SMART ADAPTATIONS FOR THE GENDER-INTEGRATED MARINE CORPS

Final Report

July 2015

The estimated cost of this report or study for the Department of Defense is approximately $143,808.00 in Fiscal Years 2014– 2015.

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Abstract

The Marine Corps is evaluating the factors and considerations associated with the integration of female Marines into previously closed military occupational specialties and units. The Marine Corps Force Innovation Office commissioned this study to help the Marine Corps better understand the potential for modifications to equipment that can reduce barriers to performance of physically demanding tasks. The study examined the Marine Corps requirements generation and equipment fielding systems with a focus on the human systems integration aspects of those systems. The study team also consulted with Ground Combat Element advocates and acquisition professionals, visited formal learning centers, engaged with Marines from the Ground Combat Element Integrated Task Force, and reviewed a broad spectrum of equipment for potential adaptation.

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Executive Summary

The Marine Corps is evaluating the factors and considerations associated with the integration of female Marines into previously closed Military Occupational Specialties (MOS) and units. The Marine Corps Force Innovation Office commissioned the Smart Adaptation study to help the Marine Corps better understand the potential for modifications to equipment that can reduce barriers to performance of physically demanding tasks.

The study examined the Marine Corps requirements generation and equipment fielding systems with a focus on the human systems integration aspects of those systems. In the course of the study, the study team consulted with Ground Combat Element advocates and acquisition professionals, visited formal learning centers, engaged with Marines from the Ground Combat Element Integrated Task Force (GCEITF), and reviewed a broad spectrum of equipment for potential adaptation.

The study team developed a framework for the evaluation of potential adaptations. The study team then used this framework to evaluate observations from the experiences of GCEITF Marines to develop the smart adaptation list contained in this report (excerpt below). While the list is not definitive, it serves as an excellent starting point to develop equipment adaptations to reduce barriers and maximize the performance of small-statured (mostly female) Marines as they perform physically demanding tasks.

Table 1 Smart Adaptation List Excerpt

Item	Observation	Tasks Affected	Recommendation	Expected Changes in Performance	Number of Personnel Potentially Affected	Estimated Financial Cost	Estimated Time to Field	Commercially Available Options
USMC Pack System	Short-statured Marines complained about the length of the USMC Pack Frame. Even when the hip belt was adjusted to the alternate configuration, short-statured Marines experienced "pack bite" where the frame would chafe their lower back and cause abrasions.	All hikes	Field multiple frame sizes or adjustable frames.	Improved pack fit leads to improved performance on hikes and reduction in injuries.	All short-statured Marines	$260/each	6 months	*Mystery Ranch* Nylinear Individual Carrying Equipment (NICE) Frames: The Futura yoke adjusts up or down quickly, and without tools, to fit torsos anywhere from 4'8 to 6'4. The waist belt can accommodate from 25 to 40+ inch waists and also features cant adjustment to facilitate women's hip bones. https://vimeo.com/80911468
Light-weight Helmet (LWH)	Female Marines had difficulty with the LWH retention harness. The nape pad is not adjustable, which makes it difficult to wear with a hair bun.	All Tasks	Field a helmet retention system that is compatible with female hair bun.	Adjustable harness provides better fit leading to improved visibility and reduced risk of injury.	All females Marine	$20.86/each	6 months	H-Style Retention Harness is available through DLA: 8470-01-530-0868/Color: Green Foliage Nape Pads are also available
AAV: Casualty Evacuation	Evacuating a casualty through the turret hatch is an extremely difficult task. It is even more difficult when done by a short-statured Marine.	Casualty Evacuation	Evaluate various options to include strap designed assist casualty evacuation.	Improved ability to evacuate a casualty through a turret hatch.	All AAV crewman (Potentially all vehicles with overhead egress)	$70/each	TBD	*Agilite* The Porcupine: Allows you to carry an injured or otherwise incapacitated person. http://agilitegear.com/collections/rescue-equipment/products/porcupine-black
LAV-25: Snatch Block	The snatch block on the LAV-25 is currently mounted high on the body of the vehicle and difficult for short-statured Marines to access. The snatch block on the LAV-L is mounted between the 2nd and 3rd road wheels making it easily accessible.	Recovery operations	Move snatch block on LAV-25 to location similar to that on the LAV-L.	Improves performance during recovery operations and standardization of LAV variants.	LAV crewman	TBD	TBD	N/A
M1A1 Abrams: M240 Machinegun	The M240 has a butterfly trigger which is difficult for Marines with small hands to engage.	Machine gun Operations	Consider the butt stock version of the M240 for use in the M1A1.	Improved ability for small-statured Marines to operate the machine gun.	Small-statured tank crewmen	TBD	TBD	N/A

- The study team considered the following criteria in development of the list:
    - Tasks affected by a potential adaptation based on the Training and Education Command's Task Criticality Analysis and the physical requirements for operation of major end items associated with ground combat arms MOSs
    - The expected changes in performance that a potential adaptation can or should offer
    - The estimated cost and time to field for a potential solution
- The study team identified problems within the current requirements, acquisition, and fielding processes. These issues are obstacles to reducing barriers to physical performance.
    - The 5^{th}–95^{th} anthropometric sizing standard used to guide equipment design was not uniformly understood and its application was sub-optimal for the needs of female and small-statured Marines. As a result of this study, the Combat Development Directorate, under the Deputy Commandant for Combat Development and Integration, is reviewing requirements definitions for equipment in order to better support small-statured (mostly female) Marines.
    - While the Service has detailed requirements for ballistic protection in infantry combat (personal protective) equipment, there is no metric for individual mobility to evaluate potential adaptations that could enhance individual performance. Without a mobility metric, initiatives to "lighten the load" lack an analytic basis for evaluation. The study team believes this is an important area for increased focus.
    - Marine Corps Systems Command (MARCORSYSCOM) recently commissioned an expansion of the 2010 Marine Corps Anthropometric Survey dataset, which will improve the design, sizing, and tariff (stocks) of equipment, especially personal protective equipment.
    - Marine Corps Logistics Command Individual Issue Facilities do not collect data on the non-availability of sizes/stock. Improper sizing (along with configuration) is viewed as the most common—and preventable—barrier to performance. Sizing and configuration training for infantry combat equipment are currently provided by MARCORSYSCOM's new equipment fielding teams. These teams are to be defunded at the end of FY-15. Continuity of this training remains undetermined as of this report. Furthermore, the Marine Corps should strengthen policies and procedures that ensure Marines are properly sized and trained in their equipment and that they are issued the appropriate sizes.
- The ability to sense the demand for equipment adaptations and evaluate potential solutions is under strain with the defunding of the Marine Enhancement Program (MEP). The MEP provides an accessible (website) venue for Marines to provide feedback and ideas into the acquisition process along with the people and processes to manage the program, evaluate potential

candidates, and implement solutions. The study team judged that the Marine Corps would benefit from a program such as the MEP, which encourages Marines to participate in the process and to help create innovative solutions to common challenges.

The study team recommends that the Marine Corps consider further research in the following areas:

- The Marine Corps should place high emphasis on development of mobility metrics for the evaluation of infantry combat equipment. Without mobility metrics, efforts to "lighten the load" lack an analytic foundation and are susceptible to failure.

The study team appreciates the support of the many organizations and dedicated professionals who contributed to this study.

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1. Background

In January 2013, the Secretary of Defense rescinded the 1994 Direct Ground Combat and Assignment Rule, which restricted women from assignment to units whose primary mission is to engage in direct combat on the ground and directed each of the Services to open all Military Occupational Specialties (MOS) and units to females by January 1, 2016. With the goal of opening units and billets to the maximum extent possible while maintaining high combat readiness, the Marine Corps continues to take a deliberate, measured, and responsible approach to assess the units, occupational fields, and specific MOSs that are currently closed to female Marines.

The Marine Corps Force Innovation Office (MCFIO) is tasked with examining the issues associated with integrating women into traditional male-only combat arms MOSs. Even as the Marine Corps takes a systematic approach to integrating women into combat arms specialties by research, assessment, and validation of current occupational standards, there exists within several of these MOSs physical and physiological barriers to performing a number of the required duties. Some of the barriers do not directly support an operational requirement, but exist because processes and procedures have been in place for long periods or equipment was designed for the average sized male Marine.

The motivation for this study is reinforced by Federal legislation. Section 527 of the National Defense Authorization Act (NDAA) for Fiscal Year 2015, titled "Removal of Artificial Barriers to the Service of Women in the Armed Forces" states that, "The Secretary of Defense shall direct each Secretary of a military department to take immediate steps to ensure that properly designed and fitted combat equipment is available and distributed to female members of the Armed Forces under the jurisdiction of that Secretary."

1.1. Purpose and Scope

This study examines the environment and proposes a framework for evaluation of potential adaptations to physical and physiological barriers that would not affect the operational capability of the unit, but would remove the impediments to success for a large number of Marines. A number of physical or physiological barriers exist when performing some of the duties associated with these MOSs. These barriers to performance are also barriers to full integration for female Marines. An adaptation in terms of equipment design, gear weight, the Marine's physical fitness, team composition, or Standard Operating Procedure (SOP) may be available to support successful completion of the required tasks, thereby removing the impediments to success. MCFIO required an analytic study to identify potential adaptations for the barriers to success, as well as the associated costs, implementation considerations, operational effectiveness, and the number of Marines potentially impacted. Results of the study will be used to help determine adaptations that should be considered for implementation.

This study focused on identifying adaptations related to:

- Shortcomings with the Infantry Combat Equipment (ICE) that is common to all Marines

- Physical/physiological requirements, Training and Readiness (T&R) events, and equipment associated with the Infantry, Light Armored Reconnaissance, Amphibious Assault Vehicle (AAV), Artillery, and Tank occupations.

Adaptations considered equipment design and its impact on the performance of occupational tasks, specifically those with MOSs currently closed to female Marines. Physical performance, team composition, equipment operating procedures, and unit SOPs informed the team's analysis. Current and developing technologies were reviewed for applicability. Costs, estimated population, and potential benefit were evaluated for each recommended adaptation.

1.2. Objectives / Tasks

The objective of this study was to provide recommendations of potential adaptations that will lower the physical barriers to performance in the combat arms MOSs. The study team divided the work into three tasks.

- Task 1: Survey of Current Plans, Programs, and Future Possibilities:
  - Determine what adaptations and gear modifications are currently being researched or planned by the Marine Corps and by other branches of the U.S. military.
- Task 2: Adaptations that Assist Performance of the Most Demanding Physical Tasks (Individual):
  - Determine and employ parameters for identifying a successful adaptation.
  - Estimate the number of Marines potentially affected by the adaptation and its operational effectiveness.
  - Identify the adaptations available and provide a summary of them with references and contact information to facilitate further study and staffing.
  - Estimate the costs, implementation considerations, and time for fielding of a potential adaptation.
- Task 3: Adaptations that Assist Performance of Tasks with Physical or Physiological Requirements (Principle End Item Equipment Restrictions):
  - Determine and employ parameters for identifying a successful adaptation.
  - Estimate the number of Marines potentially affected by the adaptation and its operational effectiveness.
  - Identify the adaptations available by providing a detailed technical summary of them with references and contact information to facilitate further study and staffing.
  - Associate the adaptation to the physical demand category of the event.
  - Estimate the costs, implementation considerations, and time for fielding of a potential adaptation.

1.3. Approach

The study approach was based on the concept that the individual Marine must first be optimized as a "system" in order to optimally perform physically demanding tasks and to effectively integrate with major end items. Personal protective equipment must be properly designed, fitted, and configured in order for the individual Marine to operate at his or her full potential.

The study team reviewed the current processes for establishing equipment requirements and developing, testing, and fielding material solutions. Study Advisory Committee (SAC) members and Subject Matter Experts (SME) from Headquarters Marine Corps (HQMC), Combat Development and Integration (CD&I), Marine Corps Systems Command (MARCORSYSCOM), Program Executive Office (PEO) Land Systems (LS), Marine Corps Operational Test and Evaluation Activity (MCOTEA), Marine Corps Warfighting Laboratory (MCWL), and Installations and Logistics (I&L) provided information regarding their roles and responsibilities in the requirements, acquisition and fielding processes.

This study leverages the Task Criticality Assessments (TCA) produced by the Marine Corps TECOM and reviewed by the Ground Combat Element (GCE) advocates. GCE advocates were provided the opportunity to identify current equipment shortfalls within their communities.[1] Additional information was gathered through site visits to the Individual Issue Facilities (IIF) under Marine Corps Logistics Command (MARCORLOGCOM), ICE Training Teams (ITT), the GCEITF, GCE formal schools, and the Marine South exposition. These exchanges reinforced the study team's need to examine systemic processes concurrent with the identification of tasks and associated prospective modifications.

1.4. Assumptions

The study was conducted on the following assumptions:

- The study team had access to Marine Corps SMEs and other agencies/experts necessary to facilitate the study and meet planned deliverable dates.
- The Marine Corps occupational tasks are valid and appropriate as input to the study and as a lens for evaluation of potential adaptations.
- Other approaches to successfully meet an occupational task may inform this study, but are not the direct focus.

The study team encountered no major obstacles that would have altered the study assumptions.

1.5. Study Advisory Committee Members

The SAC was responsible for reviewing and providing feedback to the study team during the course of this study. Each SAC member represented his or her respective organization's interest in this study. In addition, SAC members acted as the point of contact for their organization, which allowed for

quick and timely responses. Along with SAC members, this study received information from SMEs. SAC members and SMEs are listed below:

Study Advisory Committee Members:

[redacted]
Deputy GCE Branch Head
Ground Combat Branch (POG) and GCE Advocate; Plans, Policies and Operations (PP&O); HQMC

[redacted]
Engineer Advocacy Branch, I&L, HQMC (LPE)

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Program Manager, Infantry Weapon Systems (IWS)
MARCORSYSCOM

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Coordinator, Joint Center for Ground Vehicles
PEO LS, Assistant Secretary of the Navy (Research, Development and Acquisition)

[redacted]
Director
MCOTEA

Subject Matter Experts:

Individual GCE and LCE Advocates

[redacted]
Product Manager (PdM)
PdM ICE, MARCORSYSCOM

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Program Manager
Marine Expeditionary Rifle Squad (MERS), Systems Engineering, Interoperability, Architectures & Technology (SIAT), MARCORSYSCOM

[redacted]
Future Technology Officer
MCWL

[redacted]
Marine Corps Programs, U.S. Army Natick Soldier RD&E Center (NSRDEC)

[redacted]
Marine Corps Liaison
Defense Advanced Research Projects Agency (DARPA)

1.6. Deviations

The study design and execution experienced noteworthy deviations since the original sponsor request of June 2014. It was agreed at the November 21, 2014 kick-off meeting that the time constraints and exploratory nature of the study would likely lead to in-progress adjustments in scope. Those adjustments have been implemented through regular communications between the study team, the government study lead, and sponsor. Key deviations include:

- An early realization that the team needed to spend more time understanding the current requirements and acquisition systems in order to provide assessment to the processes involved in fielding equipment to the "Marine as a System." As a result, the study team invested much of its time in understanding current roles, relationships, and processes associated with the design and fielding of combat equipment.

