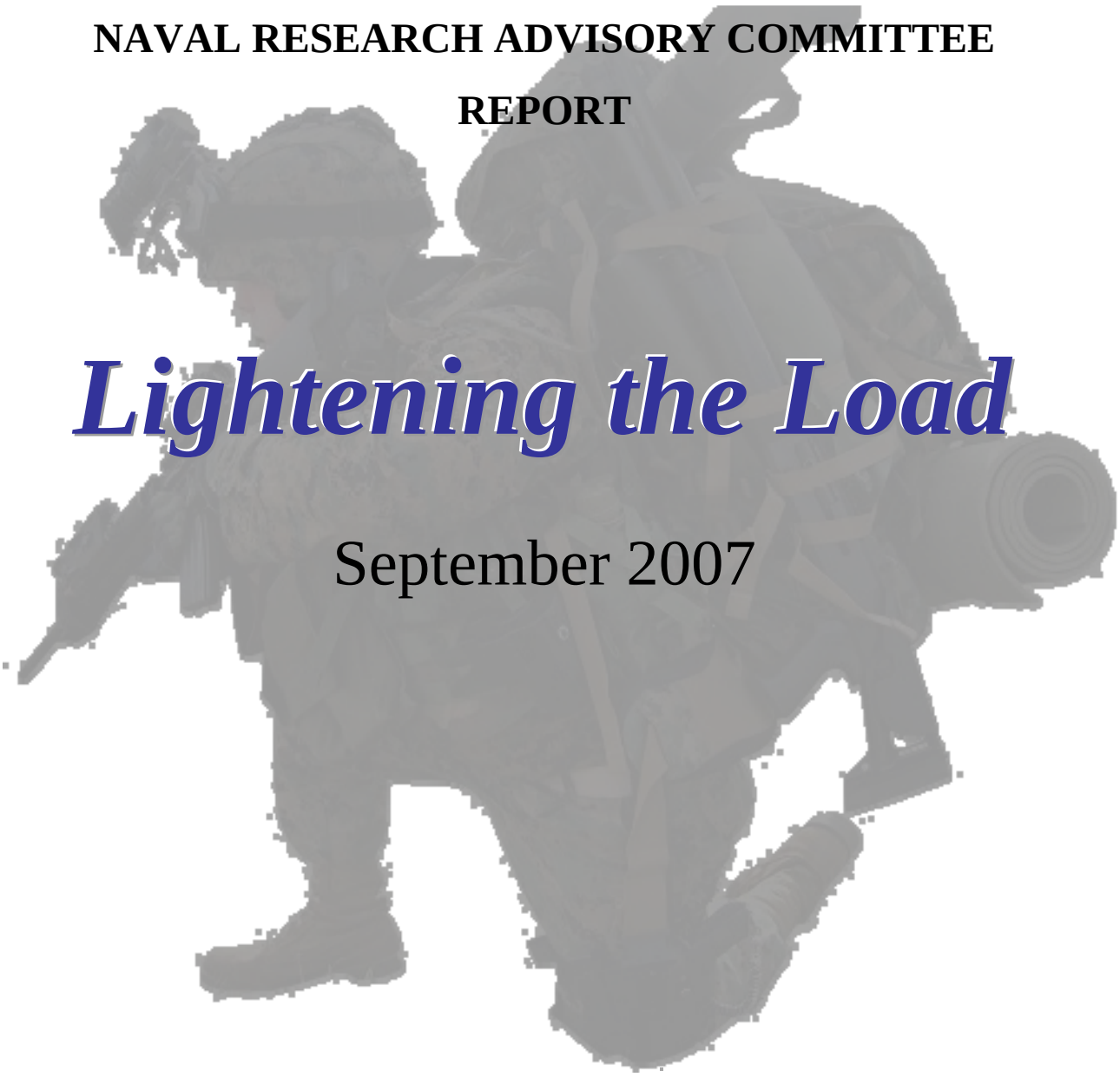

NAVAL RESEARCH ADVISORY COMMITTEE

REPORT

Lightening the Load

September 2007

OFFICE OF THE ASSISTANT SECRETARY OF THE NAVY

(RESEARCH, DEVELOPMENT AND ACQUISITION)

This report is a product of the U.S. Naval Research Advisory Committee (NRAC) Panel on Lightening the Load. Statements, opinions, recommendations, and/or conclusions contained in this report are those of the NRAC Panel and do not necessarily represent the official position of the U.S. Navy, U.S. Marine Corps, or the Department of Defense.

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Current individual combat Marine loads vary from 97 to 135 pounds. - vs. a recommended maximum of 50 pounds. Considerable anecdotal information based on current combat operations indicates heavier loads severely reduce Marine or soldier effectiveness, especially on long-duration patrols, close-in urban combat and other adverse situations. This weight is excessive and the trend will continue unless positive action is taken. The study focused on the Marine Rifle Squad as "the system," as opposed to the individual Marine, as each squad member has different tasks. The excessive loads carried by individual Marines translate to 1,620 excess pounds for the Assault Load for the Marine Rifle Squad, or 900 pounds over the recommended maximum squad load. The most optimistic outcome of current and planned S&T efforts may reduce squad loads by about 300 pounds. Another 300 pounds could be transferred from the Marines in the squad to vehicles or other assets organic to the squad. This still results in the squad carrying 300 pounds over the recommended maximum load. The study provides recommendations for the senior Navy Department leadership.

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Executive Summary

This Naval Research Advisory Committee study sought to assess the weight and volume contributors of the Marine's combat load, and to evaluate technology initiatives and other changes to reduce the burden without having an unacceptable impact on combat effectiveness, safety, or tactics. The study was done at the direction of ASN(RDA) with primary sponsorship from the Deputy Commandant of the Marine Corps for Combat Development and Integration

The operating premise was that the current loading on the individual combat Marine is excessive and that the trend will continue—unless positive action is taken. All available studies have recommended loads of no more than approximately 1/3 body weight be carried—for Marines and soldiers going into combat. There are numerous examples cited by military historians in which heavy loads directly or indirectly resulted in reduced performance, unnecessary deaths, and lost battles.

The NRAC Panel received over 100 briefings from experts who addressed the various aspects of this problem area, including: Marines returning from the Afghanistan and Iraq theaters of operation; Marine, Army and Industry Program Managers; Science and Technology Managers; Academicians; and Senior Marine Officers. The Panel also reviewed the numerous studies on this subject. It was clear to the Panel that a significant amount of study and a number of uncoordinated efforts have been conducted in an attempt to understand and mitigate the loading problem—which, unfortunately, has only gotten worse.

The focus of the mitigation effort from the Panel's perspective as well as the sponsor's should be on the Marine Rifle Squad as "the system", as opposed to the individual Marine. This is because the Marine "riflemen" within the rifle squad have different tasks and hence their weapons and equipment or "load" differs from Marine to Marine. This approach also aligns with the recently formed Marine Expeditionary Rifle Squad (MERS) office within the Marine Corps System Command.

The NRAC Panel found only limited analytical data that address combat effectiveness as a function of carried load. However, there is considerable anecdotal information based on current combat operations that indicates the heavier loads severely reduce the effectiveness of the Marine or soldier, especially during long-duration patrols, in close-in urban combat, and other adverse situations.

The Panel's top-level findings were:

(1) A Marine's current assault load varies from about 97 to 135 pounds vs. the recommended maximum of 50 pounds

(2) This translates to the Assault Load for the Marine Rifle Squad of about 1,620 pounds, 900 pounds over the recommended maximum squad load

(3) Squad and individual equipment are designed and procured independently and are not considered as a system

(4) The most optimistic outcome of current and planned S&T efforts may result in a squad load reduction of about 300 pounds

(5) Another 300 pounds could be transferred from the Marines in the squad to vehicles or other assets organic to the squad. This still results in the squad carrying 300 pounds more than the recommended maximum load

(6) Over-matching threats exist and will persist – e.g., advanced Improvised Explosive Devices (IEDs) and improved sniper capability

(7) The Program Manager, Marine Expeditionary Rifle Squad (PM MERS) does not have the directive authority to execute a systems engineering process encompassing all the components that are included in the Marine Rifle Squad loading

From the findings and deliberations, the NRAC Panel developed a set of recommendations and actions for the senior leadership:

Assistant Secretary of the Navy (Research, Development and Acquisition) (ASN (RDA)):

- Increase ONR investment in Lightening the Load
- Advocate with DDRE, an appropriately funded, multi-service S&T program for Lightening the Load

Commandant of the Marine Corps (CMC):

- Engage with the DARPA Director to nominate relevant Program Managers and achieve greater effectiveness from the Marine Liaison Officer
- Establish a partnership with DARPA on advanced ISR, lethality, and tactics to improve combat effectiveness and thereby reduce load weights

Deputy Commandant for Combat Development & Integration (DC CD&I):

- Establish maximum load weights for the Marine and the Rifle Squad
- Ensure Integration Divisions and MCWL are effectively coordinating with ONR
- Annually review all Marine Corps programs at ONR

Commander, Marine Corps Systems Command (MARCORSYSCOM):

- Assign total "Squad as a System" management authority to PM MERS
- Provide resources to create effective "Squad as a System" systems engineering capability

Chief of Naval Research/Vice Chief of Naval Research (CNR/VCNR):

- Develop, validate, and deliver three models to MARCORSYSCOM:
  - Squad combat effectiveness as a function of load, terrain, environment and other pertinent parameters
  - Impact of load on individual performance (endurance, mobility, combat effectiveness, etc.)
  - Models for system trade of studies (ISR capability, lethality, weight, mobility, survivability, etc.)

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The Problem

The U.S. Army and Marine Corps have carefully observed guidelines for the load that can be carried by a mule—the load is not to exceed one-third of the animal's body weight. This maximum burden was derived with full recognition that the mule, unlike the Marine Rifleman, would not be required to engage in combat while carrying the load.

More than 50 years ago, S.L.A. Marshall, who retired as a brigadier general in the U.S. Army Reserve, wrote what is still considered the authoritative reference on soldier load carrying. That work, *The Soldier's Load and the Mobility of a Nation*, observed that in 1950—when the world was well into the machine age—"it is conspicuous that what the machine has failed to do right up to the present moment is to decrease by a single pound the weight the individual has to carry in war. He is still as heavily burdened as the soldier of 1000 years B.C." This book is required reading for all Marines. Unfortunately, in the U.S. Army and Marine Corps the troops' burden has increased precipitously, especially in the current conflicts, and the trends show no signs of being reversed.

Continuing to increase the loads carried by Marines will not only exceed the realistic carrying capabilities of those troops, impairing their fighting abilities as well as their long-term health.

For more than a century many studies have been conducted on the recommended loads that should be carried by troops in a variety of missions and environments. There are numerous examples cited by military historians in which heavy loads directly or indirectly resulted in reduced performance, unnecessary deaths, and lost battles.

Chart 1 shows examples of the several studies and the maximum loads recommended for the combat assault mission. Also shown are the current (2007) assault

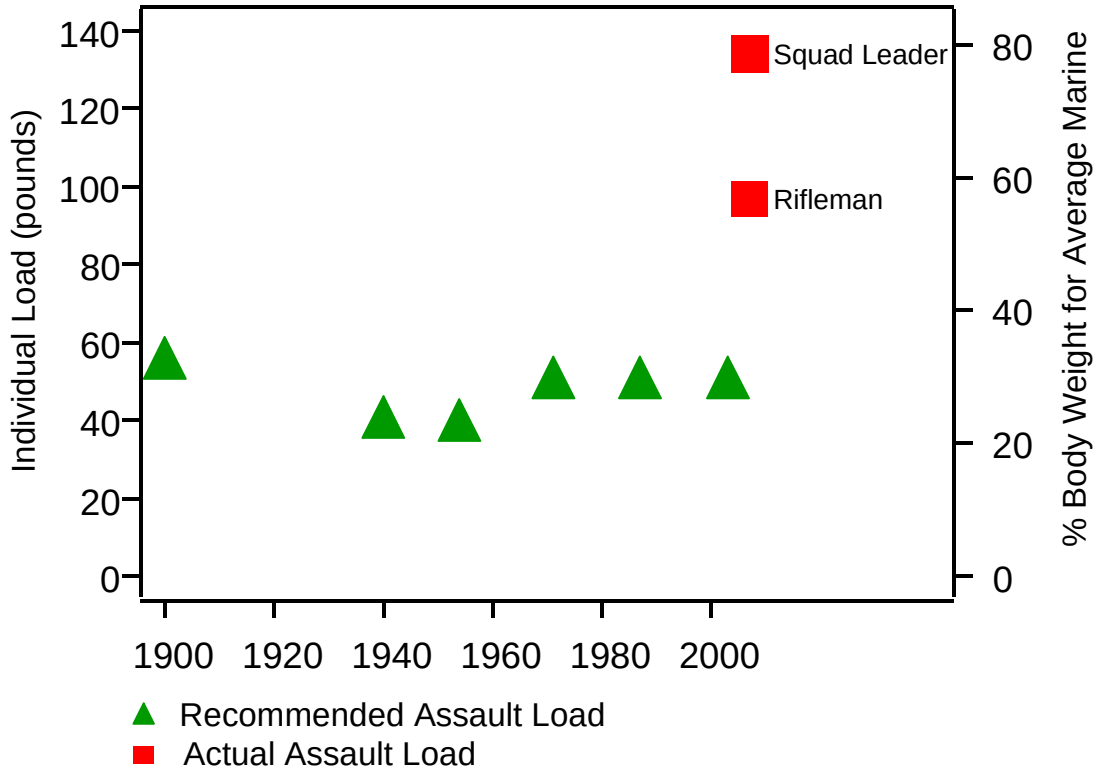

Chart 1 The Problem

loads for the squad leader and rifleman. Both are considerably in excess of all recommendations and the formally issued Military Standard.

There are only limited analytical data sets that address the combat limitations imposed upon ground combat troops by the heavier loads, especially in mountainous operations (e.g., Afghanistan) and hot environments (e.g., Iraq). However, there is more than ample and highly credible anecdotal information that indicates the heavier loads severely reduce the effectiveness of the Marine or soldier, especially during long-duration patrols, in close-in urban combat, and other adverse situations.

Studies by the Marine Corps have concluded:

(1) In 1954, the maximum combat load for a rifleman should be lowered to 40 pounds

(2) In 1971, the optimum load for a Marine in combat should never exceed 30% to 40% of his body weight

(3) In 2003, recommended that the objective weight load should not exceed 51 pounds.

From these and U.S. Army studies, the Panel accepted that the recommended load for a Marine rifleman in the assault mission should not exceed 50 pounds. The Panel has used this as the recommended assault load throughout the study.

The loads currently carried in the assault mode are shown in the chart and have been provided by the Fires, Maneuver and Integration Division of the Combat Development Directorate for the Deputy Commandant, Combat Development and Integration. Today the Marine rifleman carries approximately 97 pounds and the Marine squad leader 134 pounds. In his 1950 book S.L.A. Marshall stated, “As with any other problem in war, it is easier to state the factors than to outline the general means of correction.” This study describes potential corrective actions. (References are listed in Appendix D.)

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Terms of Reference

The study Terms of Reference were developed with guidance from the sponsor, Deputy Commandant for Combat Development & Integration (DC, CD&I), Lieutenant General James F. Amos, USMC.

The current U.S. experience in the Iraq and Afghanistan theaters of operation—with the increasing weight of Personal Protective Equipment (PPE) and new, heavier, more capable rifle squad equipment resulted in heightened concern on this issue and has motivated this study. The Lightening the Load problem is clearly recognized. The critical elements of the Terms of Reference are:

- Assess the elements of the combat load carried by today's Marine
- Identify the primary weight and volume contributors
- Identify and evaluate technology initiatives
- Consider changes in operations, logistics, and training to reduce this burden without having an unacceptable impact on combat effectiveness, safety, or tactics.

