological monitoring using biomarkers can be used to determine the performance stress curves for individuals and whether those data can be used in a predictive manner to improve decision making under realistic stress conditions.

G

Dissenting Opinion

In multiple ways and places, Chapter 3 claims or implies that a utility-based decision making technique that we will call DA has, after numerous failures, largely been replaced by more modern methods. This appendix is a rebuttal. The subject is important because DA is one of the techniques that the Marines might better take advantage of.

In their seminal 1944 book, John von Neumann and Oskar Morgenstern (VNM) proved that *rational* decision makers will make decisions *as if* they were maximizing the expected value of some scalar quantity that VNM refer to as "utility." Theirs is a mathematical theorem, so the word "rational" has the meaning implied by their assumptions. For example, VNM assume that a rational decision maker who prefers A to B, as well as B to C, will also prefer A to C. The idea of making decisions that maximize some scalar quantity (especially "profit") considerably predates VNM; their contribution is to demonstrate that doing so is inevitable for rational decision makers. VNM do not assume that rational decision makers necessarily approach problems mathematically. You are probably acting rationally when you tie your shoes in the morning, even though mathematics is the furthest thing from your mind. A determined scientist could probably demonstrate that you are maximizing the time available for more productive pursuits (utility) by minimizing the time spent on shoe tying.

VNM make no claim about how actual humans make decisions, but we assert that human decisions are typically rational, and that a significant fraction of those decisions is currently guided by calculations that amount to maximizing utility. For lack of a better term, call this formal, utility-based approach to decision making Decision Analysis (DA). Chapter 3 uses several terms for the idea—SEU, normative analysis, etc.—but one will do here. DA has been greatly aided by the advent of modern computers, to the extent that making decisions that maximize utility is now widespread. The electric grid is managed this way, inventories are maintained this way, vehicle routes are determined this way, and people are routed around traffic jams this way. Missile defenses are planned this way, and crisis management teams (fire departments, police stations, emergency vehicles) are located this way. The idea pervades and improves modern life, even when it lies in the background. Microsoft Excel™ is distributed with an engine (Solver) the primary purpose of which is to maximize some scalar quantity. There are several journals that are at least partially devoted to DA, one of which is the eponymous *Decision Analysis*. There are large (thousands of attendees) meetings held regularly all over the world where much of the agenda is devoted to recounting the successes of DA and to enabling further application.

Now, it is true that some human decision making is not rational in the sense of VNM. People sometimes have circularities in their preferences, especially when the alternatives are almost equally attractive. Humans also have a limited innate capacity for processing information, and even that capacity can be degraded by prolonged stress of the type that Marines sometimes endure. Not all attempts to apply DA succeed, and some should not even be attempted. All of these facts are undisputed, and ought to be considered by anyone tempted to apply DA to problems of the type that Marine small unit leaders face. However, Chapter 3 makes far too much of these caveats and difficulties. Occasional failures should be expected in a technique as widely applied as DA, and lessons have been learned from them. Rationality ought to remain the default assumption, even in the midst of battle. There is no good reason for Marines to systematically adopt some other decision making paradigm where the irrationality of humans is a central tenet.

The USMC regularly sends young officers to the Naval Postgraduate School and other universities for advanced education in Operations Research. A significant part of that education is devoted to rational decision making in varied circumstances, including circumstances that involve a sentient enemy. The fact that DA is alive and well is thus hardly news to the USMC. It is unfortunate that Chapter 3 states the contrary.

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