- The study team identified significant issues within the current system that can pose de facto barriers to performance.

    - The 5^{th}–95^{th} anthropometric sizing standard used to guide equipment design was not uniformly understood, and its application was sub-optimal for the needs of female and small-statured Marines.

    - The realization that while the Service has specific requirements for ballistic protection in infantry combat (personal) equipment, there is no metric for individual mobility that would be used to evaluate potential adaptations to enhance individual performance.

    - IIFs do not collect data on the non-availability of sizes/stock. This is one component (sizing), the other being configuration, associated with common physical barriers to performance. Both sizing and configuration training are currently being done by MARCORSYSCOM new equipment fielding teams that are defunded at the end of Fiscal Year (FY) -15. Continuity of this training remains undetermined as of this report.

    - The ability to sense the demand for equipment adaptations and evaluate potential solutions is under strain with the defunding of the Marine Enhancement Program (MEP) and similar tools.

2. Fielding a Marine Weapon System

2.1. Organizations and Roles

The Marine Corps' system to field equipment relies on a highly-coordinated network of organizations, each of which plays a distinct and critical role in the process. By understanding the roles of the different Marine Corps organizations, the study team gained an understanding of the systemic challenges that lead to the fielding of equipment that perpetuate physiological barriers and sub-optimize the physical performance of all Marines.

2.1.1. Deputy Commandant, Combat Development and Integration

The Deputy Commandant (DC), CD&I develops requirements for Marine Corps equipment based on operational needs. DC, CD&I, "assesses the environment, develops and validates concepts, identifies capabilities, and develops solutions to ensure Marine Corps Operating Forces (OPFOR) have the necessary capabilities to remain the world's foremost expeditionary warfighting organization."[2] MARCORSYSCOM develops equipment solutions based on the requirements provided by DC, CD&I.

2.1.2. Marine Corps Systems Command

MARCORSYSCOM is responsible for the acquisition, Life Cycle Management, and initial training for Marine Corps equipment. In the course of the acquisition process, MARCORSYSCOM utilizes anthropometric data to design equipment that meets the needs of all Marines. MARCORSYSCOM, through the DC SIAT, has cognizance of human factors engineering and Human Systems Integration (HSI) for all Marine programs. The MERS office has direct responsibility within MARCORSYSCOM for HSI and is discussed in Section 2.2.[3]

2.1.3. Marine Corps Logistics Command

MARCORLOGCOM is the Marine Corps' operational logistics organization responsible for fielded weapons systems and associated support. MARCORLOGCOM mission is "to provide worldwide, integrated logistics/supply chain and distribution management; maintenance management; and strategic prepositioning capability in support of the OPFOR and other supported units to maximize their readiness and sustainability and to support enterprise and program level Total Life Cycle Management."[4] MARCORLOGCOM executes the distribution, storage, issuance, and maintenance of equipment and operates the IIFs from which ICE is distributed to Marines. As such, MARCORLOGCOM is directly linked to the training Marines receive in the configuration and wearing of their combat equipment.

2.1.4. Marines and the Operating Forces

Marines within the OPFOR configure and employ their equipment to accomplish assigned missions. Commanders adjust equipment configurations to fit operational needs. OPFOR Marines and units are able to identify deficiencies through formal channels such as Product Quality Deficiency Reports (PQDR) and Operational Advisory Groups (OAG). Individual Marines submit suggestions primarily through their chain of command. They have also had direct access to institutional processes via

the Beneficial Suggestions and MEP.[5] The future of these two programs is in jeopardy as they are currently unfunded after FY-15.[6]

2.2. Marine Expeditionary Rifle Squad (Human Systems Integration)

The MERS office provides HSI under the "Technical Authority" of the MARCORSYSCOM (DC, SIAT). The MERS office approaches the "Rifle Squad as a System." Their focus is on the individual Marine and everything worn, carried, and consumed by the rifle squad. MARCORSYSCOM Program Managers coordinate with and utilize MERS capabilities to meet their program's HSI requirements (see Figure 1).

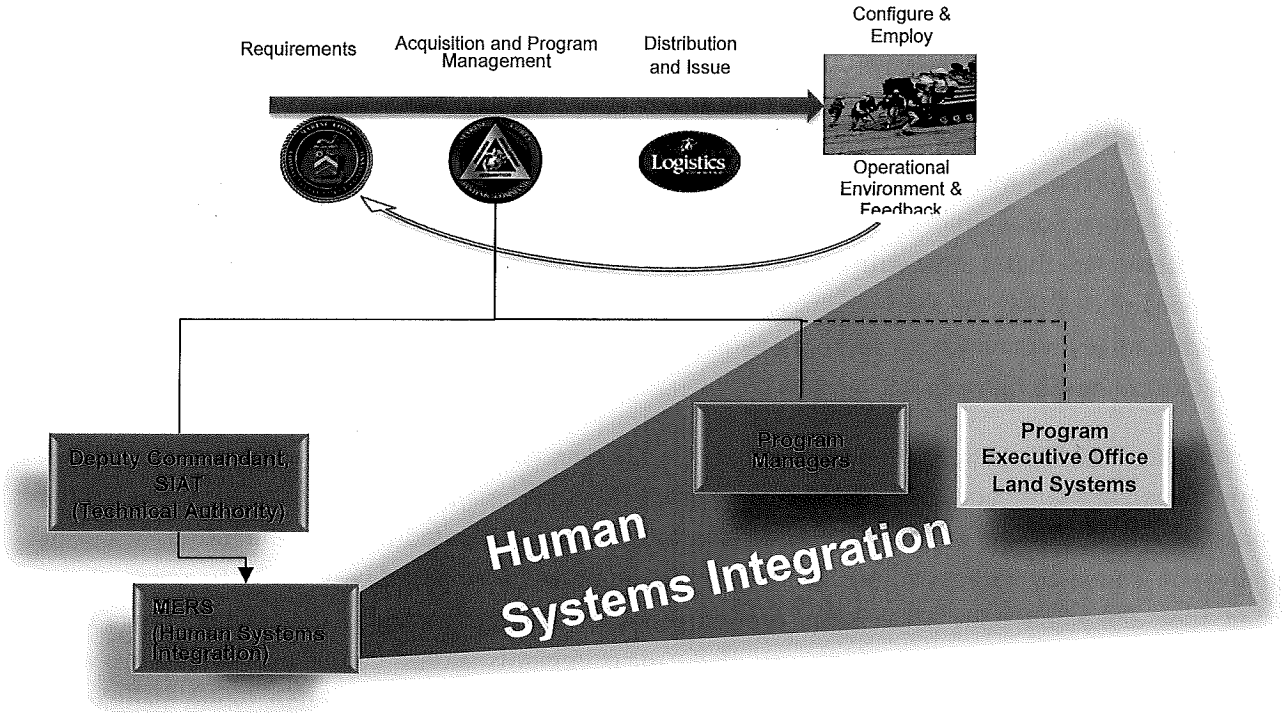


Figure 1. Marine Expeditionary Rifle Squad and Human Systems Integration

To facilitate the engineering, evaluation, and refinement of equipment in development and under consideration for procurement and issue to the infantry rifle squad, MERS established the Gruntworks Squad Integration Facility at Camp Barrett, Marine Corps Base in Quantico, VA. Gruntworks uses a human factors laboratory, an equipment prototyping and modification workshop, a mobility platform integration area, and an operational environment simulator (focused on equipment evaluation) to facilitate equipment modernization and integration tasks. HSI and ergonomics are applied to the physical integration of the infantry squad's equipment to advance improvements in weight distribution and load carriage.[7]

The Marine Corps currently has no Key Performance Parameters (KPP) or similar requirements for individual mobility. Lack of a mobility KPP inhibits the Marine Corps ability to evaluate equipment and equipment adaptations for their effect on the performance of physical tasks. To help remedy this gap, the MERS office designed the Marine Corps Load Effect Assessment Program (MC-LEAP) course. The MC-LEAP course was designed using feedback from Marines about the most common and physically demanding tasks in recent theaters of combat.[8] MC-LEAP measures the effects of various gear configurations on a Marine's mobility and performance. Through MC-LEAP, MERS is developing a baseline for mobility by which future requirements may be developed. An initial performance metric for mobility is expected during summer 2015.[9]

2.3. Equipment Design and Marine Corps Anthropometrics

The Marine Corps uses anthropometric data to inform the design of combat equipment that interfaces with or is operated by a human. Prior to the 2010, the last Marine Corps (MC) Anthropometric Survey (MC-ANSUR) was conducted in 1966 and considered only men. In 1988, the U.S. Army completed an ANSUR, which the Marine Corps leveraged and supplemented with a Marine Corps "mini-survey" in 1994. The Marine Corps "mini-survey" consisted of 470 female and 493 male Marines. A 2006 Army pilot study determined that a new Army survey was needed due to significant changes is body size and proportions since 1988. The Marine Corps concluded that the use of statistically weighted data from the 1988 Army survey was no longer appropriate. In 2009, the MARCORSYSCOM PdM ICE commissioned the NSRDEC to conduct a full-scale MC-ANSUR.[10]

The 2010 MC-ANSUR sample consisted of 1301 men and 620 women. The goals of the ANSUR were to acquire a large body of data from comparably measured males and females to serve the Marine Corps' current design and engineering needs, as well as those anticipated well into the future. A specific innovation added to address future needs was the addition of three-dimensional (3-D) scans of the head, foot, and whole body. These scans provide geometric and morphological data of the human body that cannot be gathered using traditional body measurements alone. Candidate dimensions were reviewed for relevance, replicability, and comparability to arrive at the final selection, which included 94 directly measured dimensions and 41 derived dimensions. The MC-ANSUR is currently used for future United States Marine Corps (USMC) equipment design and sizing applications. MARCORSYSCOM has commissioned NSRDEC to expand the MC-ANSUR data set.[11] Figure 2 below provides an illustration of how MC-ANSUR data could be misleading. Each dot in the diagram represents a Marine from the MC-ANSUR data set. That data set is currently a 2:1 ratio of male to female Marines, whereas the actual ratio of male to female Marines across the Corps is 12:1. Thus, the blue dotted areas of the chart should conceivably represent approximately six male Marines per blue dot. In this instance, the more accurate representation would convey that, while female Marines appear to be underserved in certain size ranges, addressing the needs of all (aggregate) Marines remains the priority for program managers.

2.3.1. Issues with Sizing of Body Armor

The study team viewed each Marine as a system designed to perform specific tasks. A central component of each system is the protective vest or body armor. The protective vest and its armor

inserts protect vital organs in the chest and abdominal cavities. The vest is also the host for the various pouches and items Marines carry in combat. The study team devoted much of its time to understanding body armor and acknowledges the expertise and information provided by PdM ICE. The current Marine Corps inventory of ICE was developed using the weighted 1988 ANSUR (U.S. Army) data along the 5th and 95th percentile requirement (aggregate). Issues of sizing associated with body armor were a principle reason for the Marine Corps' decision to review and revise its anthropometric sizing requirements. The following paragraphs detail specific information and issues relative to Marine Corps body armor.[12]

2.3.1.1. Enhanced Small Arms Protective Inserts

The current individual ballistic protection is the Enhanced Small Arms Protective Inserts (ESAPI) procured through Army contract vehicles over the past decade. Initial sizes ranged from small to extra-large. In an effort to provide additional coverage to small-statured personnel, the Army procured the extra-small ESAPI. The new extra-small ESAPI does not follow previous tariff sizing. The grading of the extra-small exceeded the normal spread in sizing in order to accommodate the largest number of small-statured soldiers. Although the extra-small creates a sizing gap, Marine Corps program managers are confident that the new plate provides effective coverage to vital organs.