The study sponsor encouraged the NRAC Panel to utilize the knowledge and experience of Marines with recent combat experience. The Panel developed a study approach and identified, reviewed and assessed technologies that could improve combat effectiveness while seeking to lighten the load. (Terms of Reference are listed in Appendix A.)

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Panel Membership

A panel of experts was assembled to address this complex and challenging problem. The panel members brought many years of valuable experience in military operations, science and technology, engineering, management, and defense acquisition. It included senior retired Marine Corps and Navy officers, former senior Department of Defense, Army and Navy government civilians, current industry leaders and academicians. The Panel was supported by an exceptional executive staff: the Executive Secretary, Major Brian Christmas, is currently assigned as Capability Integration Officer in the Fires, Maneuver & Integration Office of the Marine Corps Combat Development Command (MCCDC); he is an infantry officer with recent tours of duty in both Afghanistan and Iraq; the consultant, Mr. Greg Kesselring, is a retired Marine infantry officer who supports the Marine Corps Warfighting Lab (MCWL) as a contractor in the S&T Integration Division.

Mr. Jack Bachkosky – Chair
Former Deputy Under Secretary Defense for Advanced Technology

Dr. A. Michael Andrews II – Vice Chair
VP, L-3 Communications; Former Army Deputy Assistant Secretary and Chief Scientist

Dr. Robert Douglas
Member, Army Science Board

BGen James M. Feigley, USMC (Ret.)
Former Commander Marine Corps Systems Command

RADM Lew Felton, USN (Ret.)
Former Chief Engineer, Naval Sea Systems Command

Dr. Frank L. Fernandez
Consultant; Former Director, Defense Research Projects Agency

MajGen Paul Fratarangelo, USMC (Ret.)
NRAC Associate

Dr. Anna Johnson-Winegar
Former Deputy Assistant to the Secretary of Defense for Chemical and Biological Defense

VADM Rudy Kohn, Jr, USN (Ret.)
Former Commander, Naval Air Force, US Pacific Fleet

Mr. Norman Polmar
U.S. Naval Institute

Mr. Dick Rumpf
Former Principal Deputy Assistant Secretary of the Navy/Acting Assistant Secretary of the Navy (Research, Engineering and Systems)

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Study Approach

The NRAC Lightening the Load (LTL) Panel began work in February 2007 with the initial focus on understanding the magnitude of the loads carried by individual Marines and the Marine Rifle Squad. The Panel found that a large number of the studies and reports sponsored by the Army and Marine Corps have been published within the past 15 years and provide insight into the nature of the weight problem and the current approaches to solving it. The Panel also received more than 100 individual briefings from experts in government, industry, and academia as well as from Allied military services.

The Panel was guided by the sponsor's recommendation that ***the focus of the load lightening study should be on the Marine Rifle Squad rather than on the individual Marine***. The squad was addressed because the Marine "riflemen" within the rifle squad have different tasks and hence their weapons and equipment or "load" differs from Marine to Marine. This approach also aligns with the recently formed Marine Expeditionary Rifle Squad (MERS) organization in the Marine Corps System Command (MARCORSYSCOM).

The LTL Panel formed several sub-panels aligned with potential solution sets and the expertise of individual panel members:

- A "lighten the load" sub-panel investigated technology opportunities to reduce the weight of individual items (e.g., optics, batteries, personal armor)
- A "transfer the load" sub-panel looked at various concepts for off-loading the weight carried by the rifle squad (e.g., organic "mules"; aerial vehicles; focused re-supply)
- A "human performance" sub-panel reviewed options for improving fitness of the individual Marine (e.g., nutrition, training, ergonomics, medical statistics)
- A "systems" sub-panel reviewed current practices and potential for the future through the implementation of a systems engineering approach for the Marine Rifleman/Squad

The Panel was unable to find data with the required level of specificity to quantitatively evaluate the impact of carried load on combat effectiveness. However, the studies provided generally consistent conclusions in this area. The Panel analyzed the available information, examined technology and other alternatives from low to high risk, near to far-term, and developed a set of recommendations and actions.

Panel Briefings

The major organizations and agencies that provided briefings to the NRAC Panel were:

Marine Corps

Headquarters Marine Corps Plans, Policies, and Operations Department

Marine Corps Combat Development Command

Marine Corps Systems Command

Marine Corps Warfighting Lab

Program Managers for Marine Expeditionary Rifle Squad, Infantry Combat Equipment, Optics and Non-Lethal Systems, Infantry Weapons Systems

Army

Army Science Board

Program Executive Office Soldier

Army Directorate of Combat Development

Center for Army Lessons Learned

Army Communications and Electronics Command (CECOM) Night Vision Laboratory

Army Natick Soldier Research, Development & Engineering Center;

DOD and Navy S&T Organizations

Defense Advanced Research Project Agency

Office of Naval Research

Foreign

Canada

France

Germany

Singapore

United Kingdom

Industry

Boston Dynamics

Ceradyne Company

DuPont

General Dynamics

L-3 Communications

3M

Academia

MIT's Army Institute for Soldier Nanotechnologies

Included in the briefings was an overview of the Army Science Board FY2001 Summer Study: "The Objective Force Soldier/Soldier Team"—briefed by one of its authors—who served as a Member on this NRAC Study Panel. The Panel also met with Marines assigned to 1st Battalion 5th Marines and 1st Marine Expeditionary Force (I MEF).

(Appendix B contains the complete list of briefings to the NRAC Panel.)

Defining the Problem

The Marine Corps uses three load categories for combat troops: Assault Load, Approach March and Existence Load. As defined, Assault Load is that load associated with "conducting combat operations indefinitely with minimal degradation in combat effectiveness"; Approach March Load is that load for conducting a "20-mile march within 8 hours maintaining 90% combat effectiveness"; Existence Load is the load associated with "limited movement within confines of transportation platforms and limited marching from landing zone into secure area."

Although excessive loading exists and impacts all three Marine load categories, the Panel focused on the ***Assault Load as being the most critical***. It is the load category that has the most immediate impact on a Marine's capability to conduct a successful mission and survive.

One should note that there is an existing—but apparently disregarded—Military Standard (MIL-STD-1472F) prescribing the recommended approach load as 30% of body weight for the Assault Load. Using the average Marine weight of 169 pounds, this would

equal approximately 50 pounds. In fact, MCCDC estimates that the current (June 2007) rifleman's load is approximately 97 pounds—57% of body weight. This weight is in excess of all recommended values and will impact on the combat effectiveness of the Marine rifleman and the Marine Rifle Squad.

Chart 2 also shows weight data for the Approach March Load and the Existence Load.

Load Description	Recommended Load*	Current Rifleman's Load**
Assault Load (In the Fight) Conduct combat operations indefinitely with minimal degradation in combat effectiveness	50 lb 30% of body wt based on Avg Marine (169 lb)	97 lb 57% of body wt
Approach March Load (Getting to the Fight) Conduct 20-mile march within 8 hours maintaining 90% combat effectiveness	76 lb 45%	123 lb 73%
Existence Load Limited movement within confines of transportation platforms and limited marching from landing zone into secure area	127 lb 75%	167 lb 99%

* *MIL-STD-1472F*
** *Information received from MCCDC, Quantico*

Chart 2 Marine Rifleman Loads

An Army study, developed from the Goldman Metabolic Energy Cost Model, is considered credible and illustrative of the problem (shown in Chart 3). It did not consider loads of the magnitude carried by current Marines. (The Panel has noted that there is a paucity of data that address weight vs. combat effectiveness.)

Although a marching distance may only be illustrative, it shows a definite impact of what weight can do—especially when a Marine must be prepared to fight at the end of the march. The chart shows that as an individual's load is increased, he will be able to march fewer miles in a given amount of time. The dotted vertical lines show current estimates of the rifleman's and squad leader's Assault Load—clearly showing a drop-off of miles completed in eight hours.

Values used in the study are:

- Soldier weight: 171 pounds
- Surface: dirt
- Grade: 1%
- Work level: 350 kcal/hr.

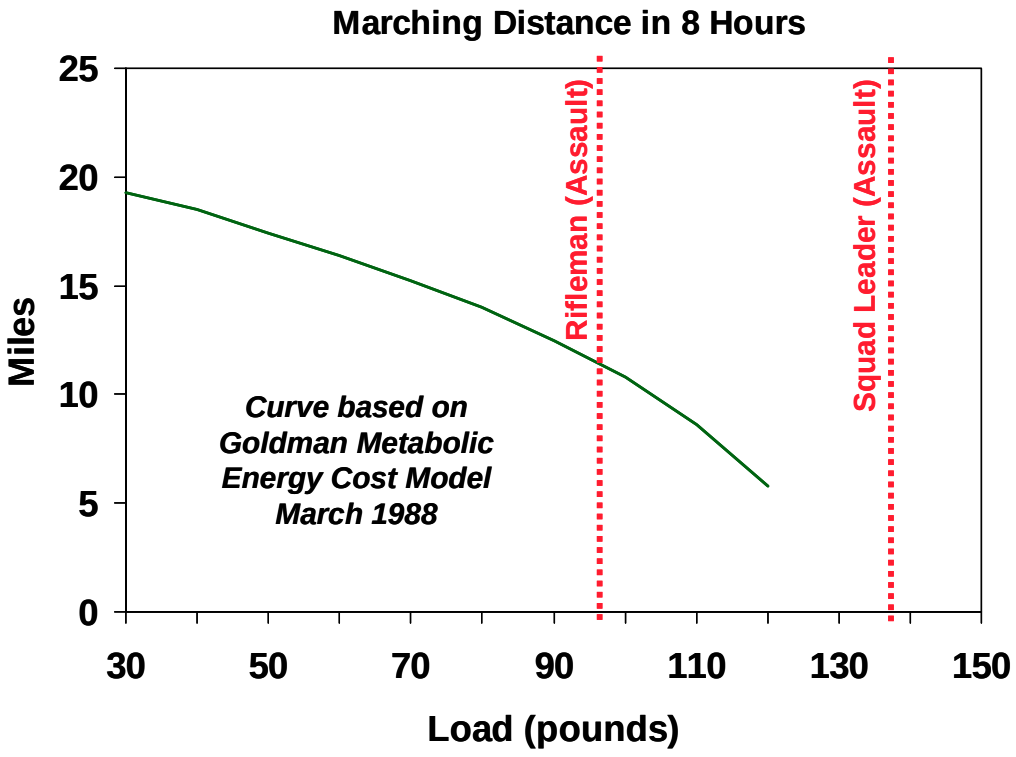

Chart 3 Load Impacts on Performance

As previously noted, the Panel focused on the Marine Rifle Squad rather than the individual Marine rifleman. The squad (depicted in Chart 4) consists of 13 enlisted Marines and a Navy hospital corpsman (usually assigned when the squad is operating independently.) The squad is organized into three, four-man fire teams plus the squad leader.

The individuals within the squad have different functions and hence there are significant differences in their weapons and equipment. For example, the squad leader carries a second radio (with additional batteries); the squad leader and three fire team leaders carry the M203 grenade launcher on the M16A4 rifle; the automatic riflemen carry the M249 Squad Automatic Weapon (SAW) in place of the M16A4 rifle; and the Assistant Automatic Riflemen also carries additional ammunition for the SAW.

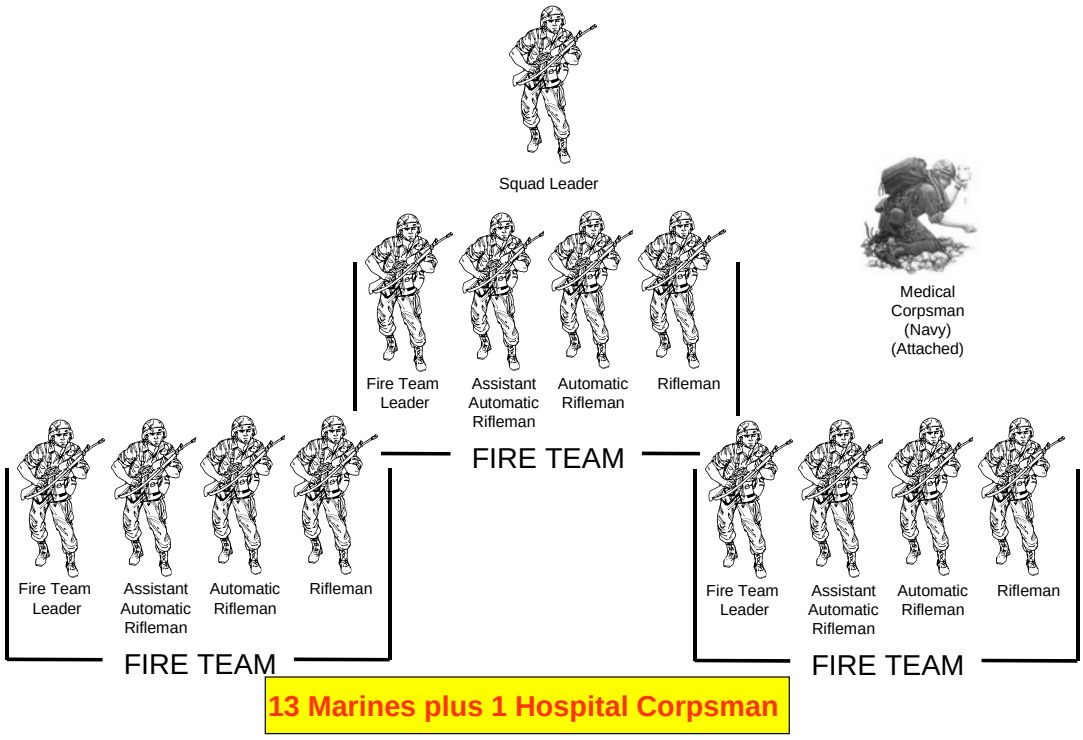

Chart 4 Marine Rifle Squad

The Assault Load consists of the weapons and equipment that a Marine carries to enable him to conduct sustained combat operations—with minimal degradation in his

combat effectiveness. As indicated in Chart 5, the recommended load is 50 pounds, based on the average weight of the Marine rifleman, which is similar to the load specified by the U.S. Army for dismounted infantry.

Based on current operational experience, the members of a Marine Rifle Squad actually carry assault loads of from 97 pounds (the riflemen and hospital corpsman) up to 134 pounds (squad leader). Thus, the minimum "overload" carried by Marines of the rifle squad is 47 to 84 pounds over the recommended nominal load.

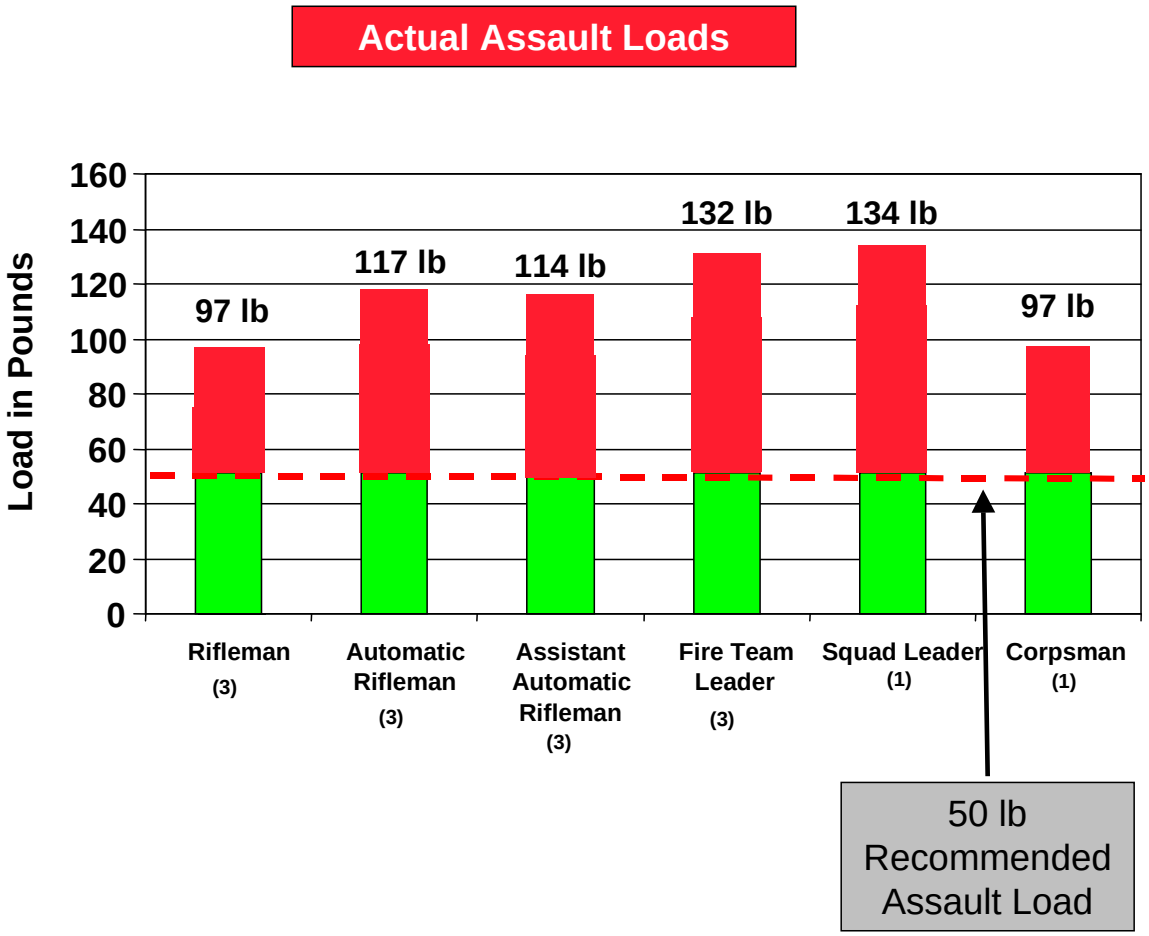

Chart 5 Individual Assault Load

Thus the aggregate Assault Load currently carried by the 14-man Marine Rifle Squad is approximately 1,620 pounds. This is about 900 pounds more than the recommended load, i.e., 14 squad members x 50 pounds each.

As shown in Chart 6, the Marine Rifle Squad's load can be aggregated into four categories:

- 599 pounds or 37% weapons, ammunition, optics
- 575 pounds or 35% Personal Protective Equipment (PPE)
- 414 pounds or 26% food, water, clothing, other
- 29 pounds or 2% communications

Although the weight required for organic communications equipment is currently a very small fraction of the total squad load, predictions are that it will increase dramatically in the near and mid-term due to increasing Intelligence, Surveillance, Reconnaissance (ISR) and communications connectivity—and could approach 10% of the squad load.

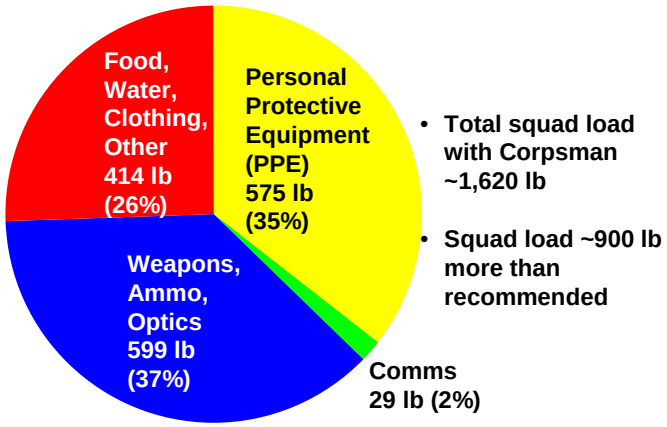

Chart 6 Squad Assault Load

The Panel reviewed all aspects of the weight of weapons and equipment carried by the Marine Rifle Squad as well as their function, bulk, method of carriage, etc. As a result, 900 pounds was recognized as the current level of "overload" by the NRAC Panel. The Panel did not discover any "silver bullets" that will enable a major reduction in the load carried by the rifle squad. Rather, it was concluded that the load reduction must be addressed in terms of:

- S&T efforts for future weapons and equipment

- Weight transfer off the squad members
- New tactics

The Panel also concluded that improved/specialized nutrition, physical training, and ergonomics would have a positive, but minimal impact on load carrying capability.

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Top Level Findings

Based on briefings, reports, analysis, and discussions, the NRAC Panel developed six top-level findings:

- The individual Marine assault load varies from about 97 to 135 pounds versus the 50 pounds recommended maximum. With the requirement to provide greater protection (survivability) for the Marine in combat, the loads that are carried have increased dramatically in the past few years. This increase has been driven primarily by the Personal Protective Equipment (PPE)—i.e., body armor—and increased squad firepower. Because of these increased loads, the overall combat effectiveness of the Marine has been impacted and shorter missions are now the norm. The impact of the excess loading is compounded by temperature, humidity, terrain, and other factors.
- The current squad Assault Load is about 1,620 pounds, about 900 pounds over the recommended maximum. The Panel is convinced that the rifle squad must be addressed as a "system". As with any other combat system (e.g. F/A-18 Hornet, Littoral Combat Ship), its capabilities, tactics and load must be considered and analyzed as a system. Trade-off studies are required to ensure that the impacts of changes (in load, etc.) are understood before they are allowed.
- Squad and individual equipment are designed and procured independently and are not considered as a system. Air, land, and space vehicles, and other systems depend on physics and engineering models to determine maximum allowable system and component weights that can be tolerated without compromising performance. The lack of a systems approach and the very limited modeling/data available for the individual Marine and squad have contributed to the rapid growth of the loads carried by Marines.

- The most optimistic outcome of currently planned S&T efforts:

  ~ 300 pound weight savings per squad through weight reduction developments in advanced personal protection and other equipment

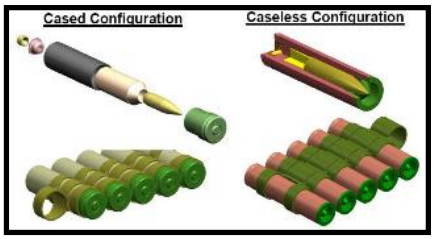
  ~ 300 pound weight transfer per squad through the use of small-unit organic vehicles or other weight transfer technique

  ~ 300 pounds of load that still needs to be addressed

- Over-matching threats exist and will probably increase. In the current combat environment, the various threats to Marines are increasing at a rapid rate, as evidenced by the advanced IEDs and sniper weapons being used in Afghanistan and Iraq. One approach to these threats is an increase in protective gear—which would further increase the total load. Obviously, this reaction to changing threats by increasing body armor has limitations. Other alternatives must be considered.

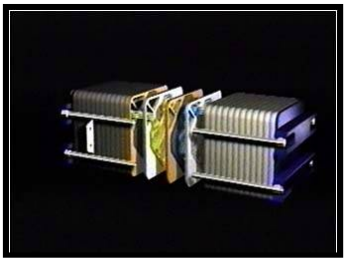
- The Program Manager, Marine Expeditionary Rifle Squad does not have the directive authority, resources, or technical capabilities necessary to execute a systems engineering process. The Marine Rifle Squad must be addressed as a "system" with respect to its weapons and equipment. PM MERS has been designated as the coordinating office for these functions but lacks the requisite directive authority to impose a systems engineering approach on the development and integration of equipment for the future Marine Rifle Squad.

Science and Technology for Lightening the Load



Future Ammunition

Future Rifleman



Future Fuel Cell

Discussions, lessons learned information and interviews indicate that the Marine Rifle Squad in general and the individual Marine in particular are carrying loads that significantly exceed those recommended by all previous studies. Because of this fact, the Panel first reviewed options (primarily in the Science & Technology area) that might reduce the weight of individual load components. Examples of these are caseless ammunition and advanced power sources.

Then, the Panel reviewed S&T and other options to offload the weight from the individual Marine to organic load carrying assets or to provide the needed resupply through more responsive logistics support.

Finally, the Panel reviewed efforts to increase the load carrying ability of the individual Marine through training focused to increase weight carrying ability such as increased endurance and back strengthening. The following section describes the NRAC analysis and interpretation of these activities.

There a number of sources of S&T investment that are relevant to reducing the weight infantrymen must carry in combat.

In the Office of Naval Research, approximately $33M (FY08) is related to this problem—the funding is distributed across about 40 separate projects in various ONR departments. The programs include the "Marine as a System" S&T Program, which was initiated in response to an NRAC recommendation in its Distributed Operations Study (2006). In addition, programs focusing on portable power, sensors, electronics, materials, and personal protection have the potential to contribute to load reduction. Programs examining warrior performance are also relevant to the subject of this study.

The US Army is investing about $120M in efforts relevant to load lightening, of which $75M can be identified as specifically related to initiatives to reducing infantry loads. The Army investments address at least five key areas: Future Force Warrior; survivability; rations; power; and sensors. The Future Force Warrior has been an investment of more than $200M for the past four years and will transition to PEO Soldier in 2008. Survivability research is focused on ballistic & primary blast protection through the use of novel fiber technologies, system designs and analytical tools; the MIT Institute of Soldier Technology and the University of California, Santa Barbara, Institute of Collaborative Biotechnology are receiving longer-term investments in this area. In the power research area, the focus is on developing component technologies for increased mission duration while decreasing the logistics burden; demonstrations of man-portable battery chargers, soldier fuel cells and micro engines are under investigation. The Army is lead service for the combat rations program and developed the First Strike Rations; future efforts address diagnostics for food pathogens in rations and special purpose/lightweight rations. Sensor research is directed towards greater situational awareness capabilities with digital enhanced night vision systems and see-through, flexible heads-up/down displays with the Arizona State University's Flexible Display Center.

In addition, DARPA's Defense Sciences Office is investing tens of millions in predominantly higher risk/payoff efforts that have the potential to reduce infantry loads, or to enhance the ability of warriors to manage heavy loads. For example, programs focused on portable power generation could reduce the load of providing battery power

for multiple communications systems associated with Distributed Operations, as well as sensors and other equipment that use electrical power. DARPA has invested in a mechanized infantry "mule" that could carry some of the squad's equipment. That project has moved into a significant 18-month operational prototype program with the Marine Corps. Other efforts with potential include work on exoskeletons to permit dismounted infantry to carry loads with less human effort. DARPA has demonstrated promising early results in their investigations into pharmaceutical/nutritional supplements to enhance warrior performance.

Although the importance of reducing the infantry load is most obvious for the Marine Corps and Army, the issue is also relevant to the Navy and Air Force. For example, Navy combat engineers and forces conducting riverine operations, and Air Force military police face similar issues driven by weapons, PPE, food, water, and equipment. In spite of the universal nature of the load problem, the NRAC Panel noted that the total DOD S&T investment in this problem represents ***only about 1% of total DOD S&T investment.***

In the judgment of the NRAC Panel, the current DOD S&T investment does have the potential to produce measurable reductions in the rifle squad's load. It is important to note the probability of success varies with each effort and that new concepts should also be pursued.

It seems likely that engineering development will yield meaningful reductions in the weight of small arms and associated ammunition. Integration of currently separate optical systems that Marines use could plausibly result in about a 30% to 70% reduction relative to the current aggregate weight of these systems. This reduction would be facilitated by a common focal plane technology that would operate in the visible and IR range, in both daylight and low-light conditions.

Anticipated advances in battery technology will not reduce loads significantly within the current battalion table of equipment, but could significantly reduce the impact of the additional communications and ISR systems that will be necessary to support Distributed Operations.

A key area for potential weight reduction is Personal Protective Equipment (PPE). PPE constitutes roughly one third of the current Marine Rifle Squad's load and thus

represents an extremely important point of potential leverage for reducing load carriage. However, this is also the area that is least certain from a technological perspective, because significant weight reduction will require a substantial and ***currently undefined*** technical breakthrough. Based on very early results, it seems possible that nanoscale fiber structures that are coherent in the bulk material could produce personal armor offering ballistic protection comparable to current SAPI materials at lighter weights than state-of-the art ceramics.

Two additional points are noteworthy: First, achieving the weight reductions discussed herein will require sustained S&T investment and because significant technical progress beyond the state of the art will be necessary. Second, technological success will only constitute a first step. Some of the weight reductions will require very substantial developmental work, acquisition programs, and infrastructure changes. For example, moving to caseless ammunition and the requisite lightweight rifle will major require re-equipping and retraining.

Category	~ Individual Weight Savings
PPE – Advanced Materials (nanotechnology)	4 to 6 lb
Weapons and Ammo – Caseless Ammo and Lightweight Weapon	5 lb
Integrated Optics	3 to 7 lb
Overall Marine Systems Integration	2 lb
Advanced Batteries	1+ lb

Possible Savings of ~ 10 to 20 pounds per Marine(~300 per squad but would still be ~ 600 pounds overweight)

Chart 7 Reducing the Weight: S&T Forecast

Even if all the aforementioned objectives are achieved through successful S&T development (Charts 7 and 8), acquisition, and infrastructure changes, the cumulative effect will be to reduce the current overloading of Marine Rifle Squads ***only by about one third***. Other approaches will be needed to address the remaining overloading of rifle squad members, which would then range from 25 to 65 pounds per Marine.

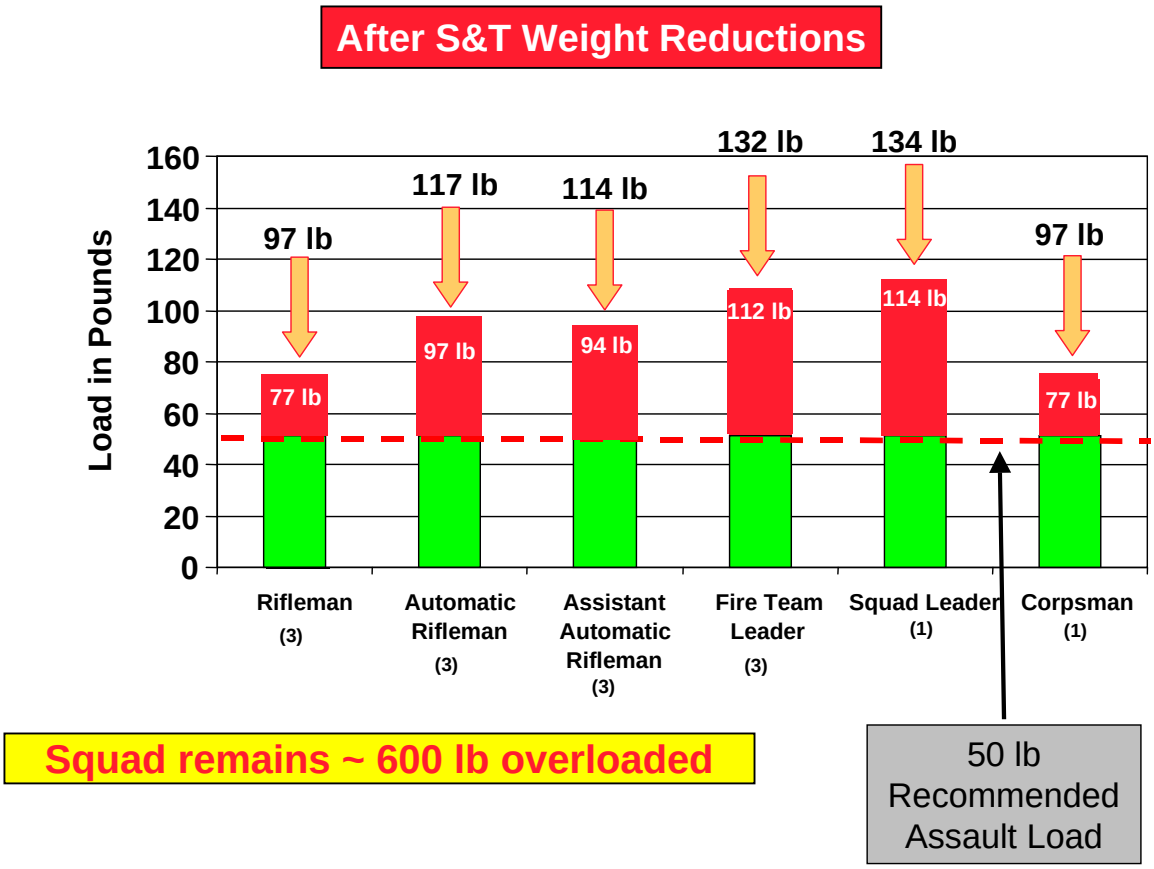


Chart 8 S&T Weight Reduction Potential

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Transferring the Load

MV-22 Osprey

A-160 Hummingbird

RQ 2-B Pioneer

GE-80 Golden Eye

Tactical Autonomous Combat - Chassis (TAC-C)

Big Dog

Internally Transportable Vehicle (ITV)

When examining the various options for lightening the load of the Marine Rifle Squad, it became clear to the NRAC Panel that pursuing lighter materials and integration alone would not achieve required weight reductions. Therefore, additional weight would have to be removed by transferring weight off the Marine. NRAC calls this component of lightening the load "Transferring the Load." This load, the equipment that will not be needed in the initial contact with the enemy, could be transferred to a load-carrying asset organic to the squad.