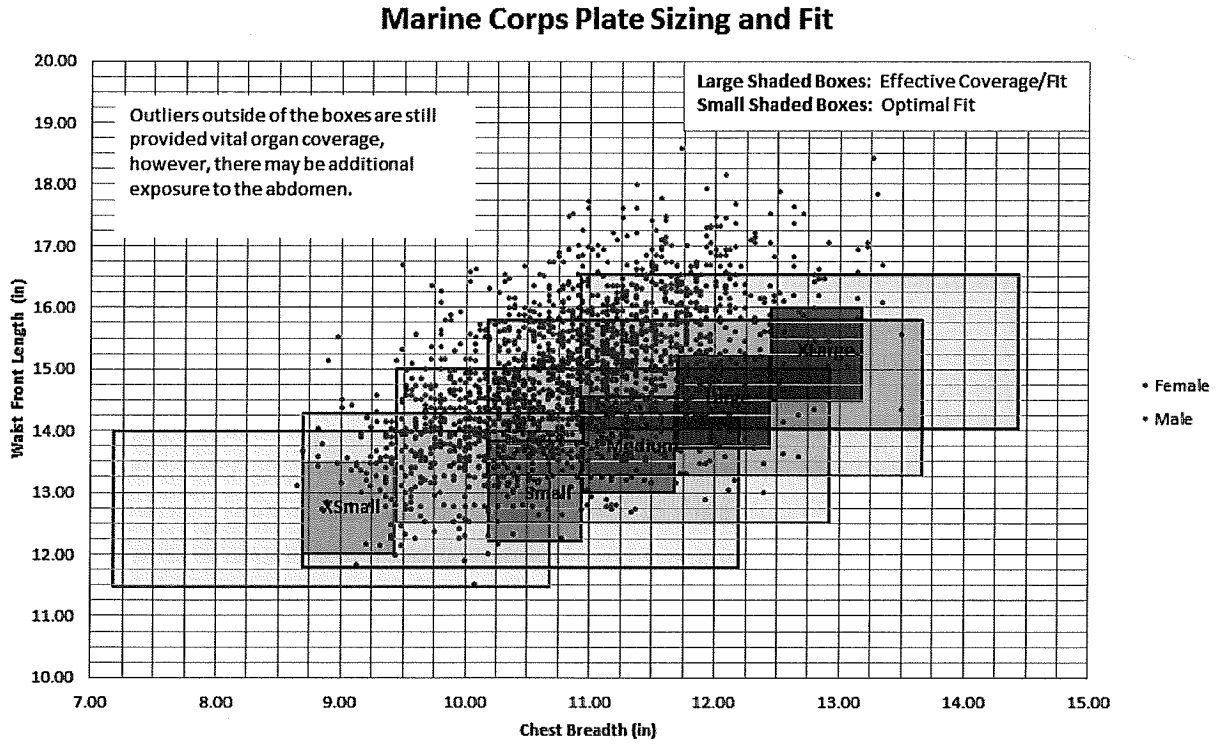


Figure 2. ESAPI Sizing and Fit on MC-ANSUR Data

The dimensions of the ESAPI chest plate were based on *optimal* coverage of vital organs defined as bustpoint to bustpoint and within 1" of the suprasternale notch to the bellybutton. This is depicted by the inner boxes above in Figure 2. The outer boxes depict *effective* coverage by each size of ESAPI.[13] These measurements were used in the development of the ESAPI. The grading of sizes (space between

sizes) is based on the program manager's best judgment that balances performance of the vest (protection and mobility) with cost of production. In lieu of accepted metrics, a program manager's assessment regarding mobility is mostly subjective.

The current method of sizing is based on accepted conventions for the assurance of vital organ coverage. However, there is debate whether using bustpoint to bustpoint is a valid measurement for the following reasons: (1) there is a large soft tissue component involved, making bustpoint to bustpoint a relatively imprecise measurement; (2) the measurement differs between men and women; and (3) bustpoint distance does not necessarily reflect vital organ coverage to the accuracy needed. For these reasons, bustpoint to bustpoint measurements were excluded from recent anthropometric studies (MC-ANSUR and ANSUR II).[14] The NSRDEC, along with the John Hopkins Applied Physics Laboratory, are working on the Allometry Multi-Organ Pipeline to better define and develop measurements for vital organ coverage.

The Allometry Multi-Organ Pipeline will develop population-specific organ atlases based on gender, race, anthropometrics, and age; investigate allometric scaling laws for various patient sizes and demographics; and implement a multi-organ approach to a determine how organs scale with respect to each other in the body. The Allometry Multi-Organ Pipeline will be key to human models for injury assessment; armor design for optimized protection or weight reduction (placement and sizing of materials); armor fit process informed by internal organ shape and demographic/external correlations; and medical applications (enhanced imaging, surgical planning, disease diagnosis).[15]

2.3.1.2. Body Armor

The current USMC body armor (Plate Carrier [PC] and Improved Modular Tactical Vest [IMTV]) were developed in 2009 before MC-ANSUR data was available. Sizing and grading were based on legacy sizing methodologies of the Modular Tactical Vest (MTV), Scalable Plate Carrier (SPC), and the Outer Tactical Vest (OTV).

Sizing for the PC and IMTV is based on the dimensions of the armor plate inserts. Currently, there are five sizes for both the PC and the IMTV to accommodate the range of plate sizes. For the PC, there is roughly .75" overlap of soft armor around the plate, and there is roughly 1.25" overlap around the plate for the IMTV. Three additional sizes of IMTV (Small-Short, Medium-Short, Large-Short) were added to the inventory in 2014 after a study demonstrated that there was a fit gap for smaller statured Marines. Small stature determination is related to body measurement proportions, in particular the proportion between torso length and chest circumference. Small stature Marines have shorter torsos in relation to chest circumference; thus, the conventionally sized vest is too long and extends significantly past the belly button, which causes mobility issues. There are four sizes of cummerbunds (worn around the waist to connect front and back panels of the vest together) that are common components for both the PC and IMTV. The sizes for the cummerbunds are 9 Pouch Attachment Ladder System (PALS) (extra-small/small), 11 PALS (medium), 13 PALS (large), and 15 PALS (extra-large). Cummerbund sizing was tied to the vest size, however, the cummerbunds can be interchanged across all of the vest sizes to account for various waist circumferences and allow for a more tailored fit (e.g., medium vest with small

cummerbund, etc.). There is currently only one size of Side ESAPI armor plate available in the Marine Corps inventory, which measures 6"x8" (Med).[16]

GCE advocates expressed uniform discontent with current body armor to the study team. Common issues expressed included excessive weight and restrictive mobility. The configuration of the body armor restricts movement inside vehicles and inhibits egress (i.e., Light Armored Vehicle (LAV), AAV, Tanks). To mitigate risks to internal mobility, vehicle crewmen wear a vest with no attachments or pouches when inside the vehicle. Personal equipment (e.g., rifle ammunition, etc.) required when operating outside the vehicle is carried separately.

PdM ICE has an ongoing Research and Development (R&D) effort to develop a Modular Scalable Vest (MSV) that leverages the MC-ANSUR data set. The prototype system uses a soft armor cut similar to that of the current PC along with new components such as a hip belt and load distribution system. As part of this development, PdM ICE conducted sizing studies and surveys at the three Marine Expeditionary Forces (MEF) to further refine the size needs of the female Marine population. The first study was conducted in February 2014 to capture the "medium-sized" Marine as a baseline. A second study was conducted in May 2014 to capture female-specific data and a third study in August 2014 to fill in data gaps. Additionally, the Marine Corps provided numerous test articles for inclusion in Army tests. Both Services rely heavily on technical support through the NSRDEC.

2.4. Employing Anthropometrics: Clarifying the 5th–95th Percentile Requirement

The Marine Corps requires equipment to accommodate, by the appropriate anthropometric measurements, the 5th-95th percentile of Marines.[17] This standard is used across the Marine Corps in the development of new equipment and acquisitions where human physical dimensions must be considered. Anthropometric requirements are established by DC, CD&I in authoritative references such as Initial Capabilities Documents (ICD) and Capabilities Development Documents (CDD). MARCORSYSCOM complies with requirements for new or modification of existing equipment as specified by DC, CD&I. Currently, MERS and PdM ICE use 2010 MC-ANSUR data to define the 5th–95th anthropometric percentiles of the Marine Corps population. The study team found that while the phrase "5th to 95th percentile" was universal, the interpretation of this phrase and potential implications relative to female and small-statured Marines were often misunderstood. The study team provided the graphic below (see Figure 3) to help stakeholders understand how the definition of the 5th percentile of Marines can have a significant impact on the female Marine population. Analysis of data on the height of all active duty Marines indicates that 7,377 females would be excluded from a data set based on a 5th percentile of all Marines. This means that 53 percent of the female Marine population would potentially be excluded or sub-optimally served by equipment using minimum height as a parameter for design. The potential that anthropometric guidance may be creating de facto barriers to performance is a major finding of this study.

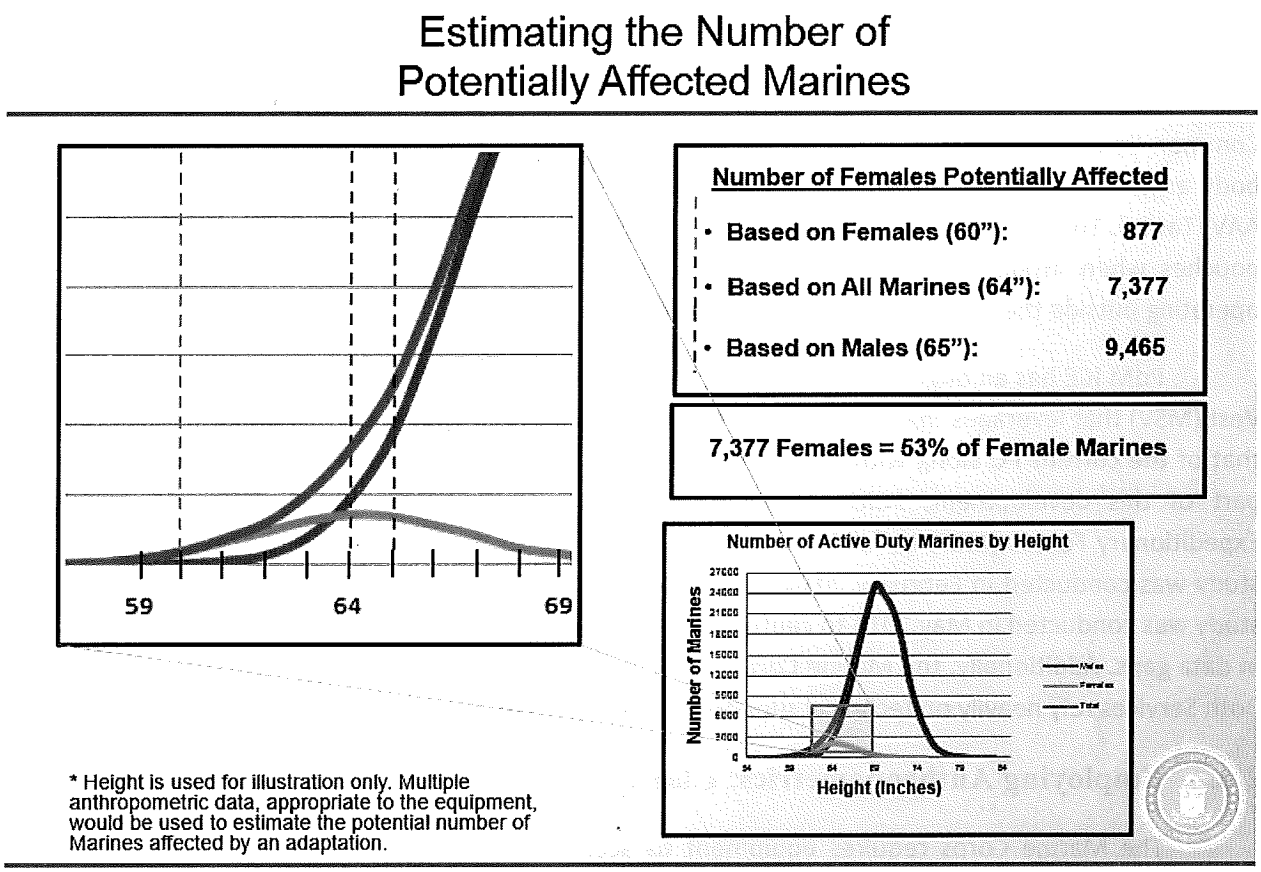


Figure 3. Estimating the 5th Percentile of Females using Height

The importance of clarifying and, as needed, expanding the 5th–95th percentile requirement to include 5th percentile females has been recognized by DC, CD&I. The Capabilities Development Directorate intends to publish a policy letter requiring the review of all Marine Corps programs that use the 5th–95th percentile requirement.[18] The Capabilities Development Directorate intends to take a two-phase approach. The first phase will implement the 2nd percentile *female* to 98th percentile *male* standard across individual clothing and infantry combat equipment.[19] The second phase will focus on requirements for current and future mobility platforms, weapon systems, and organizational equipment. Section 2.4.1 lists equipment that should be considered during phase two of the Capabilities Development Directorate review.

2.4.1. Equipment Designed for the 5th–95th Male Population

The following items have been designed based upon the 5th–95th *male* Marine percentile. The study team recommends that appropriate stakeholders review the anthropometrics requirements associated with each of these end items.

- The current AAV Family of Vehicles (FoV) and the future Amphibious Combat Vehicle (ACV) to include: crew and embarked Marines seating, crew station organization (fit, reach, vision), maintenance activities, hatch dimensions, and hatch operating requirements. The

AAV FoV is comprised of the AAV personnel variant, the AAV command variant, and the AAV recovery variant. The ACV, though not yet procured, will include a personnel variant and potentially command and recovery variants.

- The Marine Air Ground Task Force Command, Control and Communications' Networking On-The-Move (NOTM).
- All Armor and Fire Support Systems (AFSS) programs. The fire support systems include the High Mobility Artillery Rocket System (HIMARS), the Expeditionary Fire Support System (EFSS), the Precision Extended Range Munition (PERM), the AN/TPQ-46 Fire-finder Radar, the AN/TPQ-49 Lightweight Counter Mortar Radar (LCMR), and the AN/TSQ-27 Target Processing Set.
- The Assault Breacher Vehicle (ABV) and the MK154 Mine Clearance Launcher.
- All LAV variants.

2.5. Training in the Sizing and Configuration of Infantry Combat Equipment

"Most of the problems that Marines have with their (individual) equipment can be solved through proper sizing and fit (configuration)."[20]

The processes that design, procure, and field equipment are ultimately successful if the end user is outfitted with properly sized and configured equipment that facilitates performing to his or her potential. The bulk, weight, and complexity of modern infantry combat equipment makes training in the sizing and configuration of this gear critical to a Marine's performance in combat.[21]

MARCORSYSCOM is responsible for New Equipment Training (NET) as products are introduced to the OPFOR. PdM ICE currently has ITTs located at each MEF that provide initial training on items contained in a Marine's "kit" and also measure Marines for correct fit of select components.[22] ITT training consists of familiarization with select equipment, fit measurements, and configuration (including configurations for short-statured Marines). The PdM ICE contract employees who conduct the training are certified annually.[23]

The study team found that ITT training was administered inconsistently across the MEFs. During FY-14, ITTs served 2,334 personnel at I MEF, 10,995 at II MEF, and 918 at III MEF. Given their similar size, one might have expected the number of personnel trained at I and II MEF to be more alike. The study team found it incongruous that II MEF trained almost five times the number of Marines as I MEF during a one-year period. The study team visited issue facilities and ITTs at Camp Lejeune and Camp Pendleton to investigate the dissimilarity first-hand. The difference can be explained through the relationship between the issue facilities, ITTs, and MEF policy guidance. While the issue facilities belong to MARCORLOGCOM and ITTs belong to MARCORSYSCOM at the operational/institutional level, the MEF commander has control of local policy and operations. The study team observed that the relatively high number of personnel trained at II MEF was the result of MEF policy; specifically guidance from the II MEF G-4.