Chart 9 shows the equipment that could be transferred from the Marine Rifle Squad to an organic load-carrying asset during the Assault Phase. The transferred equipment includes the patrol packs, gas masks and gas mask voice adapters, MREs, Gortex gear, face paint, and a portion of the ammunition load. Because this equipment is essential to the conduct of an extended assault, it must be readily available and can only be transferred to a load-carrying asset that accompanies the squad.

It should be noted that the list of transferred equipment was developed by the NRAC Panel after discussions with combat experienced Marines. It has not been the subject of the rigorous examination that should be conducted as this load transfer concept is developed and implemented. If this offload concept is pursued, the weight carried by the squad could be reduced by about 300 pounds.

The load that still remains to be carried by the squad consists of protective items (body armor, flash protection, helmet, glasses, etc.), weighing approximately 40 pounds, plus weapons, ammunition, and water.

It should be noted that during the approach march a squad must carry an additional 360 pounds of equipment, all of which could be carried by an organic squad vehicle.

Chart 9 Transferring the Load: Offload

If a portion of the load is able be transferred off the backs of the rifle squad, then alternative vehicle and systems can be examined for this purpose. In the area of ground vehicles, the Marine Corps is committed to fielding the Internally Transportable Vehicle (ITV) (15 vehicles per infantry battalion) to provide mobility and logistics support. It should be noted that this plan would not provide for an ITV for every squad.

In addition to the manned ITV, the Army Research Laboratory (with a Congressional plus up totaling $5M in FY07) initiated the development and prototyping of six vehicles in the Tactical Autonomous Combat Chassis (TAC-C) family as an optionally driven/unmanned vehicle to offload supplies, logistics, and equipment, and to potentially serve as an autonomous medical evacuation vehicle or refueling station for the special forces. The TAC-C has application potential to a Marine Rifle Squad. TAC-C, a 3,000 pound vehicle, is C-130 and CH-53 helicopter compatible, with a 200-mile to 300-mile range, and can move autonomously up to 20 mph over extremely complex terrain. This vehicle could carry a fire team to a location with a manned driver at highway speeds up to 80 mph. When dismounted the TAC-C could operate in a follower mode, a fully autonomous vehicle or with a tele-operated mode of control. This program is an FY08 Joint Capability Technology Demonstration (JCTD) candidate.

DARPA has developed several systems that offer technological options for transferring the load. One of those, Big Dog, has been demonstrated as capable of carrying over 100 pound loads up 35 degree slopes. The Army and DARPA are jointly developing a larger and heavier Unmanned Ground Vehicle (UGV) called the Multifunction Utility/Logistics Equipment (MULE) system designed to support dismounted infantry. This system can carry up to 2,400 pounds of equipment over a 200-mile range. Current funding of $38 M (FY07) and ~$36 M (FY08) is included in the Army's Future Combat System (FCS).

Several allies, including Israel, Germany, and Great Britain are in the early stages of exploration of similar UGV systems that also offer the potential to offload dismounted infantry in urban and other complex terrains. The Panel had no visibility into the funding or schedules due to the early stages of development and prototyping and the lack of full program commitment of the nations.

A second option for transferring a portion of the load from the rifle squad is employing aviation systems. While air assets—manned and unmanned – offer the promise of partially offloading the loads carried by Marines, such assets are usually controlled by "higher headquarters," making their availability to Marine squads, platoons, and even companies highly problematic. Also, depending upon the asset, their use can be limited or halted entirely by limited availability, weather, darkness, enemy action, and other commitments and emergency demands. Thus, consideration of air assets, especially manned assets, must be considered in the context of the overall "air picture" until such time as air assets can be fully dedicated to the battalion or company logistics support role.

The MV-22 Osprey Short Take-Off/Vertical Landing (STOVL) aircraft is being fielded as an assault support aircraft replacement for the CH-46E Sea Knight and CH-53D Super Stallion helicopters. The Concept of Operations (CONOPS) for assault support of small units includes transporting squads of Marines and the now-being-acquired Internally Transportable Vehicles (ITV) from Ship to Objective Maneuver (STOM) areas. The ITV could provide the squad with limited mobility and logistics support—including transferring the load—capabilities.

Using Unmanned Aerial Systems (UAS) as direct support to limited numbers of Distributed Operations platoons and squads could provide a robust ISR capability for their mission and may provide a capability to offload some ISR and communications equipment. Marine conventional (manned) aviation and UAS assets traditionally provide general support to division, regiment, and a battalion size Marine Air Ground Task Forces (MAGTF) without "transferring the load" considerations.

The Marine Corps RQ-2B Pioneer UAS system, deployed in Iraq by squadrons VMU-1 and -2 has a superb ISR capability and can also carry up to 100 pounds equipment configured in two 35- to 50-pound capacity wing pylon-mounted containers. The normal six-hour maximum endurance of the Pioneer is slightly reduced by the aerodynamic drag of these wing stores.

The Army and DARPA are jointly funding the development of the A-160 Hummingbird, a vertical takeoff and landing UAS. The A-160 weighs about 4000 pounds, has a payload capacity of more than 300 pounds, a top speed of 140 mph, and a

24- to 36-hour endurance. The program remains as a prototype demonstration with ten air vehicles being built for DARPA and the U.S. Special Operations Command.

Also under development by DARPA is the 180-pound, vertical takeoff and landing Golden Eye-80 (GE-80). It is a candidate for FCS Tier II ($6M in FY07) as well as an FY08 JCTD. The GE-80 has an endurance of eight-hours, maximum speed of 138 mph knots, and can carry up to 30 pounds of external payload. This UAS can fly to the top of a building and "perch" to perform an ISR mission and then be commanded to drop a payload at a desired location.

CONOPS for the employment of both manned and unmanned vehicles in direct support missions to help lighten the squad load should evolve from wargames, operational test and evaluation, and advanced warfighting experiments.

The previously described technology-enabled reduction of about 300 pounds of rifle squad weight plus the approximate 300 pound weight that could be transferred to an organically assigned vehicle still does not reduce the weight to the recommended maximum assault load as shown in Chart 10. The squad remains overburdened by about 300 pounds. To further reduce this amount, additional action must be taken to achieve the recommended maximum load weight of 50 pounds per Marine.

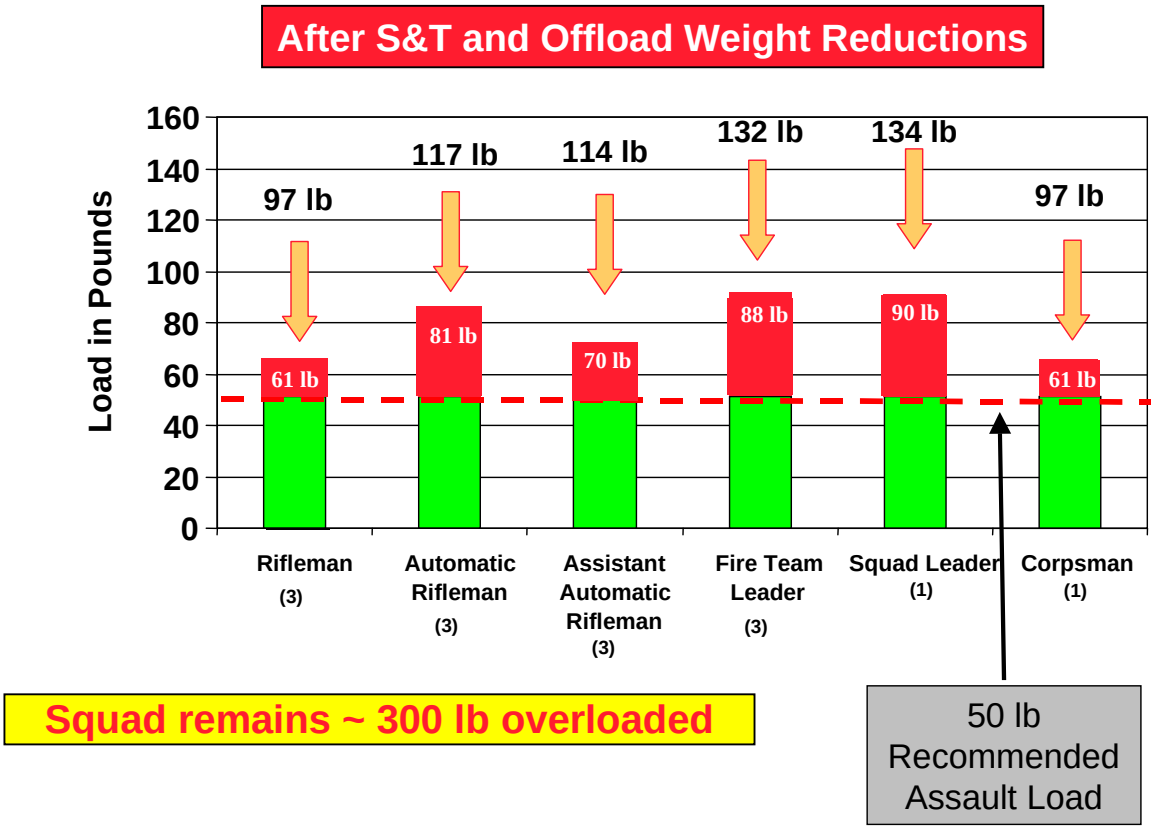

Chart 10 Offload Weight Potential Savings

Enhancing Human Performance

It is important to consider efforts that could improve the performance of the individual Marine as well as considering Science and Technology efforts to achieve weight and equipment offload options. A number of programs are under way to evaluate human performance in a broader context, but the Panel focused on those that may contribute by enhancing performance to enable Marines to carry a heavier load without degrading combat effectiveness, mobility, or survivability.

There is a maximum limit of weight that any individual, no matter how well trained and conditioned, can carry. As previously presented, conventional wisdom and studies suggest that the limit is approximately 30% of an individual's body weight (which translates to about 50 pounds in the combat environment), there are no strong empirical data to substantiate this premise. Marines deployed today carry significantly more weight – well over 100 pounds in many cases. (The photo shows a Marine who appears overloaded, even to the untrained eye!)

While it is indeed admirable that highly motivated Marines will shoulder ***any*** load assigned to them, it is not advisable to continue substantially overburdening our Marines with loads 40 to 50 pounds in excess of that recommended. The military services have established databases to collect medical information related both to direct combat injuries and to long-term disabilities incurred from carrying excessive loads. The preponderance of the information provided by the Veterans Administration shows an increasing trend in disabilities related to lower back problems and others which are a direct result from carrying excessive loads for extended periods of time.

It is a well understood physiological phenomenon that physical performance is impacted by a number of external factors, including environmental conditions, fatigue, stress, nutritional status, and overall conditioning. Differing scenarios require different levels of performance, and current Marine combat missions demand the optimal.

A number of experimental observations have been made that relate the weight of the load being carried to the following parameters: speed in covering a given distance, total distance covered in a given time, and time to complete an obstacle course (serving as one measure of agility). These measurements indicate a direct negative correlation with increasing weight. Unfortunately, these studies were limited in that:

- They did not extend the measurement to the extreme weights being carried in today's environment
- The studies were conducted under controlled laboratory conditions vice field conditions
- The data cannot be extrapolated from an "average" individual to the ranges normally seen in height, weight, physique, etc.

Therefore, it is considered necessary that these types of studies be continued, expanding the variables and incorporating more actual conditions whenever possible.

Human performance models that can be used by the squad leader are non-existent. In order to evaluate the effectiveness of the squad, one must be able to consider the individual physiological status, environment, terrain and mission requirements. Development of an algorithm to tradeoff existing capability in one member of the squad with another could improve our ability to assign tasks and optimize combat effectiveness of the unit. In addition, these data could assist in determining whether individual squad

members require medical attention or can recover through interim rest cycles and nutrition alone or temporary restriction to limited duty.

The current data being collected by the U.S. Navy-Marine Corps Combat Trauma Registry indicate an increasing number of musculo-skeletal injuries related to carrying excessive loads. These are incurred as a result of limited ability to maneuver in tight spaces and/or falling due to impact/inertia of the heavy load. These data will be used to correlate claims of long-term disabilities. The primary function of the trauma registry is to document as much information as is available about wound pattern injuries in Iraq (no control data are available for other military operations). There should be ongoing efforts in physiological modeling to fully understand the trade-offs between increasing body armor protection (i.e., weight) and the negative impact on performance (e.g. mobility, endurance).

Various approaches have been evaluated to improve individual performance. Over the years, significant changes have been made to the nutrition provided to our combat forces. The adoption of the First Strike Ration (FSR) has provided increased calories and carbohydrates to boost energy. The FSR is logistically less cumbersome with one package replacing three of the standard MREs, and it is operationally more acceptable due to improved packaging relevant to the mission.

Some nutritional supplements have known benefits while others are still considered experimental. Caffeine gum has been added to standard rations and is universally accepted by military forces. Other pharmaceutical/biological additives are being researched. Among these is tyrosine, an amino acid, which shows promise in cold weather environments. Quercetin (branded as Q-Chews) has been shown to provide an additional energy boost; however, long-term use has not been evaluated nor has an optimal dosage been established. Many individual Marines regularly use bodybuilding supplements, such as creatine and DHEA (a steroid), but their use is being discouraged due to some debilitating side effects. These products have been removed from sale at some U.S. military bases.

The previous approach to physical training has proven to be less than optimal for today's combat scenarios. Now, instead of long distance running, more emphasis is being placed on short-term sprints, and greater emphasis is placed on maneuverability

and agility. To meet these revised objectives, the standard Physical Fitness Test (PFT) is gradually being replaced with newer measures that evaluate different aspects of overall physical fitness. The leadership of the Marine Corps, understanding the impact of operational performance, is adding additional physical training activities to strengthen the lower back muscles. Individual training regimens designed by sports medicine specialists are available that could be optimized to enhance performance. Overall, the understanding of the need for physical fitness and training is at an all-time high in the Marine Corps.

Research efforts are continuing to evaluate potential improvements that can be made to balance the load and to train Marines how to carry heavy loads most effectively. These ergonomic studies will help address fatigue and endurance, and will contribute to understanding load carriage. However, these effects can be expected to make only minor contributions to solving the existing load weight problem.