In February 2012, the II MEF G-4 published a message requiring all II MEF units to receive training on designated individual equipment by the II MEF ICE Field Service Representative (FSR) prior to issue.[24] The II MEF message stated that "events have determined that II MEF units are neither requesting nor receiving the required training ... thus resulting in the improper use/configuration of individual equipment by II MEF units." II MEF requires new-joins to attend training prior to receiving their equipment from the IIF.[25] The study team found that training was recorded on paper rosters and given to the issue facility. The issue facility uses the roster primarily to ensure that the II MEF policy is being met. However, the roster is not a guarantee that the Marine will request or be issued the appropriate size.

The study team received indications that Marines may check out a smaller than recommended size of body armor (ESAPI) for an increase in mobility. The preference for small sized body armor may explain why small sized body armor may be in short supply at the IIFs. The study team recommends this issue be studied further with policy adjustments implemented as required to ensure Marines are issued appropriately sized equipment.

Conversely, though I MEF does not mandate NET, the I MEF ITT has proactively solicited their services by placing the FSR at the I MEF Headquarters to monitor the Training and Exercise Employment Plan (TEEP) and engage units preparing to deploy. It is conceivable that this approach may result in better targeted training for Marines preparing to deploy. The study team believes a combination of best practices from each MEF would increase the number of personnel trained and prioritize training to units closest to deploying.

An important near-term training issue for the Marine Corps is the pending defunding of ITTs. With the transition of current equipment from new to legacy status, the ITT functions provided by PdM ICE will be defunded at the end of FY-15.[26] As of this report, the Marine Corps has not determined whether the current ITTs will be renewed ($1.5M annually) or the responsibilities transitioned into another sector of the training and education process. The risks of a gap in training can be partially offset through the use of PdM ICE training videos that are available through YouTube and the Defense Video & Imagery Distribution System (DVIDS).

3. Identifying a Smart Adaptation

A "Smart Adaptation" is an equipment-focused change that facilitates the reduction of physical/physiological barriers to the performance of occupational tasks. Heretofore, this report discussed the enterprise-level environment in which smart adaptations must compete. This section will discuss the conceptual framework for smart adaptations with specific examples of agencies and processes that may be leveraged to enhance and enable the concept. The study team used observations from the GCEITF (see Section 3.5) to identify needs for smart adaptation. The team solicited potential solutions from a variety of sources, to include GCEITF Marines, GCE advocates, the Marine South Exposition, and market research. Each need was analyzed by the study team with excerpts presented at the end of this section as exemplars for employment of this model.

What separates smart adaptations from the activities conducted daily by the combat development and acquisition processes? The primary difference is smart adaptations' focus on the reduction of physical and physiological barriers.[27] Smart adaptations in their best form should influence requirements as they are developed. The change in DC, CD&I's approach to anthropometric requirements is the epitome of this concept. More practically, smart adaptations should provide solutions to the everyday needs of Marines in the OPFOR. Figure 4 depicts a Smart Adaptations model, which evaluates needs against potential solutions across specific parameters (e.g., cost, etc.). While the concept is simple, it must integrate with the people and processes of the larger and more complex enterprise. Sensing those needs, seeking and evaluating creative solutions, and integrating them into enterprise processes are the subjects of the following sections.

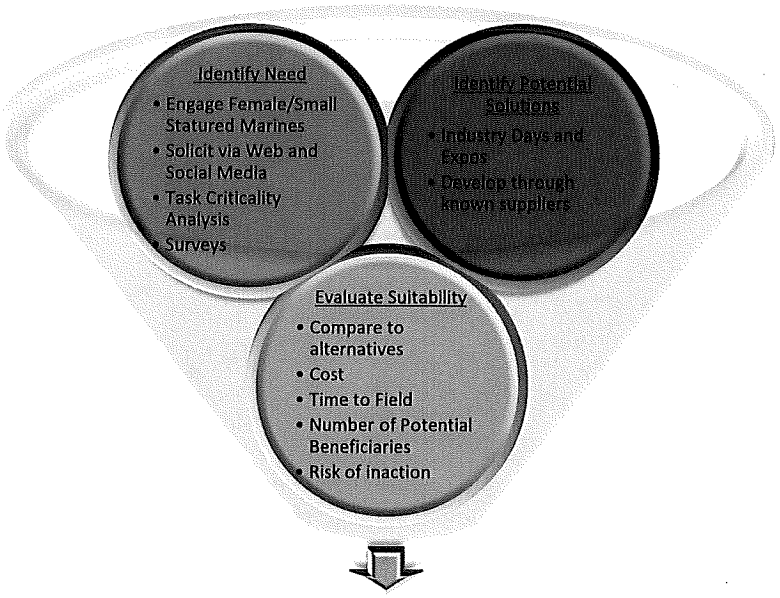


Figure 4. Smart Adaptation Model

3.1. Sensing the Need

The study team investigated several methods by which the Marine Corps can sense the need for a smart adaptation. The TECOM's TCA and observations from the GCEITF and affected schools are good starting points for identifying the need for adaptations as women are integrated into previously closed MOSs. MARCORSYSCOM equipment surveys and OAGs are established mechanisms for relevant information. Sections 3.1.1 through 3.1.4 and Section 3.3 describe Marine Corps organizations and programs that can be used to sense the need for smart adaptations. This list is not definitive, but merely provides a starting point for future efforts.

3.1.1. Ground Combat Element Integrated Task Force

The GCEITF conducted individual and collective level skills training in designated ground combat occupational specialties with male and female Marine participants. Throughout the GCEITF's existence, adaptations were invented and employed to better facilitate the interface with equipment, overcome physical challenges, and improve performance. The GCEITF provided a unique opportunity to gather information on the physical barriers to performance associated with small-statured and female Marines. To date, the GCEITF is the only activity where female Marines have been purposefully and regularly exposed ground combat equipment (i.e., artillery) designed exclusively for male Marines. The study team was able to visit with Marines from the GCEITF. Section 3.5 lists observations shared with the study team by GCEITF Marines.

Figure 5. AAV .50cal Brass Drawer Modification

Illustrative of the ideas from GCEITF Marines is a young Marine's modification to the receptacle in the AAV for spent .50 caliber brass (see Figure 5). The current container is large and bulky with a latched lid that prevents access while installed in the vehicle. Marines must remove the entire box from

the vehicle in order to empty the brass. An enterprising Marine in the GCEITF cut the side from one of the containers and fashioned a drawer that could slide in and out from the side. The drawer was light and easy to remove from the AAV. Conceivably, this "smart adaptation" should have been designed years earlier, but wasn't. The modification was also not authorized by the AAV program manager nor was he aware of it (until it received the attention from various high-level Marines). This simple adaptation implies that the Marine Corps is not harnessing the ideas of everyday Marines to maximum benefit and that our major end items may be susceptible to unauthorized modifications as a result. A well-done smart adaptation should combine wide and easy access by all Marines with processes that can rapidly address their needs.

3.1.2. Military Occupational Specialty Advocates

The study team solicited input from GCE advocates. As SMEs in their MOS, advocates provide insight regarding physical barriers to performance within their occupational fields. GCE advocates coordinate with other HQMC staff agencies, CD&I/Marine Corps Combat Development & Integration (MCCDC), MARCORSYSCOM, and the OPFOR to advocate for and influence ground combat requirements, policies, and weapon systems.

Infantry advocates presented concerns about the weight of current body armor (PC and IMTV). One advocate explained that, "Pre-OIF/OEF, the basic combat load was 35–40 pounds. Today, it is upwards of 100 pounds."[28] The 2007 Naval Research Advisory Committee report, *Lightening the Load*, concluded that the recommended load for a Marine rifleman in the assault mission should not exceed 50 pounds.[29] The current weight of a load carried by a Marine remains significantly above this recommendation and varies by mission: 81 lbs. for fighting load; 97 lbs. for assault load; 114 lbs. for approach march load; and 157 lbs. for sustainment load. These weights exclude additional equipment that may be specific to a mission. Though the advocates specify the weight component of a Marine's load, it is understood that the attributes of burden include weight as well as equipment stiffness and bulk that affect overall mobility.

The close quarters of ground combat vehicles (i.e., M1A1 Abrams, LAV, and AAV) and current body armor combine for additional constrictions to crew movement. The body armor is often worn alone to allow for movement within the vehicle and the ability to egress through the hatches. The Marines who primarily operate within vehicles often maintain a Load-Bearing Vest (LBV) with necessary gear for instances when they must operate outside the vehicle.[30] While female Marines are generally smaller than their male counterparts and thus, should fare better in tight quarters, concerns remain for the extraction of heavier Marines through hatches and for the performance of operations external to the vehicle.

3.1.3. Marine Corps Systems Command

As a key organization in the acquisition enterprise, MARCORSYSCOM has excellent resources that can be leveraged for smart adaptations. These resources include periodic equipment surveys and web-based feedback mechanisms where Marines can provide feedback and ideas. Section 3.3 describes existing programs operated by MARCORSYSCOM that could be leveraged for smart adaptations.

3.1.4. Training and Education Command

TECOM is tasked to "develop and validate gender-neutral, ground combat arms MOS occupational physical performance standards and, based on those standards, recommend MOS-specific physical assessments that provide reasonable assurance of a Marine's ability to complete combat arms MOS training and meet the requirements to serve in that MOS in a ground combat arms OPFOR unit." To that end, TECOM initiated the validation of the current T&R manuals for ground combat MOSs. This study used TECOM's TCA analyses as a reference for identifying physically demanding tasks that show potential for adaptations.[31]

Instructors and students involved in Marine Corps Force Integration Plan (MCFIP) Line of Effort (LOE) 2 provided valuable insight to overcoming physical challenges to female and short-statured Marines. During their support of LOE 2, TECOM Formal Learning Centers (FLC) were uniquely able to observe and facilitate female Marines completing (physically demanding) tasks required for graduation. The experiences of Marines and instructors from MCFIP LOE 2 and future efforts are an excellent source of smart adaptation ideas. 1)a)i)(1)(a)(i)Appendix A synopsizes observations that AAV and LAV school instructors shared with the study team during their March 2015 visit.

3.2. Identifying Potential Solutions

This section provides a synopsis of events and organizations that can be directly leveraged to provide potential solutions to identified needs for adaptation. Section 3.3 (Existing Programs with Potential to Facilitate Smart Adaptations) discusses existing Marine Corps systems that can aid both the sensing of need and identification of potential solutions.

3.2.1. Industry Days and Expos

The Marine Corps hosts Marine Expositions yearly aboard Marine Corps Bases Quantico, Camp Lejeune, and Camp Pendleton.[32] Individual Marines, Marine leadership, and personnel involved in the combat development and acquisition process are able to interact directly with hundreds of vendors. Marine Expos are trade shows where vendors receive input on customer needs, and vendors are able to display their solutions. Vendors often create products for sale directly to the individual Marine that may not be available through the Marine Corps supply system. The aggregation of vendors and Marines makes these events a good location to identify potential solutions to smart adaptation needs.

MARCORSYSCOM periodically hosts Industry Days in which they invite vendors who may provide products tailored to specific needs. PdM ICE does this routinely to meet the ever-evolving needs of personal protective equipment.

3.2.2. Marine Corps and Defense Research Organizations

3.2.2.1. Marine Corps Systems Command[33]

MARCORSYSCOM program managers strive to meet the needs of all Marines and will be an integral component of any smart adaptation program. MARCORSYSCOM's efforts to "lighten the load"

of the individual Marine directly contributes to reducing the physical barriers to performance associated with small-statured Marines.

3.2.2.1.1. Product Manager, Infantry Weapons

The PdM, Infantry Weapons efforts to reduce physiological barriers span a number of weapon systems. These modifications can be grouped into two categories: Lightening the Load and Length of Pull adjustments.

Efforts associated with lightening the load are centered on achieving identical, if not better, performance over the baseline weapons with a lighter and potentially smaller footprint. Current efforts for reducing system weight include the following: Lightweight 60mm Mortar system (fielded in October 2013) and 81mm Mortar system (fielding projected in 4th Quarter (Qtr) FY-16); the M122A1 common lightweight tripod for light and medium machine guns scheduled to be replaced with a lightweight version; the M40 Sniper Rifle barrel improvement effort currently underway to reduce weight by 1.5 pounds; and an ongoing R&D effort (single barrel initiative) to reduce the weight of the M240 system by changing to a single-barrel configuration. If this effort is successful, the M240 system can be redefined with no spare barrel for an approximate 8.25lb reduction.

To account for the changing size and shape of Marines, it has become necessary to look at methods to make the weapons usable by a larger population physiologically. The Length of Pull (arm length) necessary to achieve proper eye relief with glass optics varies from weapon to weapon and from Marine to Marine. Efforts are underway to integrate an adjustable butt stock on the M16A4 Service Rifle, M40 Sniper Rifle, and M110 Sniper Rifle. This integration does not have as great an impact on those individuals with longer arms as it does for those with shorter or smaller arms.

3.2.2.1.2. Product Manager, Anti-Armor Systems

The PdM, Anti-Armor Systems (AAS) has multiple efforts to "lighten the load." The Saber Maintenance Kit (SMK) and Electrical Circuit Test Set Tool Kit (ETK) are being combined to create the Saber Intermediate Maintenance Kit (SIMK), which will reduce the size and weight of these systems by 85lbs. In addition, the Saber transit case is being redesigned to reduce its weight by 27lbs. Replacing the Saber Position Attitude Determination Subsystem and A/C Power Supply (PAPS) with an Improved Position Attitude Determination Subsystem and A/C Power Supply (IPAPS) will reduce system weight by another 11lbs.

3.2.2.1.3. Product Manager, Infantry Combat Equipment

3.2.2.1.3.1. Modular Scalable Vest

PdM ICE has resourced R&D of the MSV. The MSV is an early prototype for the next generation of Marine Corps body armor. PdM ICE conducted Fit Tests with the support from the Anthropology Team, NSRDEC in three segments that culminated in May 2014. The fit test will aid the development of sizing and design of the MSV.