Beyond the most basic equipment carried by Marines are items that can generally be associated with the issues of "uncertainty" and "risk." "Uncertainty weight" can take the form of special clothing to compensate for the potential changes in climatic conditions, potential for special threats (e.g., nuclear, biological, chemical), or additional consumable items (food, batteries, etc.) due to uncertainties imposed by the lack of confidence in the supply system or the possibility of extended mission time after an operation has begun. "Risk" weight can generally be associated with the variability of the enemy to be encountered and his actions upon engagement. This "risk" weight often takes the form of extra ammunition beyond prescribed loads. The issue then becomes how to reduce the burdens imposed by uncertainty and risk. Changes in tactics, and opportunities presented by advance training simulations may hold the key to successfully bringing the individual Marine and squad loads to within acceptable limits.

Fundamental Changes are Needed

It is clear from the previous sections of this report that even the most optimistic weight reduction and offloading estimates leave approximately 300 to 400 pounds of weight in excess of the recommended squad load. For an individual squad member, this represents about 20 to 30 pounds above the recommended maximum of about 50 pounds (for the average Marine who weighs 169 pounds).

In addition, the requirement for enhanced communication and ISR data transfer within the squad and to/from higher echelons of command under the concept of Distributed Operations will add even more weight to the load carried by the rifle squad. Marines are currently above the reasonable limit of load bearing ability and methods for reducing the load through technology and transfer will help but are not expected to solve the problem.

Given this situation, the NRAC Panel concluded that further progress in this critical area would require a major change in the approach that must be taken to lighten the load. In discussions with the Marine leadership, it became clear to the Panel that the need for fundamental change is now recognized and that game changing tactical concepts are being aggressively explored. Preliminary results from several Limited Objective Experiments (LOEs) associated with “Combat Hunter”, a new tactic that raises a Marine's

"hunting" awareness and capability in combat situations, show signs that a modification in tactical concepts could have a positive impact on loads carried by Marines. The departure from traditional small unit tactics that are often reactive in nature, to a philosophy of combat that employs new methods and "field craft" skills, has a direct bearing on the elements of operational risk, and thus the loads previously associated with it. New leverage is created when the preponderance of tactical risk is transferred to the enemy. This transfer is a fundamental tenet of Combat Hunter and its corresponding techniques and procedures. Also, it affords new opportunities to shed risk-induced excess weight and tailor loads that recognize the new tactical advantage. The opportunities presented by new approaches can be manifested in a net reduction of carried weight, which in turn can increase human performance; an iterative improvement to the new tactic itself.

New tactics alone will not provide the operational (and weight reduction) advantages that are needed. The tasks associated with new tactics must be expertly transferred to the minds of the Marines who must execute them. They must be performed and practiced under conditions that most closely represent the "real" world, and their standards of performance must be carefully measured. Learning in combat, while inevitable to some degree, is not the preferred training venue. Training simulations have proven their worth for the transfer of knowledge and skills in a cost-effective manner. The opportunities that can be provided by highly advanced, squad-level immersion simulation clearly should be explored. Small unit level simulators with extremely high fidelity "environments" that can closely replicate the conditions of the present "Arab street" and other combat areas greatly reinforce the effectiveness of new tactics. This added proficiency and confidence in tactical execution directly affects the fact and perception of risk. This in turn provides an opportunity for Marines to decrease their risk-induced weight burdens. Combined with the "gaming" technologies identified in the NRAC study on Distributed Operations (2006), advanced squad-level immersion simulations provide another opportunity to shed weight and thus improve overall performance of the Marine and his squad.

Combat Hunter has the potential to significantly increase survivability through increased lethality rather than increases in body armor, providing the potential for

significant weight reduction. This type of new tactical concept may scale to accommodate future mission needs without increasing squad weight, a very important and desired attribute for uncertain future combat situations.

To further illustrate the approach that the NRAC Panel is advocating, Chart 11 presents an example of using advanced ISR technology for rapid target location, identification and designation for direct and indirect fires. Enhancing the squad's ability to leverage available ISR and fires can provide overmatch capabilities against unconventional and larger conventional forces. Essentially, this example seeks a solution to extend the lethal range of the squad well beyond that of the enemy—using our superior technology.

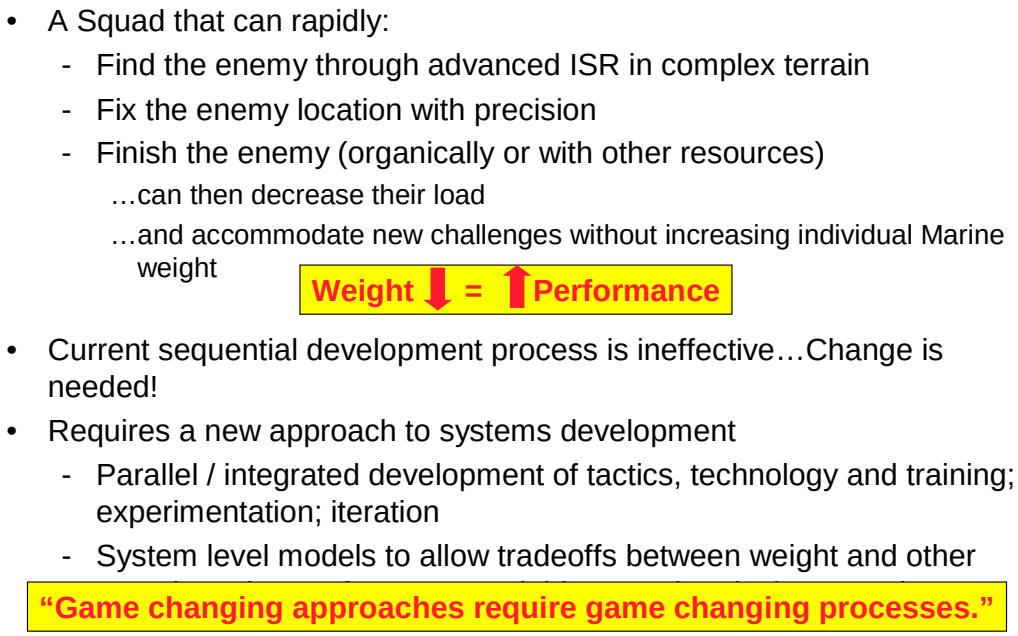

Chart 11 Game Changing Concept

Effective new tactics must be developed that can leverage this technology advantage. Then Marines must be appropriately trained to employ both the tactics and the technology. All three: new technology, new tactics, and new training will be required to make this a reality.

If successful, this new approach could significantly decrease the amount of required personal protection equipment and firepower (weapons and ammunition) that must be carried to the fight by individual Marines. Ultimately, this approach may scale to accommodate future missions without increasing weight.

As previous combat experience has shown, the weight of the dismounted soldier and Marine has a direct effect on his ability to fight effectively. This thinking is highlighted by the catch phrase … decreasing weight will increase combat performance for the squad with the converse, unfortunately, also being true!

The new tactics, technology, and training synergy required for this new approach is very different from the current sequential approach. Today, tactics drive requirements—which then drive technology—and training is then conducted as a final step in the process. The major difficulty with this current, sequential approach is that it is more suited to slowly evolving changes—not to an enemy whose tactics change quickly—in some situations faster than ours can change. As a result, the NRAC Panel believes that a new approach to the required squad systems development is required.

The first step:

- ***establish the squad as the core system*** that needs this change.

The second step:

- ***facilitate an integrated, parallel development of tactics, technology and training with frequent, systems level, experimentation*** to provide the necessary iteration as new facts are discovered.

The final step:

- ***develop system-level models*** that include the ***results of the experiments and that allow for tradeoffs between weight and squad performance parameters***. These will provide predications where current data do not exist and will help design future experiments.

Systems Approach to Lightening the Load

The rifle squad is a complex system of systems with leaders, automatic riflemen, and riflemen acting in concert to accomplish a variety of missions. Complex systems always present sets of conflicting and competing tasks that must be reconciled to achieve a balanced, affordable and fully integrated product—which meets the needs of the customer. Fortunately there are well-documented sets of successful standard practices that can guide us in a systematic way to achieve the goal of reducing weight carried by the squad. It is imperative that the Marine Corps employ these proven, successful methods to enable the desired results.

Chart 12 depicts the seven Program Managers (PMs) who are responsible for the equipment that the Marine fights with and wears "outside the wire." An associated color-coded "pie chart" illustrates the percentage responsibility for each PM. For example, the PM for Infantry Combat Equipment (PM ICE) is responsible for 55% of the load. This part of the load includes the personal protection body armor. The ammunition PM is responsible for 18% and so on. PM Marine Expeditionary Rifle Squad (MERS) is responsible for 0% of the load but has coordinating responsibilities among the other PMs.

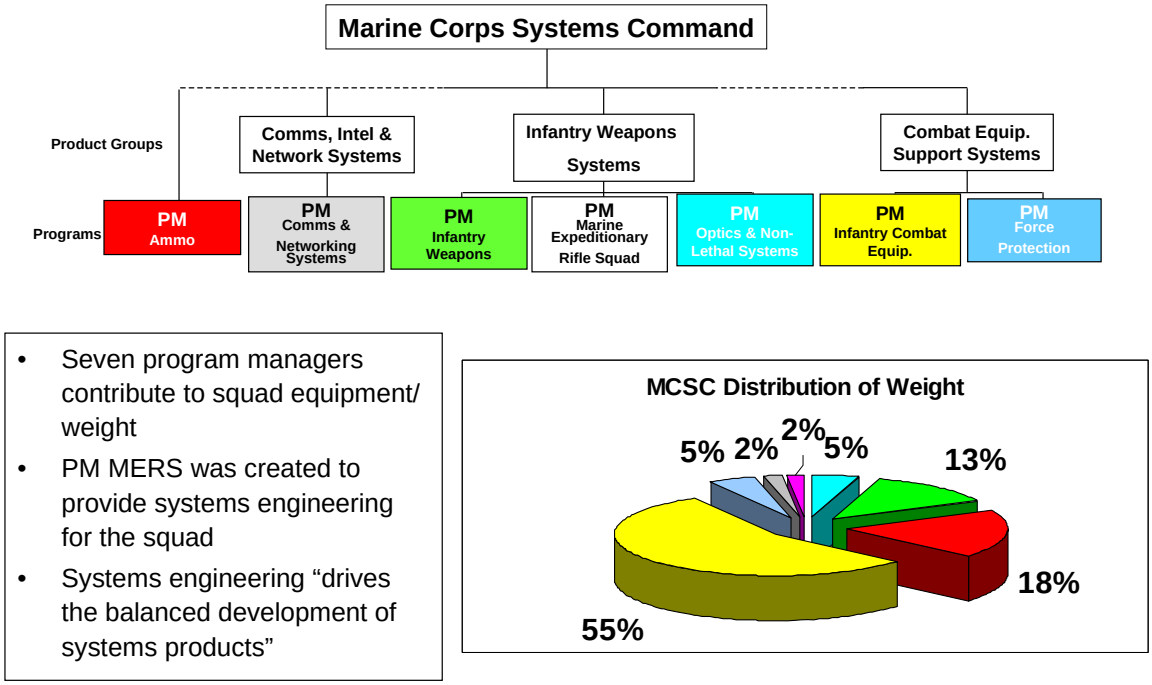

Chart 12 Current Acquisition Approach

The seven PMs report through different product groups, as shown. For example, PM ICE and PM Force Protection both report to the Combat Equipment Support Systems Product Group and PM MERS through Infantry Weapons Systems Product Group.

This management structure poses challenges to PM MERS in the execution of his duties. For example, suppose he analyzed power requirements and determined that selecting a single type of battery or power source for optics and communications equipment had logistics and weight benefits. In order to implement such a recommendation, he would have to cross multiple PMs and Product Groups. PM MERS

can coordinate such efforts, however, this office does not have the directive authority to make it happen.

A further example would be implementation of a "game changing" concept. Implementation of this concept would require extensive interaction across multiple PMs and Product Groups under MARCORSYSCOM. It would also demand interaction with other departments within CD&I.

It is important to note that the original intent of establishing PM MERS was to provide a single directive authority for integration of the various components of equipment within the rifle squad and to perform the related systems engineering functions. Unfortunately, this original vision has not fully materialized.

According to the *Systems Engineering Fundamentals* text published by the DOD Systems Management College at Ft. Belvoir (2001), "systems engineering drive the balanced development of systems products." The NRAC Panel findings indicate that PM MERS cannot drive either the integration or system engineering process.

A Marine rifleman, as equipped in November 2006, is depicted in Chart 13. Each of the items is color-coded with the color scheme applied to each PM on the previous chart. (Not pictured are groin and neck protectors and Side-SAPIs. Also not shown are the grip pod on the M16A4, cooling vest, fire resistant balaclava, and load bearing equipment.)

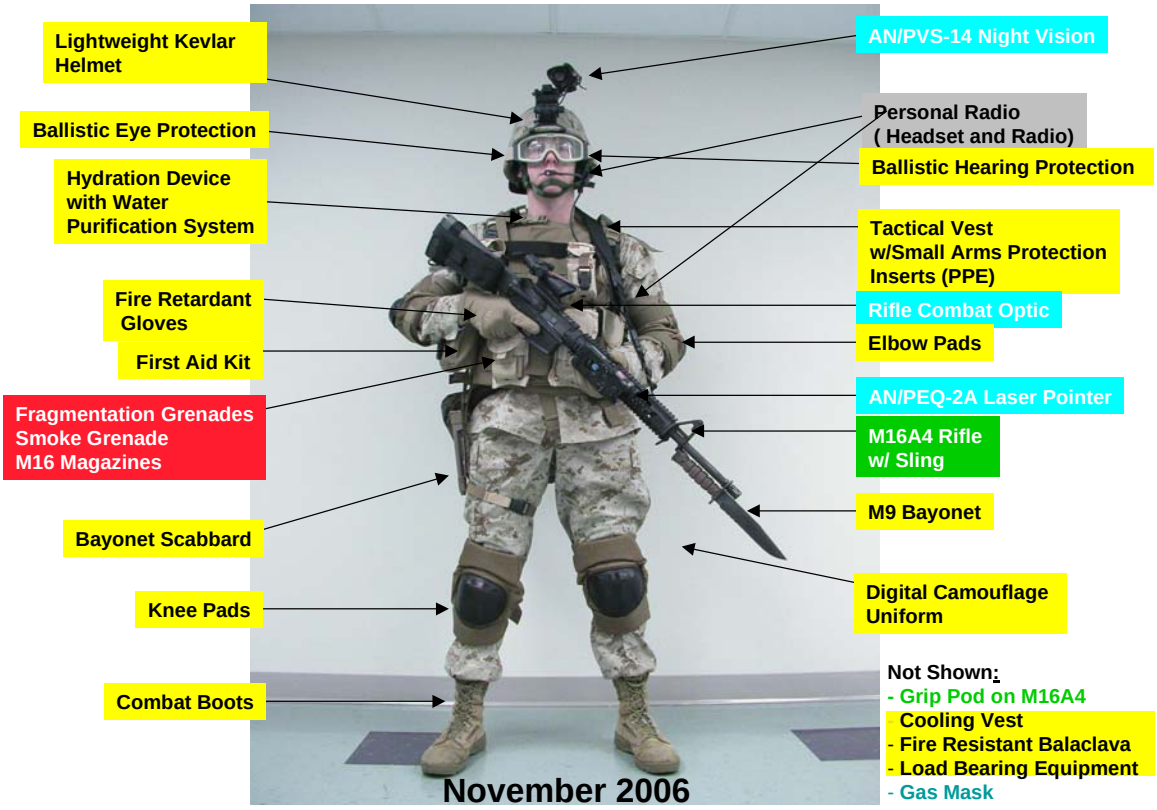

Chart 13 Marine Rifleman

Chart 14 is the weight breakdown by type of equipment and color-coded by the responsible PM. Weights shown are in pounds. (A complete weight allocation by Marine Rifle Squad position is provided in Appendix E.)

EQUIPMENT	QTY	WEIGHT EACH	WEIGHT TOTAL (POUNDS)
LIGHTWEIGHT HELMET	1	3.45	3.45
FR GLOVES, FROG	1	0.3	0.3

MODULAR TACTICAL VEST	1	14.45	14.45
E-SAPI SET (MEDIUM, FRONT AND BACK)	1	11	11
SIDE-SAPI SET	1	5	5
PATROL PACK	1	2.42	2.42
RCO	1	1	1
SERVICE RIFLE, M16A4	1	8.24	8.24
COMBAT ASSAULT SLING	1	0.42	0.42
M-16 MAGAZINE WITH 30 ROUNDS	7	1.05	7.35
MULTI-PURPOSE BAYONET	1	1.3	1.3
GRENADE, HAND, G8811 FRAGMENTATION	2	2	4
100 OZ HYDRATION SYSTEM (FILLED)	1	6.91	6.91
MRE	3	1.3	3.9
IMPROVED FIRST AID KIT (IFAK)	1	1	1
PAINT, FACE, CAMOUFLAGE STICK	1	0.14	0.14
PERSONAL ILLUMINATION SYSTEM	1	0.62	0.62
BALLISTIC EYE WEAR	1	0.15	0.15
EAR PLUGS WITH CASE	1	0.1	0.1
M50 GAS MASK W/HOOD, ALL ACCESSORIES (MEDIUM)	1	5.6	5.6
GORTEX TOP	1	2.2	2.2
GORTEX BOTTOM	1	2.2	2.2
PVS-14	1	1.7	1.7
PEQ-15 ATPIAL w/out SOFT CASE (through CY07)	1	0.51	0.51
IWNS-T	1	2	2
KNEE, ELBOW PAD SET	1	1	1
IISR/QUIET PRO W/SPARE BATTERY	1	X	1.96
STATIC WEIGHT OF REGULAR COMPLETE UNIFORM		8.41	8.41
TOTAL			97.33

Chart 14 Weight Breakdown

A top-level view of the Systems Engineering approach is shown in Chart 15. It draws attention to those aspects of the process that PM MERS is not currently capable of performing (shown in the boxes outside of the large ellipse).

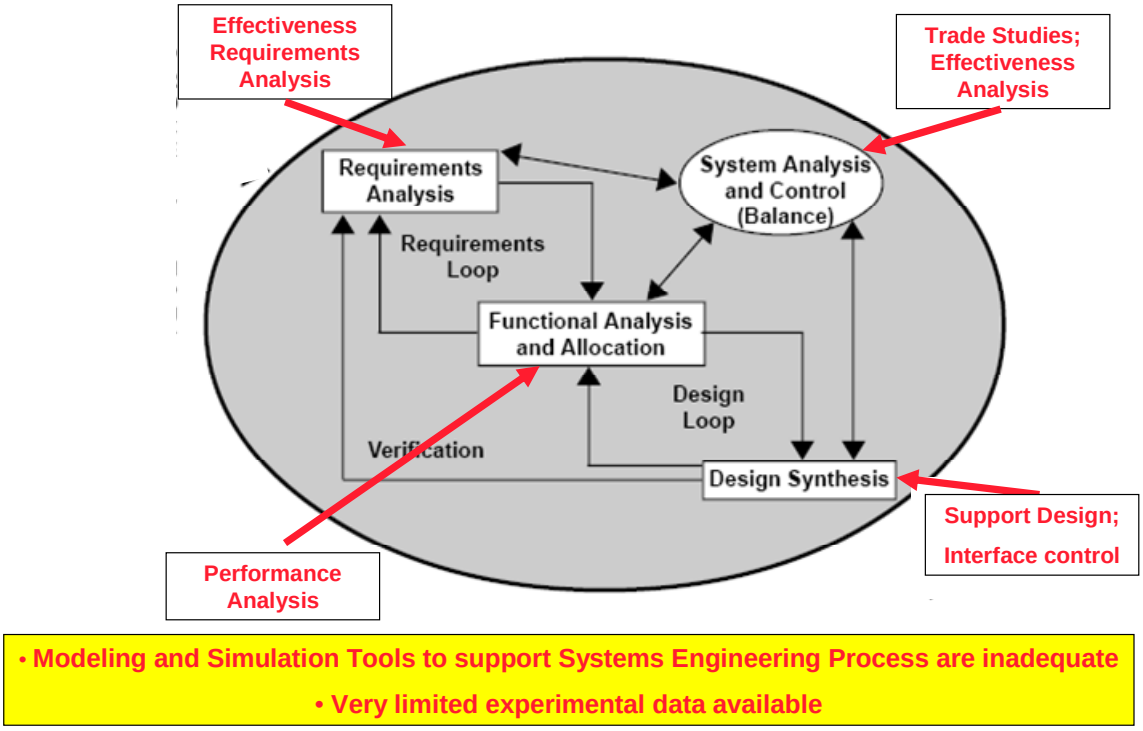

Chart 15 Systems Engineering Process

The systems engineering process requires four key functions to be performed:

(1) Requirements analysis

(2) Tradeoff analysis for system effectiveness

(3) Functional analysis to determine performance

(4) Design synthesis primarily for the purpose of interface control.

To perform these fundamental analysis activities, data and models to actually conduct the analysis are required. While various subsystem models exist,

a system-level squad model does not appear to exist. Based on these facts PM MERS, or any other entity, is unable to effectively perform critical design management activities at the squad level. This lack of data and models is further complicated by the absence of a central design agent (such as PM MERS) that has directive tasking authority for the management of the squad as a system.

The NRAC Panel findings in this area are:

- PM MERS does not have the directive authority necessary to execute an effective systems engineering process
- Data and system level models are needed for development of requirements and implementation of systems engineering process
- Data and system level models on relationship of squad equipment weights to mission effectiveness do not exist
- PM MERS is unable to conduct trade-off analysis to reduce squad load and/ or increase squad effectiveness in: weapons (range, accuracy); survivability; mobility; sensors/situation awareness; logistic responsiveness, and immediate fires

An effectively functioning systems engineering process requires a single, centralized decision authority responsible for system level analysis and tradeoffs, performance and reliability allocations, interface controls, resource prioritization among subsystems and components, and the adjudication of space, weight and power, among a myriad of other tasks. PM MERS was originally established with these sets of responsibilities. Much progress has been made by PM MERS in the past several years, but the final goal of effectively managing the squad as a system has not yet been attained.

The present organization design within the Marine Corps Systems Command does not provide the decision and directive authority required by an effective systems engineering process for the squad as a system. While the NRAC Panel does not recommend the establishment of a new Program Executive Office (PEO) for this task nor advocate the creation of a new Product Group Director (PGD) with corresponding subordinate program managers, it does conclude that PM MERS lack of authority for all elements and components of the squad precludes effective management. Reductions in

present and future squad weights will not be realized without this authority operating within a fully resourced and technically capable systems engineering approach.

The NRAC Panel agrees that the current SYSCOM PGD organizational design along product lines provides the most direct "line of sight" to the customer in the field, and supports that approach. The issue, which the squad-as-a-system presents, is how to manage and direct the aggregation of various products into a new system that spans multiple PGDs and PMs in a disciplined and effective manner.

There are many examples of effective internal management across multiple product lines. The creation of new aircraft or vehicle programs offices does not require subsuming all subsystem PMs within its organizational design. However, it does require that system-level PMs possess the authority, responsibility, resources and technical means to task other PMs. For the specific items of interest, the system-level PM must be allowed to determine how subsystems will interface and be integrated to ensure that the system requirements—in this case the rifle squad—are satisfied. The NRAC Panel concludes that PM MERS does not possess this directive authority, either by policy or his "level" within the SYSCOM organizational design. The current method of "negotiations" between PM MERS and other PMs, which supply subsystem products to the squad, does not substitute for decisional authority in all matters pertaining to the rifle squad.

Along with the responsibility and authority to effectively manage the squad as a system, the resources to accomplish specific tasks by PM MERS are disbursed across seven PMs within the command. The Panel concludes that these financial resources need to be centrally managed by a single source. At present, squad subsystems individually compete with each other in the POM process, and then compete again against other larger platform systems (combat vehicles, command centers, missile defense systems, etc.) until resource allocation within the Marine Corps is complete. In addition to realigning and reallocating resources across the various systems engineering activities, and balancing and aligning the squad-as-a-system, the Panel believes it will also be more competitive if the resource allocation process is centrally managed.

An established central management and resource authority (operating within recognized principles of systems engineering) will still not succeed if it does not possess

the requisite technical capabilities and associated personnel. Systems engineering technical management require the tools and engineering staff that can properly use them. PM MERS and the Marine Corps have made positive steps in this direction over the past year and are to be commended. These ongoing activities are critical to the success of managing the squad-as-a-system. The Panel's conclusions on a systems engineering approach are summarizes below.

- PM MERS was established as a program office to ***institute systems integration*** but has not fully matured due to a ***lack of authority, resources, and capabilities.***
- ***Reductions in weight*** will not be realized without a ***systems engineering approach.***
- ***A disciplined systems engineering approach is mandatory*** as we move toward the future Marine and introduce new capabilities into the squad as a system.
- ***Trades of weight vs. new capabilities*** must be conducted to ensure projected weight reductions ***enabled through S&T and weight transfer*** are not eroded.

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Present and Future Trade-Offs

Chart 16 Present and Future Trade-Offs

There are many new systems that are maturing in the S&T base that have application to the Marine Rifle Squad. The introduction of new capabilities has almost always added additional weight onto the Marine and thus has probably impacted his physical performance on the battlefield. Capability and weight tradeoffs of new/improved vs. legacy systems/devices are needed to prevent a Marine from becoming a "Christmas tree" where various good ideas are added to the Marine load.

Chart 16 illustrates some of the ways that a Marine Rifle Squad might leverage new technology to advance overall capability. One of the examples is a coupling of a dedicated ISR platform with physical and operational training for calls for fire and close air support. To implement this new capability, the Marine Rifle Squad leader would

designate the desired impact point for precision fires. Use of a designator system would require training and would probably have a weight and power penalty. If non-organic precision fires were readily available and could be counted on, then an offset weight in type weapons carried and the number of rounds of ammunition could be considered. An effectiveness and survivability tradeoff analysis would provide insight regarding this approach.

Another example is the use of dedicated ISR with a change of tactics. Dedicated ISR might be the enabling technology that would make Combat Hunter viable and effective. As with the previous example, a tradeoff study might determine whether a reduction in PPE would be feasible.

Tradeoffs would also be required to select the best type of vehicle for equipment offload. Some of the figures of merit would include: mobility in various terrain types; degree of human intervention required; survivability, and transportability.

Recommendations

"The Problem" defined at the beginning of the report framed the challenge for the NRAC Lightening the Load Study. The NRAC Panel received briefings, studied relevant reports and analyzed data to examine approaches to reduce weight, transfer the load, optimize human performance, and develop a systems approach for outfitting the Marine Rifle Squad. The recommendations are in several categories: Science & Technology; Models; Experiments and Tests; and Management.

Science & Technology: The NRAC Panel understands that the current S&T programs in the Navy, Army and DARPA are the foundation for future lightening the load technology solutions.

NRAC recommends that the Marine Corps increase their engagement with ONR —and their principal investigators—in the problem definition stage. It appears to the Panel that current practice is for the Marine Corps to provide ONR with a set of requirements to solve a known problem. For the LTL problem, it will probably require a paradigm shift or "game changing" set of technology solutions to get ahead and stay ahead of our adversaries. This set of technology investigations will significantly benefit from early and continuing collaboration among the Marine Corps headquarters staff and ONR.

In addition, NRAC believes that the Marine Corps needs to establish an enhanced representation at DARPA focused on game changing technologies to dramatically lighten the Marine's load. The Marine Corps can garner considerably more support from DARPA than they have at present if they can provide technically superior individuals with good ideas to become both advocates and managers of these efforts. Furthermore, providing operationally experienced Marines at the lieutenant colonel – colonel level to more effective liaison officers between other DARPA PMs and the Marine Corps can also have significant future payoffs.

The Panel strongly recommends that investment in this area be increased to a level commensurate with its importance to the Marine Corps. In addition to managing weight, related focus areas include improvement of rifle squad lethality, survivability, mobility and training.

Models: There is a compelling requirement to develop human performance models that measure individual load vs. combat effectiveness as impacted by load, terrain, environment, etc. that enable systems-level tradeoff analyses at the individual Marine and Rifle Squad level. Current models lack fidelity and have not been validated with data.

Experiments and Tests: In order to develop and validate the models, experimental data on individual squad and system performance must be generated. Collaboration for this and the evaluation of new concepts should involve all of the S&T stakeholders (ONR, Army, DARPA, and allies).

Management: The Marine Corps should recognize the importance of establishing the squad and its equipment as a formal program with an associated Capability Development Document (CDD), and managed by a single source within MARCORSYSCOM—as a system. The NRAC Panel recommends that MCCDC perform the functions necessary to establish the squad as a program and that MARCORSYSCOM assign total management authority to PM MERS and manage this program as an integrated system.

Proposed Actions

The NRAC Panel has assigned proposed actions to the leaders who can play a significant role in solving the problem of lightening the load for the Marine Rifle Squad. The actions are grouped under: the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN (RDA)); the Commandant of the Marine Corps (CMC); the Deputy Commandant for Combat Development & Integration (DC CD&I); the Commander, Marine Corps System Command (COMMARCORSYSCOM); and the Chief and Vice Chief of Naval Research (CNR/VCNR).

ASN (RDA): As described in this study the Marine load problem is significant and negatively impacts combat effectiveness. The Panel found that there were a number of individual, unconnected S&T programs addressing protection, survivability and weight reduction efforts. The ONR investment in Lightening the Load related efforts ($33M in FY08) should be increased and better integrated and focused to successfully achieve the goals of this effort. The Panel recommends that ASN (RD&A) take the lead—with DDRE—in advocating an appropriately funded, integrated, multi-Service S&T program for Lightening the Load.

CMC: DARPA pursues research and technology where risk and payoff are both very high and where success may provide dramatic advances for traditional military roles and missions. To ensure that the Marine Corps takes advantage of DARPA's desire to perform "game changing" S&T, the Commandant of the Marine Corps should begin a dialogue with the Director of DARPA. The Panel recommends that the Commandant take action to nominate Marine officers with innovative ideas as Program Managers and Marine Liaison Officers to more aggressively articulate Marine Corps needs with DARPA PMs. The second action is to establish a partnership with DARPA to define and initiate a program (or programs) to achieve advanced ISR, lethality, tactics to improve combat effectiveness and thereby reduce load weights

DC CD&I: The Panel recommends that the Deputy Commandant for Combat Development & Integration take three critical actions to address the load-carrying problem. The first is to establish and formalize maximum loads for the Marine and rifle squad. The second is to ensure the Integration Divisions and MCWL are effectively identifying and prioritizing needs with ONR and DARPA in the development of programs to address the Marine Corps needs. The third is to ensure that the right Marine Corps needs are being addressed at ONR and importantly that these are getting the best "bang for the buck" with the DC CD&I annually reviewing all Marine Corps programs at ONR. The Marine Corps S&T Strategic Plan provided the first steps in this process, but the Panel found that ONR PMs might not fully understand the Marine Corps needs in the squad-as-a-system concept.

COMMARCORSYSCOM: The Marine Rifle Squad should be recognized as a system. COMMARCORSYSCOM should assign total squad-as-a-system management authority to PM MERS. To allow this assignment to be effectively accomplished, the needed resources must be provided to create effective squad-as-a-system systems engineering capability.