The Marine Corps writes "The MSV will utilize both a lighter weight soft armor, which offers 10-15 percent weight reductions over current soft armor, and the Enhanced Capability Small Arms Protective Inserts (ECSAPIs), which provide increased ballistic protection at the current ESAPIs weight. In

FY-15, a limited user evaluation for MSV will take place with fielding to follow once funding becomes available."[34]

3.2.2.1.3.2. Central Osteoarticular Relief and Performance Structured Load Distribution System

The Marine Corps is developing a load distribution system that aims to more effectively distribute loads between the shoulders and hips. The system is called the Central Osteoarticular Relief and Performance Structured (CORPS) Load Distribution System (LDS) and is currently under evaluation. The CORPS LDS was used in the 2014 Size and Fit study conducted by the Marine Corps to determine fit characteristics of the system and identify any fit issues with the system. The CORPS LDS has been evaluated through a series of studies at Naval Health Research Center (NHRC) to assess physiological impacts and potential benefits of the system. Initial results indicate that the use of the LDS trends the body to a more natural, unloaded posture and that the LDS helps reduce impact on joints. Further studies are planned for FY-15 to characterize the use of the system and to assess how the use of the system affects combat effectiveness.

3.2.2.1.3.3. USMC Pack Study

The Marine Corps Pack (interface) Study began in January 2015 in conjunction with the NHRC. Testing includes a proof of concept study (modified main pack that is integrated in with the PC) and is then followed by a field study to assess operational effectiveness of the system. The study will include smaller stature participants and will determine if a modified pack interface places Marines in a better biomechanical position during extended load carriage. The Marine Corps is also working to develop a pack interface that can be worn with the current Marine Corps pack and would enable the pack to be worn more comfortably with body armor and to provide for a better fit.

3.2.2.2. Marine Corps Warfighting Laboratory

The MCWL rigorously explores and assesses Service concepts using an integral combination of wargaming, concept-based experimentation, technology assessments, and analyses to validate, modify, or reject the concept's viability. This exploration and assessment also identifies capability gaps and opportunities in order to inform future force development.[35] The director of MCWL (now Director, CD&I Futures Division) also serves as the Deputy Director of the Office of Naval Research (ONR).

MCWL periodically commissions a publication, *United States Marine Corps 10-in-10 Technologies: Commercial Technology Forecasting Initiative,* "identifying the ten most promising leading edge commercially available technologies for the Marine Corps that will emerge in the next ten years." Based on MITRE's November 2013 report, MCWL requested additional in-depth reporting on four technologies: Advanced Battery Technologies, Advanced Fuel Cells, Smart Fabrics and Textiles, and Lightweight Carbon Composites. Each of these technologies aligns with Marine Corps efforts to reduce the size and weight of equipment. 1)a)i)(1)(a)(i)Appendix B describes these technologies in greater detail.

3.2.2.3. Defense Advanced Research Projects Agency

DARPA has a variety of research programs with the potential to reduce physical barriers to performance (see 1)a)i)(1)(a)(i)Appendix C). One of DARPA's major areas of research is in robotics. Potential applications include exoskeletons, which can increase the individual's ability to perform

physically demanding tasks and autonomous robots that can relieve a Marine of a portion of his or her combat load.[36] While robotics research has made significant strides in the past few years, a common limitation of all prototypes to date is their need for electrical power. Current exoskeletons exhaust onboard battery power within an hour of constant use. DARPA, MCWL, and other organizations are actively working on solutions to the power challenge. It is conceivable that technology may actually change the nature of how many current tasks are performed.

3.3. Existing Programs with Potential to Facilitate Smart Adaptations

Sections 3.3.1 through 3.3.3 and Table 2 discuss existing programs with potential application to smart adaptation.

3.3.1. Marine Enhancement Program

The MEP was created in 1989 in response to Congressional guidance to improve the lethality, comfort, and survivability of the infantryman.[37] Although the Infantryman is the primary user of the MEP, much of the equipment fielded through the MEP serves all Marines. Figure 6 from the Marine Corps Concepts and Programs website depicts items fielded through the MEP.[38]

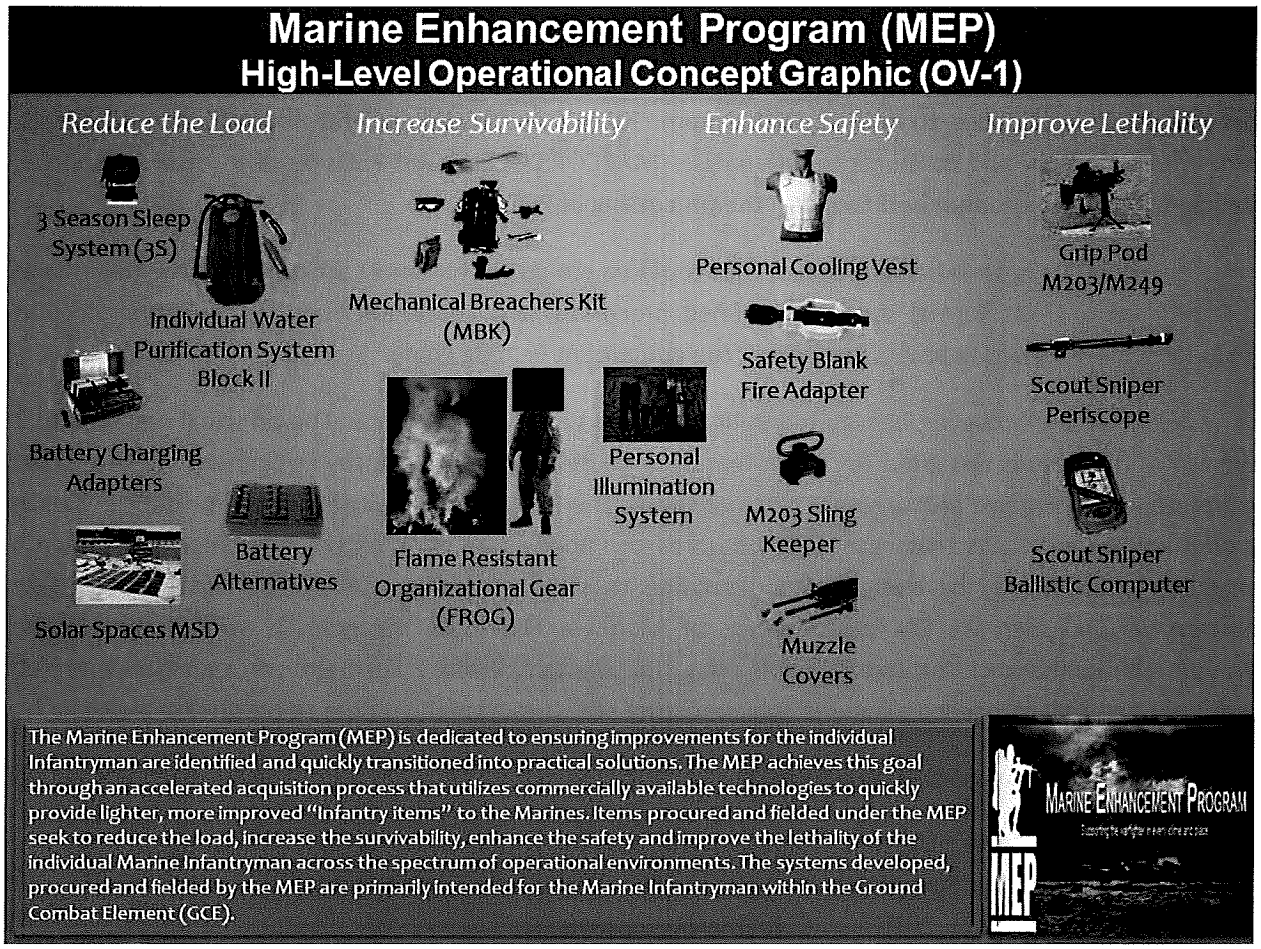


Figure 6. MEP Fielded Initiatives

Any Marine can submit their idea via the MARCORSYSCOM MEP website.[39] In addition to submission of an idea, the website solicits data regarding the MOS and gender of the submitter. These data elements make the MEP website well-suited to solicit ideas specific to the needs of female Marines, especially those in physically demanding MOSs.

Once an idea is submitted, the MEP Working Group reviews each submission for relevance, impact, and feasibility. Proposed solutions must be commercially available or require minimal development to be eligible. The MEP Working Group consists of representatives from MARCORSYSCOM; DC, PP&O (GCE Advocates); and DC, CD&I (Requirements). Marine Corps annual funding for the MEP is $3.5M (Procurement, Marine Corps [PMC]), $2.5M (R&D), and $0.5M Operations and Maintenance (O&M) (Advertising).

While seemingly ideal for smart adaptation purposes, the MEP is not programmed for funding beyond FY-15, and advertisement efforts have been suspended. The MEP submission site will remain hosted on MARCORSYSCOM SIAT website, but the working group is not scheduled to convene to review submissions.[40]

3.3.2. Product Quality Deficiency Report Program

The Marine Corps PQDR Program is designed "to maximize operational effectiveness, prevent recurring deficiencies, and ensure safe handling of equipment and safety of personnel."[41] The DC for I&L provides policy guidance to the PQDR program. MARCORLOGCOM facilitates processing of PQDRs, monitors reporting, and conducts trend analysis. MARCORSYSCOM and PEOs work to resolve reported deficiencies and to monitor and facilitate the processing of PQDRs.

The PQDR is an existing program that could be employed for smart adaptations. The benefits of this program include formal structure, refined processes, and consistent funding. The program also includes a majority of the actors involved in the equipment fielding chain.

The PQDR; however, has limited utility as a smart adaptation vehicle. The principal reason is that the PQDR program is designed to obtain feedback for existing Marine Corps equipment while a smart adaptation may require procurement of a new item. The PQDR is optimally designed for deficiencies in workmanship and flaws that case safety hazards or impede operation of the equipment.[42] Though a smart adaptation may be designed to overcome these shortcomings, its primary aim is to reduce barriers to and increase the performance of Marines. The PQDR program is well known in the equipment maintenance community but is not as familiar to operators. Furthermore, a unit has a limited number of closely controlled accounts, which restrict access to a small number of Marines in a unit.

3.3.3. Beneficial Suggestion Program

"Often the best solutions come from the people with firsthand knowledge. The Beneficial Suggestion Program provides a way for all personnel to suggest ways to improve operations."[43]

The Beneficial Suggestion Program's mission is to create and sustain the capability to process suggestions that continuously improve operations and readiness at all levels of the Marine Corps. The program offers individuals the opportunity to help the Marine Corps and obtain cash rewards of up to $25,000 for adopted suggestions. The Beneficial Suggestion Program provides a communication channel between all personnel and higher levels of leadership regarding ways to improve operations and ensure all good solutions will be considered.[44]

The Beneficial Suggestion Program was hosted and supported by MARCORLOGCOM. The program recently moved to Headquarters, Marine Corps (Programs & Resources) and is currently in an "operational pause".[45]

3.3.4. Comparison of Existing Programs for Smart Adaptation Use

Table 2 compares the MEP, PQDR and Beneficial Suggestion programs for employment as a smart adaptation vehicle. Of the existing programs, the study team determined the MEP to be best suited for Smart Adaptation use. The current MEP possesses the medium (web), people, and processes required for a functional program. The current data elements could be used with little to no changes. The MEP is due to be defunded at the end of FY-15 with no similar program to take its place.

Table 2. Comparison of Existing Programs for Smart Adaptations

Programs	Pro	Con	Potential Changes
MEP	▪ Suitability of program (identifies need, solicits solutions, evaluates and integrates into Marine corps processes) ▪ Accessible to all Marines ▪ Infrastructure (website and funds) currently exists ▪ Refined processes inclusive of stakeholders	▪ Defunded after FY-15 ▪ Needs (minor) adaptation to expand to all MOSs	▪ Requires funding for FY-16 and beyond ▪ Expansion to all MOSs is easily accommodated as MEP website includes gender data element
PQDR	▪ Formalized process ▪ Direct access to Program Managers ▪ Processes are integral to equipment programs	▪ Imperfect alignment of program goals ▪ Accessibility limited ▪ In-service equipment only	▪ Major changes to scope and management to include consideration of new equipment and accessibility by all Marines
Beneficial Suggestion Program	▪ Accessible to all Marines ▪ Potential for financial reward for adopted suggestions (Incentive for Marine participation)	▪ Under "operational pause." FY-16 funding unknown ▪ Potentially too general to be easily adapted for Smart Adaptations ▪ Not integrated with equipment fielding processes	▪ Remove from Operational Pause and fund as required ▪ Review processes to ensure adequate stakeholder involvement

3.4. Evaluation of Physical / Physiological Barrier Mitigation Solutions

This section discusses criteria for the evaluation of potential smart adaptations. The study used observations from the experiences of GCEITF Marines to develop the list in Table 3 in Section 3.5. While the sample size for this data is small, the observations have direct relevance and acceptable credibility as the population included female Marines in the process of executing tasks associated with previously closed MOSs. The study team provided analysis of each observation akin to the front-end screening that would be done through the MEP. MOS advocates and acquisition professionals are best qualified to develop definitive solutions, prioritize resources, and schedule fielding in consonance with their program area's goals.

3.4.1. Criteria

Five criteria were used to evaluate each proposed solution. The five criteria were effectiveness, effect on existing equipment, timeliness, financial cost, and the number of personnel affected. For reporting, effectiveness and suitability were combined into a single output under the heading of "Expected Changes in Performance."

3.4.1.1. Effectiveness

The effectiveness of a proposed solution rests on the ability to objectively measure individual performance associated with operational effectiveness prior to and after solution implementation. Quantifiable performance standards form the foundational measures of effectiveness for this aspect of solution evaluation. Measurement of these values provides analytic rigor to ensure that appropriate solutions are developed and fielded, physical and physiological barriers are reduced, and increase the ability of Marines to perform physically demanding tasks.

Effectiveness is evaluated on the following scale:

1. Individual T&R Manual Activity Performance Measurements – Improves performance, No change in performance, Decreases performance.
2. Equipment Operator's Manual Activity Performance Measurements – Improves performance, No change in performance, Decreases performance.