CNR / VCNR: To better address Marine Corps needs through ONR S&T effort, the CNR and VCNR need to work together in setting program goals, funding levels and metrics for the required S&T efforts. An important area that should be with more focus and funding is the development and validation of models for: (1) squad combat effectiveness as a function of load, terrain, environment and other pertinent parameters;

(2) impact of load on individual performance (endurance, mobility, combat effectiveness, etc.); and (3) system-level tradeoff studies (ISR capability, lethality, weight, mobility, survivability, etc.) In the area of transferring the load, a new effort is needed to evaluate organic vehicles for load carrying. The action for both CNR and the VCNR is to capitalize on all unmanned vehicle developments to satisfy organic needs of the Marine Rifle Squad.

These proposed actions are summarized below.

ASN (RDA)

- Increase ONR investment in Lightening the Load
- Advocate with DDRE, an appropriately funded, multi-service S&T program for Lightening the Load

CMC

- Engage with the DARPA Director to nominate relevant Program Managers and achieve greater effectiveness for the Marine Liaison Officer
- Establish a partnership with DARPA on advanced ISR, lethality, and tactics to reduce load weights, and to improve survivability and combat effectiveness

DC CD&I

- Establish maximum load weights for the Marine and the Marine Rifle Squad
- Ensure Integration Divisions and MCWL are effectively coordinating with ONR
- Annually review all Marine Corps programs at ONR

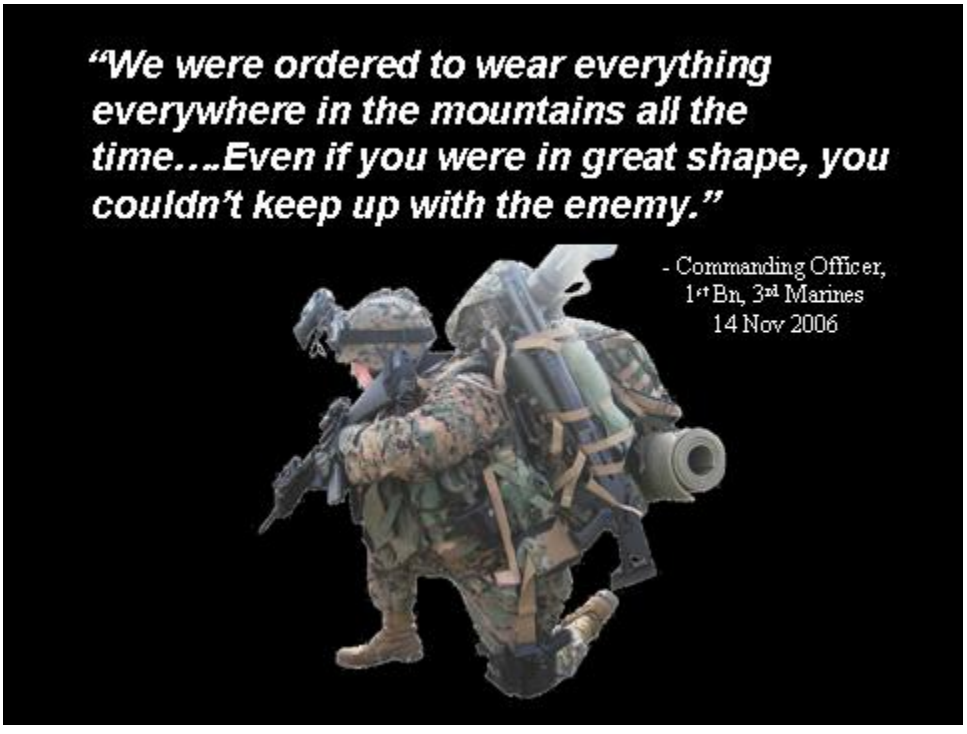
COMMARCORSYSCOM

- Assign total “Squad as a System” management authority to PM MERS
- Provide resources to create effective “Squad as a System” systems engineering capability

CNR / VCNR

- Develop, validate and deliver three models to MARCORSYSCOM:
  - Squad combat effectiveness as a function of load, terrain, environment and other pertinent parameters
  - Impact of load on individual performance (endurance, mobility, combat effectiveness, etc.)

- Models for system trade of studies (ISR capability, lethality, weight, mobility, survivability, etc.)
- Capitalize on all unmanned vehicle developments to satisfy organic needs of the Marine Rifle Squad



APPENDIX A

TERMS OF REFERENCE

The signed version will appear here in the final LTL PDF document

Lightening the Load
NRAC Summer Study 2007

Objectives:

The objectives of this study are to assess the elements of the combat load carried by today's Marine; identify the primary weight and volume contributors; identify and evaluate technology initiatives; and consider changes in operations, logistics, and training to reduce this burden without having an unacceptable impact on combat effectiveness, safety, or tactics.

Background:

The load carried by today's Marine is too heavy and has sizable volume. In addition to weapons, ammunition, water, food, and other essentials, Marines are equipped with the most advanced equipment (protective body armor, sensors, communications, and location devices) available. While this equipment provides more effective combat capabilities and facilitates dispersed operations, it does not come without penalty. Current asymmetric adversaries are not similarly burdened. The load carried by Marines negatively impacts their combat efficiency, causes fatigue, reduces agility and immediate response capabilities, and has other undesirable effects.

It is desired that this study identify and evaluate as many of the factors that contribute to the load carried by today's Marines in combat and the options that could be considered to reduce this burden, thereby providing greater agility and flexibility for those directly engaged in the fight.

Specific Taskings:

1. Review current loads, identify the major weight and volume components, and determine which are dictated by mission / tactics / environment / sustainability / survivability / doctrine.

2. Identify and evaluate S&T initiatives (US and allies) that are being or could be pursued to lighten the load. These should include, but not be limited to, new materials, weapons, protective body armor, and ergonomic development of load bearing equipment. Explore opportunities to combine/ integrate equipment components or reduce the quantities of items carried. Identify those items that should be accelerated.

3. Discuss to the extent possible changes to logistics re-supply concepts (including robotic mules and others), that would contribute to lightening the individual combat load.

As appropriate comment on how tactics, training and operational procedures might reduce the load burden.

4. Review bio-engineering / human effects studies for today's standards at maximum load based on a set number of conditions. Utilize this as the baseline for the end state of all taskings listed above.

APPENDIX B

LIST OF BRIEFINGS

Topic	Organization	Briefer
Welcome/Guidance	Marine Corps Combat Development Command	LtGen James Amos, CG MCCDC
Distributed Operations Architecture Study	DARPA	Col Joe Kennedy, Program Manager
Considerations for Lightening the load to Improve Infantry Performance	Experiment Division, Marine Corps Warfighting Lab	Col Steve Penn, Director
MERS Brief/Demonstration	PM Marine Expeditionary Rifle Squad	Mr. Mark Richter, PM
ONR S&T in Support of Lightening the Load	ONR 30, Expeditionary Maneuver Warfare and Combating Terrorism Department	Mr. George Solhan, Dept. Head; Mr. Ashley Johnson
Distributed Operations (DO)	Fires and Maneuver Capabilities Development Directorate, MCCDC	Col Robert Durkin, Director
Army Science Board FY2001 Summer Study: "The Objective Force Soldier/Soldier Team"	Army Science Board	Dr. Robert Douglass, Study Co-Author
US Army SITREP on Current Efforts	Research & Technology, Secretary of the Army Staff	Dr. Thomas Killion, Deputy Assistant Secretary for Research & Technology
Logistics Concept in Support of DO	Log Vision Team HQMC	Mr. Nick Lindowitz, Head; Maj Niewenhous
Infantry Battalion Enhancement Period Program (IBEPP)	G-3 TECOM	Maj Russ Boyce, Staff officer
Logistics Concepts and IBEPP Training	Commander, RCT 8 and various staff officers	Regimental Combat Team 8 (RCT 8)
Wolfpack	Operational Experimentation, Rapid Reaction Technology Office	Col D. J. O'Donohue, Staff Officer
General Dynamics Robotic Systems	John H. Northrop & Associates	Mr. John H. Northrop, Executive Director
General Dynamics Robotic Systems	General Dynamics Robotic Systems	Mr. Dilip Patel, PM
Future Force Warrior	FFW Technology	Ms. Carol Fitzgerald, PM
PEO Soldier	PEO Soldier-PM Soldier Warrior Tech Mgt Directorate	Mr. Dave Schimmel, S&T Lead, Hardware Systems, Power
Army Power Efforts	Army Power Division	Mr. Ed Plichta, Div. Chief
ONR S&T Efforts in Portable Power	Code 331 ONR Ship Systems and Engineering Division	Dr. Michelle Anderson, PM

Topic	Organization	Briefer
Priorities for Lightening the Load	Operations Div Plans, Policies, and Operations Headquarters, US Marine Corps	BGen Joseph Dunford, Director
Modeling and Simulation	Boston Dynamics	Dr. Rob Playter, Vice President of Engineering
Body armor, policy and regulations, other equipment	Program Office, Infantry Combat Equipment	Mr. Dan Fitzgerald, PM
Caseless ammo & other Lightening the Load efforts	Program Office, Infantry Weapons Systems	LtCol Tracy Tafolla, PM
Biomechanics and Human Performance	Ergonomics Team U.S. Army Natick Soldier Research, Development & Engineering Center	Dr. Jeffery Schiffman and Dr. Lief Hasselquist, Staff
MCWL Perspective on Lightening the Load	Marine Corps Warfighting Lab (MCWL)	BGen Randolph Alles, CG MCWL
Performance Enhancement	Nutritional Biochemistry, US Army NSRDEC	Dr. Patrick Dunne, Senior Advisor & Nutritional Biochemist
CALL Overview and Lessons Learned Process	Center for Army Lessons Learned Liaison Officer	Mr. Bill Bender, Staff
Marine Corps Center for Lessons Learned	Marine Corps Center for Lessons Learned	Col Pete DeSalva, Staff Officer
Future of USMC Optics and Integration	Program Office, Optics and Non-Lethal Systems	LtCol Scott Huelse, PM
Internally Transportable Vehicle	Logistics Capabilities Office CDD, MCCDC	Maj B. Van Chapmen, Staff Officer
Joint Light Tactical Vehicle briefs	Mobility - Counter Mobility Section CDD, MCCDC	Mr. Chris Yunker, Staff
Enhance Cognitive Performance	DARPA Defense Sciences Office (DSO)	Dr. Amy Kruse, PM
Clothing and Individual Equipment	Program Office, Clothing and Individual Equipment, US Army	LtCol John Lemondes, PM
Soldier as a System LTL Efforts	US Army	Mr. Bob Conklin, Staff
UK LTL Efforts	Equipment Capability Directorate (Ground Manoeuvre), UK Ministry of Defence	Mr. Adrian Randall, Branch Head
Canadian LTL Efforts	Defence Research and Development Canada (DRDC)	Maj Linda Bossi
French LTL Efforts	French Army	LtCol Philipe Susnjara
Singapore LTL Efforts	Singapore Army	LtCol Gary Chan
German LTL Efforts	German Army	SgtMaj Joerg Ehret

Topic	Organization	Briefer
Optics	Night Vision and Electronic Sensors Directorate, CERDEC	Dr. Fenner Milton, Director
Advanced Light Strike Vehicle	Marine Corps Warfighting Lab	Mr. Harold Bannister, Analyst
Lighter Warfighter Load through Nanotechnologies	MIT, Institute for Soldier Nanotechnologies	Dr. William Peters, Executive Director
XM29 FCS Development	Advanced Systems & Technology Development, L-3 Communications	Mr. James Kimbrell, Chief Technologist, Director
XM29 FCS Development	Land Combat Systems, Brashear L-3 Communications	Mr. John Kidder, Senior Manager for Business Development
Metal Matrix & Battery Materials	3M	Mr. Doug Magnuson, Mr. Jim Sorensen, Staff
Soldier Radio Waveform (SRW)/Commercial Wireless	CERDEC, US Army-RDECOM	Gayle Grant, Program Director
Adaptation of Commercial Wireless Tech for Implementation in the Tactical Environment	CERDEC, US Army-RDECOM	Sharon Mackey, Branch Chief
Ceramics	Ceradyne Company	Mr. Marc King, Vice President, Armor Operations/ Washington
Soldier Load	Directorate of Combat Development (DCD), USAIC	Mr. Jim Stone, Deputy Director
DARPA Efforts	Defense Sciences Office	Dr. Brett Giroir, Director
DuPont and Warfighting Load Reduction	Dupont Government Solutions	Mr. Michael Crickenberger, Vice President
DuPont and Warfighting Load Reduction	Global Applications and Life Applications	Mr. Bruce Burkholder, Manager

Other Panel Interactions

Subject	Organization	Responsible Individual(s)
Current ONR S&T investment discussion via VTC	ONR 30, Expeditionary Maneuver Warfare and Combating Terrorism Department	Mr. Ashley Johnson, Division Director
LTL discussion with MajGen Fratarangelo (Ret) and BGen Fiegley (Ret)	I MEF	LtGen Mattis, CG
Physiology research discussion with Dr. Johnson-Winegar	Naval Health Research Center	Mr. Michael Galarneau, Research Physiologist
Medical records statistical information	San Diego Naval Hospital	Dr. Lisa Pearse, LCDR, MC, USN
LTL-related information	Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC)	John Uscilowicz, JTAPIC Deputy
LTL-related information	United States Army Institute of Surgical Research (USAISR) Ft Sam Houston	Ms. Mary Spott, Staff

Subject	Organization	Responsible Individual(s)
LTL-related medical statistical information	Veterans Administration	Ms. Sandie Harms-Taylor, Staff
Table of Equipment and Personal Protective Equipment	1st Bn 5th Mar CO, 1st Bn 1st Mar CO, and various I MEF	I MEF Staff Officers
Panel Discussion on Lightening the Load-OIF experiences	Various	Marines

APPENDIX C

ABBREVIATIONS

ASN (RDA)	Assistant Secretary of the Navy (Research, Development and Acquisition)
ATPIAL	Advanced Target Pointer Illuminator Aiming Light
CERDEC	Communications-Electronics Research Development and Engineering Center
CDD	Combat Development Directorate
CD&I	Combat Development and Integration
CG	Commanding General
CMC	Commandant of the Marine Corps
COMMARCORSYSCOM	Commander, Marine Corps Systems Command
CNR	Chief of Naval Research
DARPA	Defense Advanced Research Projects Agency
DC CD&I	Deputy Commandant for Combat Development & Integration
DDRE	Director of Defense Research and Engineering
DO	Distributed Operations
DOD	Department of Defense
DRDC	Defence Research and Development Canada
DSO	Defense Sciences Office
HQMC	Headquarters Marine Corps
IBEPP	Infantry Battalion Enhancement Period Program
IED	Improvised Explosive Device
IFAK	Improved First Aid Kit
IISR	Integrated Intra-Squad Radio
ISR	Intelligence, Surveillance, and Reconnaissance
ITV	Internally Transportable Vehicle
IW	Infantry Weapons
IWNS	Independent Weapon Night Sight
IWS	Infantry Weapons Systems
JCTD	Joint Capability Technology Demonstration
LTL	Lighten the Load
MAGTF	Marine Air-Ground Task Force
MCCDC	Marine Corps Combat Development Command
MARCORSYSCOM	Marine Corps Systems Command
MCWL	Marine Corps Warfighting Lab
MEF	Marine Expeditionary Force
MERS	Marine Expeditionary Rifle Squad
MRE	Meal Ready to Eat
MULE	Multifunction Utility/Logistics Equipment Vehicle
NRAC	Naval Research Advisory Committee
NREMT	National Registry of Emergency Medical Technicians
NSRDEC	Natick Soldier RD&E Center
OEF	Operation Enduring Freedom (Afghanistan)
OIF	Operation Iraqi Freedom

ONR	Office of Naval Research
PEO	Program Executive Office
PFT	Physical Fitness Test
PGD	Product Group Director
PM	Program Manager
PPE	Personal Protective Equipment
PT	Physical Training
RCT	Regimental Combat Team
RDA	Research Development and Acquisition
RDECOM	Research Development and Engineering Command
SAPI	Small Arms Protective Insert
SITREP	Situation Report
SRW	Soldier Radio Waveform
S&T	Science and Technology
TECOM	Training and Education Command
TOR	Terms of Reference
UAS	Unmanned Aerial System
USAISR	U.S. Army Institute of Surgical Research
VCNR	Vice Chief of Naval Research

APPENDIX D

REFERENCES

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- Marine Corps Development Center report, by Capt. Thomas R. Spence, 1954
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- Army/Marine Integrated Individual Fighting System Study, 1987.