3.4.1.2. Effect on Existing Equipment and Procedures

This criterion addresses the need to modify existing equipment or procedures. In addition to solving the immediate need, potential adaptations may affect other equipment or the nature of how a task is performed.

The effect on existing equipment and procedures is evaluated on the following scale:

1. Solution requires - No modification to existing equipment or procedures prior to fielding.
2. Solution requires - Minor modification to existing equipment or procedures.
3. Solution requires - Significant modification to existing equipment or procedures.

3.4.1.3. Time Required to Implement

The time required to implement the proposed solution shall be measured in months. A solution's time estimates shall address solution refinement, R&D, initial fielding, and full fielding and sustainment.

Calculation of the estimated time to field a solution shall consider the following factors:

- Solution Refinement - Months
- Research & Development - Months
- Initial Fielding - Months
- Full Fielding/Sustainment - Months

3.4.1.4. Financial Cost

The financial impact of a proposed solution shall address initial and sustainment costs, as appropriate. Costs estimates should include the financial aspects of training, equipment modifications, new or additional equipment procurement, and O&M costs. As appropriate, organizations within the Marine Corps who will carry the direct burden of these costs should be identified.

Financial Cost estimates should include the following:

- Estimated Funding Amount
- Frequency (one time versus recurring)
- Proposed source of funding (e.g., PMC, O&M, etc.)

3.4.1.5. Number of Personnel Affected

A key factor in the evaluation of a smart adaptation is the number and type of personnel affected. For the purposes of gender integration, a smart adaptation might enable an increased number of female and small-statured Marines to perform physically demanding tasks, thereby providing increased opportunities for these Marines while preserving and/or enhancing combat readiness.

Estimates for the number of personnel affected by a potential adaptation should include the following:

- Estimated Quantity of Personnel Affected (numbers for female integration can be developed as MOSs and unit are opened)
- Estimated Type of Personnel Affected (e.g., MOS, Units, stature, gender, etc.)
- Influence Catalyst (Starting date or event)(i.e., opening of an MOS to female Marines)

3.5. List of Potential Smart Adaptations

Table 3 is a list of potential smart adaptations based on observations of the experiences of GCEITF Marines and evaluated using the above criteria. Though the number of (female and short-statured) Marines from which observations were gathered was small, the relevancy and credibility of the data is strong. Throughout their time in the GCEITF, female Marines trained to and performed physically demanding tasks associated with the GCE for extended periods of time, making them a very relevant population for observation. The credibility of these observations was maximized by having the study team engage Marines in the field and on their equipment while the GCEITF was deployed to 29 Palms, California.

The analysis of effectiveness and the effects on existing equipment of potential adaptations resulted in the column for expected changes in performance in the table. Where appropriate, the study team also provided nomenclature and product information when a commercial product exists that meets the needs of a desired adaptation.

Table 3. List of Potential Solutions

Equipment Type	Item	Observation	Field Mitigation	Physical Barrier	Tasks Affected	Recommendation	Expected Changes in Performance	Number of Personnel Potentially Affected	Estimated Financial Cost	Estimated Time to Field	Commercially Available Options
Infantry Combat Equipment	Plate Carrier	Some short-statured Marines felt the current PC was too long even when properly fitted. Complaints included impeded movement, improper ride of side ESAPI and, in certain circumstances, impingement to the throat.	N/A	Impeded movement, chafing, and discomfort lead to a decrease in performance.	All tasks that require bending	Re-evaluate the available sizes of the PC.	Increased comfort leading to improved performance	Short-statured Marines	TBD	TBD	N/A
Infantry Combat Equipment	Plate Carrier	Shoulder Straps: The weight of the PC and other inserted and attached equipment creates discomfort and fatigue (narrow shoulder straps).	Several Marines purchased commercially available shoulder pads designed as aftermarket pads for body armor.	Current straps can cause an increase in pain and fatigue in shoulders and neck when worn for extended periods (load distribution).	All Tasks	Add shoulder pads into the PC's Component inventory.	Reduce fatigue related injuries and increase comfort, leading to increased performance.	All Marines	$25/set	6 months	*High Speed Gear* Shoulder Pads (Wasatch/Weesatch): Will adapt to any webbing shoulder strap up to two (2) inch width. Shoulder pads are a thin, soft gel-like padding to help manage load.
Infantry Combat Equipment	Plate Carrier	The side ESAPI causes chafing. Marines attempt to reduce chafing by inserting padding between the side ESAPI and their body (e.g., cut-out ISO mat, feminine hygiene pads, etc.).	With no commercial product available, Marine used different methods to create a cushion (e.g., Feminine sanitary pads, etc.)	Chafing and discomfort lead to a decrease in performance.	All tasks that require extended wear of the PC	Modify the cummerbund as required to prevent chafing.	Reduction of chafing and increased comfort, leading to increased performance.	All Marines whose duties require extended wear of the PC.	TBD	TBD	N/A
Infantry Combat Equipment	Plate Carrier	Due to the bulk of the PC worn with attachments, Marines who operated in the LAV, AAV, and Tanks experience restricted mobility and unable to get in and out of the vehicle through the turret hatches. Crewmen currently wear the PC with attachments carried separately (e.g., magazine pouches, etc.).	All vehicle MOSs wear "slick flaks" (nothing attached) when operating inside the vehicle. The load bearing equipment is utilized when operating outside the vehicle.	Crewmen are unable to get in and out of the vehicle through the turret hatches while wearing the PC with attachments. Decreased mobility can slow task execution and increase fatigue.	Operations internal to the vehicle. Risks loss of needed personal equipment in a vehicle emergency.	Field a vest and attachments that provide increased mobility and allow crewmen to enter and exit through turret hatches.	Vest suitable for wear inside vehicle and improves safety during vehicle emergency	All AAV, LAV, Tank crewman	TBD	TBD	N/A
Infantry Combat Equipment	USMC Pack System	Short-statured Marines complained about the length of the USMC Pack Frame. Even when the hip belt was adjusted to the alternate configuration, short-statured Marines experienced "pack bite" where the frame would chafe their lower back and cause abrasions.	N/A	Current pack frame results in improper load carriage and chafing/abrasions for short-statured Marines leading to injury and fatigue.	All hikes	Field multiple frame sizes or adjustable frames.	Improved pack fit leads to improved performance on hikes and reduction in injuries.	All short-statured Marines	$260/each	6 months	*Mystery Ranch* Nylinear Individual Carrying Equipment (NICE) Frames: The Futura yoke adjusts up or down quickly, and without tools, to fit torsos anywhere from 4'8 to 6'4. The waist belt can accommodate from 25 to 40+ inch waists and also features cant adjustment to facilitate women's hip bones. https://vimeo.com/80911468

Equipment Type	Item	Observation	Field Mitigation	Physical Barrier	Tasks Affected	Recommendation	Expected Changes in Performance	Number of Personnel Potentially Affected	Estimated Financial Cost	Estimated Time to Field	Commercially Available Options
Infantry Combat Equipment	USMC Pack System	Small-waisted Marines could not tighten the hip belt sufficiently, preventing pack system distribution of weight to the hips.	N/A	Improper weight distribution leads to fatigue and corresponding reduction in performance	All hikes	Field smaller hip belt sizes.	Reduction in fatigue leading to increase performance on hikes	All small-statured Marines	N/A	12-18 months	N/A
Infantry Combat Equipment	USMC Pack System	A common issue Marines experienced is that the hip belt will loosen during hikes. The hip belt requires tightening throughout the hike creating additional exhaustion. The same was said of the top shoulder straps.	Examples: Hip belt tied into a knot and secured into the PC front flap.	Improper weight distribution leads to fatigue and corresponding reduction in performance	All hikes	Procure buckles to prevent straps from loosening during hikes.	Reduction in fatigue leading to increased performance on hikes	All Marines	N/A	6 months	*Mystery Ranch* Autolock buckle: rated at 250lbs.
Infantry Combat Equipment	USMC Pack System	For Weapons Company Marines (Machine gunners & Mortarman), the pack was not designed for the additional weight and load associated with the MOS. Several Marines had broken their frames, generally, in the same location. The pack and frame endure above average wear and tear (e.g., Handles, buckles ripped out, bent or broke frame and top front part of pack ripped apart, etc.).	Supply repair/replace.	Degradation of pack system precludes proper carriage of assigned combat equipment leading to fatigue and corresponding decrease in performance	All hikes	PdM ICE investigate excessive wear and tear of pack system associated with machine gunners and mortarman Marines.	Reduction in fatigue leading to increased performance on hikes	All 0331 and 0341	N/A	TBD	N/A
Infantry Combat Equipment	USMC Pack System	The pack was not designed for carriage of weapon systems and MOS specific gear (e.g., M240 tripod, mortar base plate, etc.).	Some Marines were using bungee cords to help secure the crew served weapons and the excess cord would be held in their hands while hiking.	Improper weight distribution and inability to adequately secure MOS-specific equipment lead to fatigue and corresponding reduction in performance	All hikes	Incorporate straps for weapon carry.	Reduction in fatigue leading to increased performance on hikes	All 0331 and 0341	$740/Pack	TBD (Pending USMC Pack Study)	*Mystery Ranch* Overload MSOB: This pack gives you the ability to secure sniper and crew-served weapons between the pack and frame without decreasing capacity for mission essentials or sustainment gear. http://www.mysteryranch.com/nice-overload-3zip-bvs-pack_2
Infantry Combat Equipment	Light-weight Helmet (LWH)	Female Marines had difficulty with the LWH retention harness. The nape pad is not adjustable, which makes it difficult to wear with a hair bun.	One Marine switched out her issued straps for commercial harness (H harness) that has adjustable capability.	Potential to impede vision (driving & sighting weapons). Increased risk of injury due to improper fit (vehicle rollover).	All Tasks	Field a helmet retention system that is compatible with female hair bun.	Adjustable harness provides better fit leading to improved visibility and reduced risk of injury.	All females Marines	$20.86/each	6 months	H-Style Retention Harness is available through DLA: 8470-01-530-0868/Color: Green Foliage Nape Pads are also available
AAV	Driver's seat	Maximum elevation of the seat does not allow the small-statured driver to fully clear the hatch ring. The Marine's neck is at the level of the hatch ring, which can cause injury to the neck if the driver is thrust forward.	N/A	Potential for injury	Driving	Examine alternatives to mitigate the risk neck injury to short statured AAV drivers (ergonomic adjustments, throat protection).	Reduce risk of injury	Short statured AAV crewmen	TBD	TBD	N/A

Equipment Type	Item	Observation	Field Mitigation	Physical Barrier	Tasks Affected	Recommendation	Expected Changes in Performance	Number of Personnel Potentially Affected	Estimated Financial Cost	Estimated Time to Field	Commercially Available Options
AAV	Turret seat	Marines expressed discomfort when seated in the turret seat. Marines (all sizes) removed the turret seat back rest to alleviate lower back pain.	Marines (all sizes) removed the turret seat back rest to alleviate lower back pain.	Discomfort and fatigue	Vehicle and weapon systems operations	Examine design alternatives to turret seat for increased comfort.	Improved task performance from reduction in fatigue	All AAV crewman	TBD	TBD	N/A
AAV	Casualty Evacuation	Evacuating a casualty through the turret hatch is an extremely difficult task. It is even more difficult when done by a short-statured Marine.	N/A	Lack of mechanical advantage degrades a short-statured Marines ability to safely extract a wounded crewman through the AAV turret hatch.	Casualty Evacuation	Evaluate various options to include strap designed assist casualty evacuation.	Improved ability to evacuate a casualty through a turret hatch.	All AAV crewman (Potentially all vehicles with overhead egress)	$70/each	TBD	*Agilite* The Porcupine: Allows you to carry an injured or otherwise incapacitated person. http://agilitegear.com/collections/rescue-equipment/products/porcupine-black
LAV	Snatch Block	The snatch block on the LAV-25 is currently mounted high on the body of the vehicle and difficult for short-statured Marines to access. The snatch block on the LAV-L is mounted between the 2nd and 3rd road wheels making it easily accessible.	N/A	Current mount on LAV-25 impedes access by short-statured Marines	Recovery operations	Move snatch block on LAV-25 to location similar to that on the LAV-L.	Improves performance during recovery operations and standardization of LAV variants.	LAV crewman	TBD	TBD	N/A
LAV	Spare Tire	Short-statured Marines have difficulty dismounting and mounting the spare tire due to height of spare tire mount.	Females use their legs to leg press the tire onto the vehicle.	Difficulty accessing spare tire.	Maintenance Operations	Design spare tire mount to facilitate accessibility by shorter statured Marines.	Improved ability to perform wheel maintenance	Short-statured LAV crewman	TBD	TBD	N/A
LAV	25mm Cannon	Marines expressed difficulty with the assembly and disassembly of the 25mm cannon due to the weight, bulk, and location of the receiver.	N/A	Marines strain to accomplish task. Update to a 30mm cannon will exacerbate this challenge.	Maintenance of the 25mm cannon	Design a sling or similar device to facilitate raising and lowering of the 25mm cannon receiver.	Reduce the physical challenges and risk to injury associated with maintenance of the 25mm cannon.	All LAV crewman	TBD	TBD	N/A
LAV	Driver Seat	A 5'2" Marine driver has difficulty seeing the ground with the seat fully raised.	N/A	Ability of short-statured Marines to safely drive LAV	Driving	Modify LAV driver's position (e.g. seat, pedals, steering wheel).	Improved ability for short-statured Marines to safely drive LAV.	Short-statured LAV crewman	TBD	TBD	N/A
LAV	Transfer Level Lock	A Small-statured Marine expressed difficulty reaching the transfer case lock lever.	A small-statured Marine had to wedge herself between the periscopes in the driver's hull.	Hampered ability of small-statured Marines to manipulate transfer case lock lever.	Driving	Consider fielding of lever extension kit or reposition the lever.	Improved ability for small-statured Marines to safely drive LAV.	Short-statured LAV crewman	TBD	TBD	N/A
LAV	Seat Belts	The seat belts in troop compartment do not fit with the PC on.	Marines removed the seat belts and the VC/Gunner back rests for more room.	Safety	Personnel transfer	Extend length of the seat belts.	Increased safety of personnel.	All LAV passengers	TBD	TBD	N/A
M1A1 Abrams Tank	Coaxial Ammo Storage	The ammo storage area for the coaxial is difficult to reach specially the most inboard slot. Marines with short arms have difficulty reaching the bottom ammunition box.	Some Marines have used a pinch bar to reach the bottom ammo box.	Inability to reach lowest container of ammunition without equipment assistance.	Operation of the coaxial machinegun	Redesign ammunition storage area or provide a tool to assist access to bottom ammo box.	Improved/quicker access to ammunition.	All Tank crewman	TBD	TBD	N/A
M1A1 Abrams Tank	Ammo Door Knee Switch	Marines with short legs have difficulty engaging the knee switch for the 120 mm ammo door.	Marines lift their leg to engage the switch or use their hands.	Difficulty engaging knee switch.	Loading of main gun	Redesign/reposition switch to accommodate short-statured Marine.	Ability of short-statured Marine to access ammunition.	Short Statured Tank Crewman	TBD	TBD	N/A

Equipment Type	Item	Observation	Field Mitigation	Physical Barrier	Tasks Affected	Recommendation	Expected Changes in Performance	Number of Personnel Potentially Affected	Estimated Financial Cost	Estimated Time to Field	Commercially Available Options
M1A1 Abrams Tank	Hub Cap Tool	Difficult to remove the wheel hub cap with available tools.	The tool to remove the hub cap is locally fabricated.	None. However, could lead to use of unauthorized tools and procedures to remove wheel hub cap.	Wheel maintenance	Review tools and procedures for removal of M1A1 Tank hub cap.	Improvement to maintainability of M1A1 Tank.	Tank crewmen and maintainers	TBD	TBD	N/A
M1A1 Abrams Tank	Parking Brake	A 5'2" Marine expressed difficultly reaching the parking brake release handle.	N/A	None. Affects convenience for driving of vehicle by small statured Marines.	Driving	Investigate repositioning of the parking brake release handle for easier access.	Improves ergonomics for vehicle driver.	Short-statured Tank crewmen	TBD	TBD	N/A
M1A1 Abrams Tank	120 mm ammunition	Unloading the 120 mm rounds from the tank can be difficult for shorter Marines. Rounds are handed in and out via the turret hatch.	Some short-statured Marines place their Flak on the turret to prevent metal on metal contact between the tank and ammunition.	Short-statured Marines lack overheard reach to hand rounds directly to Marine outside turret.	Ammunition handling	Place non-conductive material over hatch ring during ammo transfer that allows rounds to rest firm surface during hand-off.	Safe and secure transfer of ammo by short-statured crewmen.	Tank crewmen	Minimal	Less than 6 months	N/A
M1A1 Abrams Tank	Driver Seat	Many drivers complained of discomfort and lower back pain during extended driving.	N/A	Discomfort and fatigue can negatively affect task performance.	Driving (extended periods)	Investigate more comfortable driver's seat.	Reduction in fatigue leading to improved task performance.	Tank crewman	TBD	TBD	N/A
M1A1 Abrams Tank	M240 Machinegun	The M240 has a butterfly trigger which is difficult for Marines with small hands to engage.	N/A	Inability to operate M240 Machine Gun with butterfly trigger.	Machine gun Operations	Consider the butt stock version of the M240 for use in the M1A1.	Improved ability for small-statured Marines to operate the machine gun.	Small-statured tank crewmen	TBD	TBD	N/A
M1A1 Abrams Tank	.50 cal Machine Gun	The .50 cal Machine Gun Charging Cable is difficult to manipulate (requires long, straight pull) and easily frayed.	N/A	Primarily a maintenance and reliability issue.	Machine gun Operations	Field a thicker charging cable (similar to the one used on the M240).	More reliable performance of the .50 cal machine gun.	Tank crewmen	TBD	TBD	N/A
155 Lightweight Howitzer	Elevation Wheel Step	Short-statured Marines have trouble reaching the breech, especially during high angle fire. The step below the elevation wheel is too low.	N/A	Hampered ability to perform gun mission.	Howitzer loading	Redesign of elevation wheel step to assist short-statured Marines.	Improved ability for short-statured Marines to perform all gun tasks.	Short-Statured Artillery crewmen	TBD	TBD	N/A
155 Lightweight Howitzer	Counter Balance	Some small-statured Marines are not heavy enough to engage the counter balance when laying the gun.	N/A	None. Crew composition or SOP fully accommodates.	Cannon operation	None Required	N/A	N/A	N/A	N/A	N/A
155 Lightweight Howitzer	Loading Step	Short-statured Marines experiencing difficulty placing ammunition on the load ramp are using the breech platform as a step.	N/A	Hampers ability to load ammunition.	Cannon Operation	No Recommendation. (Current adaptation)	Allows short-statured Marines to load artillery projectile.	Short-Statured Artillery crewmen	N/A	N/A	N/A
Medium Tactical Vehicle Replacement (MTVR) (Artillery Prime Mover)		Short statured Marine cannot reach 7-ton truck bed to load and unload. The shorter Marines stacked pallets to be able to load the 7-ton.	N/A	Hampered ability to load and a potential safety hazard.	Loading and unloading MTVR	Provide a platform for which Marines can gain height advantage load and unload.	Improvement in task performance and safety.	Short-Statured Artillery crewmen	TBD	TBD	N/A
MTVR (Artillery Prime Mover)	Ladder	When exiting the rear of the 7-ton, the shorter Marines have a hard time "feeling" for the muzzle brake, which is used as a step when dismounting from the 7-Ton. The tailgate cannot be lowered until the howitzer is detached from prime mover.	N/A	Inhibits ability to mount/dismount the vehicle via the tailgate and poses safety hazard.	Mount and dismount of MTVR.	Investigate alternative method to mount/dismount MTVR.	Increased safety of personnel	Artillery crewmen	TBD	TBD	N/A

Equipment Type	Item	Observation	Field Mitigation	Physical Barrier	Tasks Affected	Recommendation	Expected Changes in Performance	Number of Personnel Potentially Affected	Estimated Financial Cost	Estimated Time to Field	Commercially Available Options
MTVR (Artillery Prime Mover)	Cargo Hatch T-handle	Shorter Marines have a difficultly reaching the T-handle on the tailgate.	N/A	Inhibits operation of the tailgate.	Loading and unloading MTVR.	Provide a platform or ladder to facilitate access by short-statured Marine.	Improvement in task performance and safety.	All short-statured Marines	TBD	TBD	N/A
Miscellaneous	Female Urination Device	Female Marines have a difficult time finding a place to relieve themselves in field.	N/A	Inability to quickly and modestly relieve oneself can negatively affect task performance.	All	Field Female Urination Devices to allow women to urinate standing up without undressing.	Potential improvement to all task performance	All female Marines	$21.99/each	6 months	*Sheewee* Extreme: A urination device that allows women to urinate without removing clothes while standing or sitting. The Extreme comes with a carry case and an extension tube.
Miscellaneous	Sports Bras	Female Marines with larger busts can experience significant discomfort while performing physical tasks. Sports bras have proven effective in increasing comfort and physical performance. Specific sports bra is highly dependent on individual preference.	Marines wore their preferred brand of sports bras.	Discomfort potentially leading to decreased performance.	All	Consider increase to female uniform allowance for athletic undergarments.	Increased comfort leading to improved performance.	All female Marines	$56.00/each	N/A	Cost estimate based on *Lynx Sportswear* Racer Back

Figures 7 through 11 provide greater detail on select items from the above table. The figures include illustrations of current equipment and the barriers to performance posed by them. As appropriate, commercially available products are depicted that may help reduce those barriers.

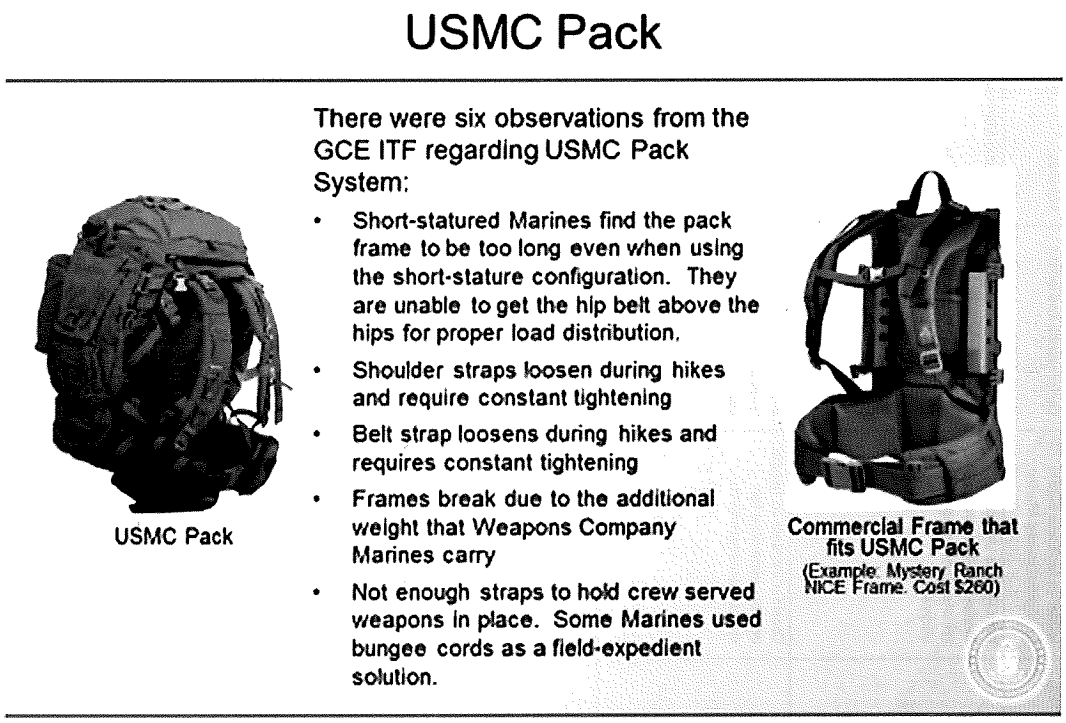
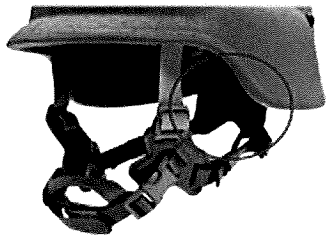


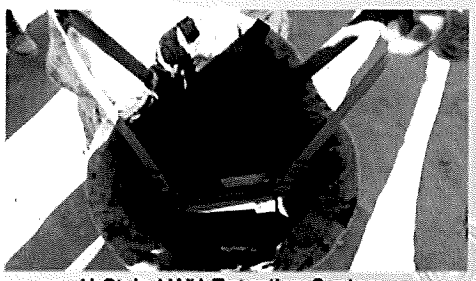
Figure 7. USMC Pack

Light Weight Helmet Retention System

- Female Marines had difficulty with the LWH retention harness.
  - The nape pad is not adjustable, which makes it difficult to wear with a hair bun.
- H-style had potential benefits for female Marines with hair buns
  - The U.S. Army Advanced Combat Helmet uses an H-Style retention system
  - The H-style retention system is available through DLA
    - Cost: $21/each



Current LWH Retention System



H-Style LWH Retention System

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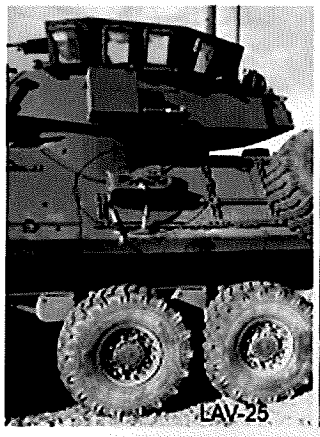
Figure 8. LWH Retention System

LAV Snatch Block

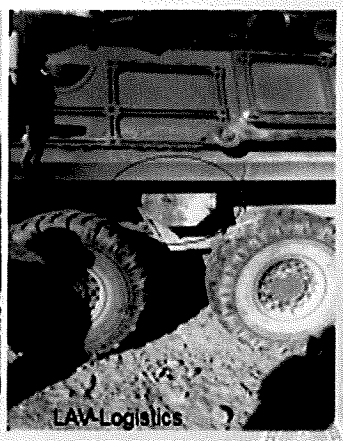
- The snatch block on the LAV-25 is currently mounted high on the body of the vehicle and difficult for short-statured Marines to access.

•The LAV-Logistics variant provides better access to the snatch block for short-statured Marines.

- The snatch block on the LAV-L is mounted between the 2nd and 3rd road wheel.



LAV-25



LAV-Logistics

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Figure 9. LAV Snatch Block

M1A1 Tank M240 Machine Gun Trigger

- The M240 has a butterfly trigger which is difficult for Marines with small hands to engage and negatively affects accuracy.
- Consider the butt stock version of the M240 for use in the M1A1 Tank.
  - Potential procurement or redistribution of existing buttstock weapons

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Figure 10. M1A1 Abrams M240 Trigger

LW 155 M777A2 Howitzer

- Short-statured Marines have trouble reaching the breech when standing on the step below the elevation wheel.
  - The challenge is exacerbated during high angle fire.
- Consider repositioning of the elevation wheel step to assist short-statured Marines.

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Figure 11. LW155 Howitzer Step

4. Recommendations for Further Study

The Smart Adaptation study has already had an impact on the requirements development and infantry combat equipment acquisition offices of the Marine Corps. Despite the success of this effort, the study merely scratched the surface of needed research into the integration of female and small-statured Marines with combat apparel and weapons systems. Each of these efforts would make significant contributions to the reduction of barriers to physical performance of occupational tasks for small-statured Marines with the additional potential to improve performance for all Marines.

4.1. Mobility Metrics for Human Performance

The Marine Corps - a force that values speed and agility - lacks mobility metrics for evaluating the combat equipment worn by the individual Marine. While MARCORSYSCOM product managers consider mobility in the design of individual equipment, that consideration is neither formalized nor data-driven. As a result, the Marine Corps has no basis for understanding the relationship between ballistic protection and mobility with regard to the safety of personnel. A mobility metric would provide needed analytic momentum toward efforts to lighten the load.