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APPENDIX E

MARINE RIFLE SQUAD LOADS
(in pounds)

ASSAULT LOAD FOR RIFLEMAN			
EQUIPMENT	QTY	WEIGHT EACH	WEIGHT TOTAL
LIGHTWEIGHT HELMET	1	3.45	3.45
FR GLOVES, FROG	1	0.3	0.3
MODULAR TACTICAL VEST	1	14.45	14.45
E-SAPI SET (MEDIUM, FRONT AND BACK)	1	11	11
SIDE-SAPI SET	1	5	5
PATROL PACK	1	2.425	2.425
RCO	1	1	1
SERVICE RIFLE, M16A4	1	8.24	8.24
COMBAT ASSAULT SLING	1	0.42	0.42
M-16 MAGAZINE WITH 30 ROUNDS	7	1.05	7.35
MULTI-PURPOSE BAYONET	1	1.3	1.3
GRENADE, HAND, G8811 FRAGMENTATION	2	2	4
100 OZ HYDRATION SYSTEM (FILLED)	1	6.906	6.906
MRE	3	1.3	3.9
INDIVIDUAL FIRST AID KIT (IFAK)	1	1	1
PAINT, FACE, CAMOUFLAGE STICK	1	0.14	0.14
PERSONAL ILLUMINATION SYSTEM	1	0.625	0.625
BALLISTIC EYE WEAR	1	0.15	0.15
EAR PLUGS WITH CASE	1	0.1	0.1
M50 GAS MASK W/HOOD, ALL ACCESSORIES (MEDIUM)	1	5.6	5.6
GORTEX TOP	1	2.2	2.2
GORTEX BOTTOM	1	2.2	2.2
PVS-14	1	1.7	1.7
PEQ-15 ATPIAL w/out SOFT CASE (through CY07)	1	0.51	0.51
IWNS-T	1	2	2
KNEE, ELBOW PAD SET	1	1	1
IISR/QUIET PRO W/SPARE BATTERY	1	X	1.96
STATIC WEIGHT OF REGULAR COMPLETE UNIFORM		8.408	8.408
TOTAL			97.33

ASSAULT LOAD FOR AUTOMATIC RIFLEMAN			
EQUIPMENT	QTY	WEIGHT EACH	WEIGHT TOTAL
LIGHTWEIGHT HELMET	1	3.45	3.45
FR GLOVES, FROG	1	0.3	0.3
MODULAR TACTICAL VEST	1	14.45	14.45
E-SAPI SET (MEDIUM, FRONT AND BACK)	1	11	11
SIDE-SAPI SET	1	5	5
PATROL PACK	1	2.425	2.425
SQUAD AUTOMATIC WEAPON, M249	1	15.3	15.3
LBE FOR M-249	1	7.341	7.341
CARTRIDGE, 5.56 LINK (200)	2	6.9	13.8
GRENADE, HAND, G8811 FRAGMENTATION	2	2	4
100 OZ HYDRATION SYSTEM (FILLED)	1	6.906	6.906
MRE	3	1.3	3.9
INDIVIDUAL FIRST AID KIT (IFAK)	1	1	1
PAINT, FACE, CAMOUFLAGE STICK	1	0.14	0.14
PERSONAL ILLUMINATION SYSTEM	1	0.625	0.625
BALLISTIC EYE WEAR	1	0.15	0.15
EAR PLUGS WITH CASE	1	0.1	0.1
M50 GAS MASK W/HOOD, ALL ACCESSORIES (MEDIUM)	1	5.6	5.6
GORTEX TOP	1	2.2	2.2
GORTEX BOTTOM	1	2.2	2.2
PVS-17C	1	3	3
AN/PAS-D(V2)	1	2.8	2.8
PEQ-15 ATPIAL w/out SOFT CASE (through CY07)	1	0.51	0.51
KNEE, ELBOW PAD SET	1	1	1
IISR/QUIET PRO W/SPARE BATTERY	1	X	1.96
STATIC WEIGHT OF REGULAR COMPLETE UNIFORM	1	8.408	8.408
TOTAL			117.57

ASSAULT LOAD FOR ASST AUTOMATIC RIFLEMAN			
EQUIPMENT	QTY	WEIGHT EACH	WEIGHT TOTAL
LIGHTWEIGHT HELMET	1	3.45	3.45
FR GLOVES, FROG	1	0.3	0.3
MODULAR TACTICAL VEST	1	14.45	14.45
E-SAPI SET (MEDIUM, FRONT AND BACK)	1	11	11
SIDE-SAPI SET	1	5	5
PATROL PACK	1	2.425	2.425
RCO	1	1	1
SERVICE RIFLE, M16A4	1	8.24	8.24
COMBAT ASSAULT SLING	1	0.42	0.42
M-16 MAGAZINE WITH 30 ROUNDS	7	1.05	7.35
MULTI-PURPOSE BAYONET	1	1.3	1.3
GRENADE, HAND, G8811 FRAGMENTATION	2	2	4
100 OZ HYDRATION SYSTEM (FILLED)	1	6.906	6.906
MRE	3	1.3	3.9
INDIVIDUAL FIRST AID KIT (IFAK)	1	1	1
PAINT, FACE, CAMOUFLAGE STICK	1	0.14	0.14
PERSONAL ILLUMINATION SYSTEM	1	0.625	0.625
BALLISTIC EYE WEAR	1	0.15	0.15
EAR PLUGS WITH CASE	1	0.1	0.1
M50 GAS MASK W/HOOD, ALL ACCESSORIES (MEDIUM)	1	5.6	5.6
GORTEX TOP	1	2.2	2.2
GORTEX BOTTOM	1	2.2	2.2
SPARE BARREL M-249	1	1.4	1.4
OTHER COMPONENTS M-249	1	1.7	1.7
CARTRIDGE, 5.56 LINK (400)	2	6.9	13.8
PVS-14	1	1.7	1.7
PEQ-15 ATPIAL w/out SOFT CASE (through CY07)	1	0.51	0.51
IWNS-T	1	2	2
KNEE, ELBOW PAD SET	1	1	1
IISR/QUIET PRO W/SPARE BATTERY	1	X	1.96
STATIC WEIGHT OF REGULAR COMPLETE UNIFORM		8.408	8.408
TOTAL			114.23

ASSAULT LOAD FOR FIRE TEAM LEADER			
EQUIPMENT	QTY	WEIGHT EACH	WEIGHT TOTAL
LIGHTWEIGHT HELMET	1	3.45	3.45
FR GLOVES, FROG	1	0.3	0.3
MODULAR TACTICAL VEST	1	14.45	14.45
E-SAPI SET (MEDIUM, FRONT AND BACK)	1	11	11
SIDE-SAPI SET	1	5	5
PATROL PACK	1	2.425	2.425
RCO	1	1	1
SERVICE RIFLE, M16A4	1	8.24	8.24
COMBAT ASSAULT SLING	1	0.42	0.42
M-16 MAGAZINE WITH 30 ROUNDS	7	1.05	7.35
MULTI-PURPOSE BAYONET	1	1.3	1.3
GRENADE, HAND, G8811 FRAGMENTATION	2	2	4
G940 GREEN SMOKE GRENADE	2	2	4
100 OZ HYDRATION SYSTEM (FILLED)	1	6.906	6.906
MRE	3	1.3	3.9
INDIVIDUAL FIRST AID KIT (IFAK)	1	1	1
PAINT, FACE, CAMOUFLAGE STICK	1	0.14	0.14
PERSONAL ILLUMINATION SYSTEM	1	0.625	0.625
BALLISTIC EYE WEAR	1	0.15	0.15
EAR PLUGS WITH CASE	1	0.1	0.1
M50 GAS MASK W/HOOD, ALL ACCESSORIES (MEDIUM) (plus voice adapter (.2 lbs))	1	5.8	5.8
GORTEX TOP	1	2.2	2.2
GORTEX BOTTOM	1	2.2	2.2
CARTRIDGE, 40MM, HIGH EXPLOSIVE DUAL PURPOSE M433 QTY OF 18	1	1	14.5
GRENADE LAUNCHER, M203	1	3	3
AMMUNITION, SMOKE	1	2.4	2.4
AMMUNITION, FLARES	1	1	1
LBE FOR M-203	1	8.665	8.665
PVS-14	1	1.7	1.7
PSQ-18 (ENHANCED SIGHT M-203)	1	1.2	1.2
PEQ-15 ATPIAL w/out SOFT CASE (through CY07)	1	0.51	0.51
IWNS- I^2	1	2.2	2.2
IISR/QUIET PRO W/SPARE BATTERY	1	X	1.96
KNEE, ELBOW PAD SET	1	1	1
STATIC WEIGHT OF REGULAR COMPLETE UNIFORM		8.408	8.408
TOTAL			132.50

ASSAULT LOAD FOR SQUAD LEADER			
EQUIPMENT	QTY	WEIGHT EACH	WEIGHT TOTAL
LIGHTWEIGHT HELMET	1	3.45	3.45
FR GLOVES, FROG	1	0.3	0.3
MODULAR TACTICAL VEST	1	14.45	14.45
E-SAPI SET (MEDIUM, FRONT AND BACK)	1	11	11
SIDE-SAPI SET	1	5	5
PATROL PACK	1	2.425	2.425
RCO	1	1	1
SERVICE RIFLE, M16A4	1	8.24	8.24
COMBAT ASSAULT SLING	1	0.42	0.42
M-16 MAGAZINE WITH 30 ROUNDS	7	1.05	7.35
MULTI-PURPOSE BAYONET	1	1.3	1.3
GRENADE, HAND, G8811 FRAGMENTATION	2	2	4
G940 GREEN SMOKE GRENADE	2	2	4
100 OZ HYDRATION SYSTEM (FILLED)	1	6.906	6.906
MRE	3	1.3	3.9
INDIVIDUAL FIRST AID KIT (IFAK)	1	1	1
PAINT, FACE, CAMOUFLAGE STICK	1	0.14	0.14
PERSONAL ILLUMINATION SYSTEM	1	0.625	0.625
BALLISTIC EYE WEAR	1	0.15	0.15
EAR PLUGS WITH CASE	1	0.1	0.1
M50 GAS MASK W/HOOD, ALL ACCESSORIES (MEDIUM) (plus voice adapter (.2 lbs))	1	5.8	5.8
GORTEX TOP	1	2.2	2.2
GORTEX BOTTOM	1	2.2	2.2
CARTRIDGE, 40MM, HIGH EXPLOSIVE DUAL PURPOSE M433 QTY OF 18	1	14.5	14.5
AMMUNITION, SMOKE	1	2.4	2.4
AMMUNITION, FLARES	1	1	1
GRENADE LAUNCHER, M203	1	3	3
LBE FOR M-203	1	8.665	8.665
PVS-14	1	1.7	1.7
PEQ-15 ATPIAL w/out SOFT CASE (through CY07)	1	0.51	0.51
THERMAL BINOS	1	3.75	3.75
148	1	1.88	1.88
IISR/QUIET PRO W/SPARE BATTERY	1	X	1.96
KNEE, ELBOW PAD SET	1	1	1
STATIC WEIGHT OF REGULAR COMPLETE UNIFORM	1	8.408	8.408
TOTAL			134.73

ASSAULT LOAD FOR CORPSMAN			
EQUIPMENT	QTY	WEIGHT EACH	WEIGHT TOTAL
LIGHTWEIGHT HELMET	1	3.45	3.45
FR GLOVES, FROG	1	0.3	0.3
MODULAR TACTICAL VEST	1	14.45	14.45
E-SAPI SET (MEDIUM, FRONT AND BACK)	1	11	11
SIDE-SAPI SET	1	5	5
PATROL PACK	1	2.425	2.425
M-9 PISTOL	1	2.1	2.1
MAGAZINE WITH 15 ROUNDS	2	0.45	0.9
100 OZ HYDRATION SYSTEM (FILLED)	1	6.906	6.906
MRE	3	1.3	3.9
INDIVIDUAL FIRST AID KIT (IFAK)	1	1	1
PAINT, FACE, CAMOUFLAGE STICK	1	0.14	0.14
PERSONAL ILLUMINATION SYSTEM	1	0.625	0.625
BALLISTIC EYE WEAR	1	0.15	0.15
EAR PLUGS WITH CASE	1	0.1	0.1
M50 GAS MASK W/HOOD, ALL ACCESSORIES (MEDIUM)	1	5.6	5.6
GORTEX TOP	1	2.2	2.2
GORTEX BOTTOM	1	2.2	2.2
UNIT 1 BAG/ 6 IV'S/ 02 TANK QUESTIONABLE	1	25	25
IISR/QUIET PRO W/SPARE BATTERY	1	X	1.96
STATIC WEIGHT OF REGULAR COMPLETE UNIFORM		8.408	8.408
TOTAL			97.81

STATIC LOAD			
EQUIPMENT	QTY	WEIGHT EACH	WEIGHT TOTAL
UNIFORM, UTILITY, CAMOUFLAGE	1	2.97	2.97
UNIFORM, UTILITY, BELT	1	0.3	0.3
T-SHIRT, GREEN	1	0.18	0.18
UNDERSHORTS, BOXER	1	0.25	0.25
BOOTS, COMBAT WITH LACES	1	4.1	4.1
SOCKS,	1	0.16	0.16
WATCH, WRIST	1	0.1	0.1
CARD, ID	1	0.028	0.028
DOG TAGS	1	0.1	0.1
UNIFORM, UTILITY, CAP	1	0.22	0.22
TOTAL			8.41

APPROACH MARCH LOAD			
EQUIPMENT	QTY	WEIGHT EACH	WEIGHT TOTAL
IMPROVED LOAD BEARING EQUIPMENT	1	10.5	10.5
ENTRENCHING TOOL WITH CASE	1	2.5	2.5
EXTRA SOCKS	2	0.16	0.32
PONCHO	1	1.6	1.6
PONCHO LINER	1	1.6	1.6
MRE	3	1.3	3.9
TOOTH BRUSH WITH PASTE	1	0.3	0.3
CHAPSTICK	1	0.01	0.01
100 OZ HYDRATION SYSTEM (FILLED)	1	6.906	6.906
TOTAL			27.64

EXISTENCE LOAD			
EQUIPMENT	QTY	WEIGHT EACH	WEIGHT TOTAL
100 WEIGHT FLEECE JACKET	1	0.661	0.661
300 WEIGHT FLEECE JACKET	1	1.322	1.322
POLYPRO TOP	1	0.44	0.44
POLYPRO BOTTOM	1	0.462	0.462
COLD WEATHER GLOVES AND MITTENS	1	1.325	1.325
WATCH CAP	1	0.55	0.55
100 OZ HYDRATION SYSTEM (FILLED)	1	6.906	6.906
SHAVING GEAR, TOWEL, FACE CLOTH	1	2	2
INSECT REPELLANT	1	0.75	0.75
SEWING KIT	1	0.1	0.1
MAT, ISOPOR	1	1.5	1.5
BIVY SACK	1	2.2	2.2
MODULAR SLEEPING BAG	1	4.5	4.5
TWO MAN TENT	1	8.5	8.5
JLIST SUIT COMPLETE WITH BOOTS AND GLOVES	1	10	10
BATTERIES, AA (4)	2	0.375	0.75
TOTAL			41.97