The study team was informed in March 2015 that MERS personnel are working on an initial metric for mobility that may be available during summer 2015. The study team recommends the Marine Corps fully resource this effort. Once an initial metric is established, expanded testing should include MC-LEAP course iterations to establish a solid baseline of performance by Marines wearing the following different items:

- Levels and layers of protection to measure the impact of each item of equipment (e.g., body armor, helmet, ammunition pouches, etc.)
- Optimally and sub-optimally sized pieces of equipment:
    - Such a study would permit correlation of anthropometric and sizing data to performance of physically demanding tasks.
    - The study team recommends testing begin with body armor with ESAPI plates as the largest and heaviest piece of personal protective equipment.
- Potential smart adaptation candidates once adequate baselining is complete

4.2. Modeling the System for Individual Protective Equipment

A future study should consider the chain of activities and associated analysis from anthropometric data to employment with the OPFOR. Elements of this study would include, but not be limited to anthropometric data, performance metrics, tariff sizing[46], issuance/fit, and configuration policy and procedures. Such an effort would provide a comprehensive model of the equipment fielding

system that would facilitate identification of analytic and systemic gaps and breakdowns that contribute to sub-optimized performance of physically demanding tasks.

The 2010 MC-ANSUR survey was a much needed update to the previous 1966 Marine Corps effort and U.S. Army 1988 data; however, the sample size and gender distribution were constrained by the number of volunteers. MARCORSYSCOM has commissioned an expansion of the current dataset, and the study team recommends the Marine Corps place its full support behind this effort.

The study team also understands that tariff sizing has not been reviewed since the previous (U.S. Army) ANSUR in 1988. It is possible that the supply system may be stocking improper numbers of each size of a piece of equipment based on outdated tariffs. As the Marine Corps expands the MC-ANSUR database, it should update the tariff-sizing model that drives supply stocks.

Appendix A. Observations from the AAV and LAV School Houses

The study team visited the AAV and LAV schools at Camp Pendleton, CA during March 2015. The team interviewed instructors and staff from each school who interacted with female Marines who were a part of the MCFIP LOE 2. Potential adaptations and pertinent observations are listed below.

AAV:

- There is no height restriction—minimum or maximum—to operate the AAV. The study team recommends that the AAV community research and, if warranted, define minimum and maximum height requirements for service as an AAV crewman.
- The most physically difficult requirement for an AAV crewman is the swim qualification. Given the unforgiving operating environment in which the AAV operates, the study team recommends no changes.
- There is difficulty with the emergency egress (individual and casualty) due to the hatch size. This observation is addressed in Section 3.5.
- Smaller Marines have difficulty with the .50 cal machine gun charging handle. They are unable to push down the charging handle from a seated position and have to stand up to gain leverage. This observation is addressed in Section 3.5.
- A short-statured Marine has to sit close to the edge of the seat to reach the pedals, leaving a significant gap between the Marine's back and the back seat rest. The Marine can be slammed back into the back seat rest if he or she hits something. The study team recommends further research and testing to determine options for modification that improve Marine performance while preserving and enhancing safety.
- There is not a lot of room inside the AAV, so smaller is often better for moving internally to the vehicle. The equipment was made for smaller Marines. Comparing recent anthropometric data (MC-ANSUR) to previous data taken in 1966, the average size of the male Marine was smaller when the AAV was designed.
- AAV T&R tasks are crew vice individually based. Determining the individual component of a crew task will be important to any adaptation considered for this community.

LAV:

- A 61" Marine expressed that she has difficulty seeing the road from the driver seat. The school informed the study team of an informal 65"-75" height requirement which is not reflected in the MOS Manual. The study team recommends that the LAV community research and, if warranted, define minimum and maximum height requirements for service as an LAV crewman.
- Marines prefer the Jankel-type LAV seats, which were removed from the LAV FoV due to an incident resulting in fatality. These seats provided greater comfort during long missions and

in rough terrain. The study team recommends this item be referred to the LAV community for resolution.

- The 25 mm cannon is heavy and awkward to remove and install on the LAV. The receiver is located between the troop commander and the gunner. Marines have to contort their bodies to remove and install the 100lb. receiver. This observation is addressed in Section 3.5.

Appendix B. Summary of Marine Corps Warfighting Laboratory's Examination of Four Technologies[47]

1. Lightweight Carbon Composites

Lightweight carbon composites have multiple applications and are a potential solution for reducing weight Marines carry. Carbon-fiber composites weigh about one-fifth as much as steel, but still maintain its strength and stiffness. Using modern textile techniques, the carbon filaments are woven or stitched together to create cloth-like fabrics that are then bound to a matrix to create a composite structure that is both strong and lightweight. The aerospace industry has already adopted the use of carbon fibers to replace alloys such as aluminum and titanium.

1.1. Liquid body armor

A key innovation in this area of research is the "shear thickening" liquid added to conventional Kevlar fabrics. BAE Corporation uses shear thickening fluid made up of freely suspended particles that react to a disturbance by colliding, locking together, and becoming hard. The treated Kevlar fabric quickly and temporarily hardens when something kinetically disturbs it and returns to its original flexible liquid state. The fabric forms a protective and temporary barrier allowing the body armor to provide far greater protection at a drastically lighter weight and material thickness. The hardening occurs in milliseconds and then the body armor becomes flexible again. The resulting body armor is significantly lighter and more flexible. This composite material has undergone ballistic testing and the test results indicate that the application of BAE's shear thickening fluid to Kevlar can reduce bullet penetration with 45 percent less ballistic fabric thickness. In tests, ten layers of "shear thickening" liquid-treated Kevlar fabric out performed thirty-one layers of traditional untreated Kevlar fabric. Liquid armor also distributes the impact over a wide area as opposed to being concentrated in one place as with conventional body armor.

Poland recently developed their own formula for Shear Thickening Fluid that could replace Kevlar.[48]

1.2. Kevlar XP

DuPont launched Kevlar XP for hard armor applications that offers 20 percent greater ballistic performance and increased protection without sacrificing other performance requirements. The new product combines Kevlar KM2 Plus fiber and a new thermoplastic resin that improves upon the original Kevlar technology. Kevlar XP for hard armor technology produces a lighter-weight helmet. This material produces hard armor applications at a 20 percent reduction in weight while maintaining the same performance as the current materials.

National Military Armament (NATMIL) is currently producing tactical vests including a MOLLE loop tactical vest with National Institute of Justice (NIJ) Level IIIA protection. All vest models are made from a blend of ballistic material known as Ultra High Molecular Weight Poly-Ethylene Fiber (UHMWPE).

NATMIL chemical and ballistic engineers have been able to optimize the coating of each fiber with specialized materials to make better use of the woven fiber in a ballistic fabric. When compared to traditional ballistic fabrics, NATMIL's UHMWPE fiber has a higher tensile strength, a lighter weight, and can even stop fast moving sharp objects such as arrows. The vest (only 6.5lbs) provides full Department of Justice (DOJ) Level IIIA protection without the use of additional armor plates.

2. Smart Textiles

Emerging application areas for smart textiles include garments that provide personal protection to first responders and personnel who may be exposed to extreme conditions. There are fabrics that help regulate body temperature, reduce wind resistance, control muscle vibration, and guard against extreme environmental hazards – all of which help improve individual performance. Smart textile applications for the defense industry and homeland security include, but are not limited to textiles (or smart armor) that instantly becomes hard, rigid, or stiffens to protect against ballistic threats; clothing enabling the wearer to function in contaminated or extreme environments; clothing that detects and reacts to the weather; built-in antennas; power distribution; fabrics that change color to fit in with the environment; and wearable textiles with embedded sensors for monitoring such parameters as vital signs, stress, and toxic substances. As with many consumer products, there is a potential military utility for smart textiles. The utility is found in weight reduction, enhanced communications, illumination, decontamination, monitoring, and camouflage. Emerging application areas for smart textiles include garments that provide personal protection and imbedded communications to first responders and personnel who may be exposed to extreme conditions.

3. Advanced Battery Technologies

Advanced battery chemistries, including lithium manganese dioxide and lithium-ion types, are driving a shift to address the current weight and service life limitations of current batteries. Batteries that use materials other than lithium are starting to get attention from industry. As the price of lithium continues to increase due to demand coupled with limited availability, alternative chemistries such as zinc-air and others based on more readily available materials should become more attractive to industry. Advanced batteries can be used to lessen the battery charge duration time as well as the degradation over usage.

As an example, for a typical three-day mission in Afghanistan, the average Marine carries a minimum of seven battery types weighing between 16-20lbs. Some Marines carry up to 35lbs of batteries to power specialized equipment. Research to lighten battery weight with high energy density, and specific focus on speeding up the charging process of existing high performance lithium-ion batteries, is of keen interest to the Marine Corps.

Marine Corps vehicles could also benefit from some of the advanced battery initiatives to include those from the Army Tank Automotive Research Development and Engineering Center that consider new technologies that minimize integration efforts based on leveraging current vehicle form factor. Reduced weight, reduced volume, increased lifecycle, and an advanced battery management

system at the cell level as opposed to the module level for existing systems are factors of importance for Marine Corps vehicles.

4. Advanced Fuel Cells

Fuel cells can convert 40–60 percent of their fuel's energy into power for a vehicle. Fuel cells are twice as efficient as internal combustion engines. Research in fuel cells is focused on improving efficiencies and reducing cost. Fuel cells run silently and have low heat signatures and thus are less vulnerable in the battlefield environment. Fuel cells are more quickly rechargeable when compared to traditional batteries. They have long run times and provide constant power. They are also twice as efficient at generating electricity when compared to traditional combustion engines, which can reduce logistic demands on the battlefield.

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Appendix C. Summary of DARPA Programs with Potential to Reduce Physical Barriers to Performance

DARPA has a variety of research programs in new areas of advanced technology such as information technology, electronics, materials science, and new technologies emerging from the biological sciences.[49] The Marine Corps Liaison to DARPA provides information on the following programs.

1. Soldier Protection System

The increasing lethality of enemy ballistic and blast threats—such as bullets, fragments, explosively formed projectiles, shaped charges, and Improvised Explosive Devices (IEDs) has resulted in substantial increases in the weight of protective armor and, consequently, the weight of tactical and combat vehicles. The DARPA Soldier Protection Systems (SPS) Program is developing and demonstrating lightweight armor material systems to defeat current and potential ballistic and blast threats with performance substantially better than today's protective armor systems.

DARPA is focused on materials and material systems that can control the energy absorption and propagation of ballistics or blasts. Guided by mechanics-based modeling, new materials with superior mechanical properties are being developed and formulated into novel ballistic armor systems. In addition, hierarchical structures that can achieve survivability against high-intensity underbody blasts are being developed to provide greatly enhanced protection to the occupants of both tactical and combat vehicles. These approaches aim to enable new lightweight armor that can defeat a broad spectrum of combined threats.

2. Legged Squad Support System (LS3)

To alleviate physical weight carried by troops, DARPA is developing the LS3 to integrate with a squad of Marines or Soldiers. LS3 seeks to demonstrate that a highly mobile, semi-autonomous legged robot can carry 400lbs of a squad's load, follow squad members through rugged terrain, and interact with troops in a natural way that is similar to a trained animal and its handler. The LS3 program goal is to develop a robot that will go through the same terrain the squad goes through without hindering the squad's mission. The robot could also serve as a mobile auxiliary power source to the squad so that troops can recharge batteries for radios and handheld devices while on patrol.

3. Warrior Web

The Warrior Web program seeks to develop technologies required to prevent and reduce musculoskeletal injuries caused by dynamic events typically found in the warfighter's environment. The program goal is a lightweight, conformal under-suit that is transparent to the user (like a diver's wetsuit). The suit seeks to employ a system (or web) of closed-loop controlled actuation, transmission, and functional structures that protect injury prone areas and focusing on the soft tissues that connect and interface with the skeletal system. The program is also seeking other novel technologies that prevent, reduce, ambulate, and assist with healing of acute and chronic musculoskeletal injuries.

In addition to direct injury mitigation, Warrior Web will have the capacity to augment positive work done by the muscles to reduce the physical burden by leveraging the web structure to impart joint torque at the ankle, knee, and hip joints. The suit seeks to reduce the metabolic cost of carrying a typical assault load and compensate for the weight of the suit itself while consuming no more than 100 Watts of electric power from the battery source.

The Warrior Web program will consist of two separate but related program tasks.

1. Task A, Warrior Web Alpha, seeks to develop a mix of core technologies critical to the realization of a Warrior Web capability. The Warrior Web Alpha effort examines five key Technology Areas: core injury mitigation technologies; comprehensive analytical representations; regenerative actuation; adaptive sensing and control; and suit human-to-wearer interface.

2. Task B, Warrior Web Bravo, is expected to develop an integrated suit capability by leveraging the technology developed by Task A efforts and incorporating the most appropriate breakthroughs into a suit that shows the best performance. The final suit is expected to be tested in appropriate mission profiles under realistic loads to evaluate performance.

4. DARPA Robotics Challenge

The Department of Defense's strategic plan calls for the Joint Force to conduct humanitarian, disaster relief, and related operations. Some disasters, due to grave risks to the health and wellbeing of rescue and aid workers, prove too great in scale or scope for timely and effective human response. The DARPA Robotics Challenge (DRC) seeks to address this problem by promoting innovation in human-supervised robotic technology for disaster-response operations.

The primary technical goal of the DRC is to develop human-supervised ground robots capable of executing complex tasks in dangerous, degraded, and human-engineered environments. To achieve its goal, the DRC is advancing the art of supervised autonomy, mounted and dismounted mobility, and platform dexterity, strength, and endurance. Improvements in supervised autonomy in particular, aim to enable better control of robots by non-expert supervisors and allow effective operation despite degraded communications (low bandwidth, high latency, intermittence).

Appendix D. Acronyms

Acronym	Definition
3-D	Three-Dimensional
AAS	Anti-Armor Systems
AAV	Amphibious Assault Vehicle
ABV	Assault Breacher Vehicle
ACV	Amphibious Combat Vehicle
AFSS	Armor and Fire Support Systems
ANSUR	Anthropometric Survey
CD&I	Combat Development and Integration
CDD	Capabilities Development Documents
CDD	Capabilities Development Directorate
DARPA	Defense Advanced Research Projects Agency
DC	Deputy Commandant
DOJ	Department of Justice
DRC	DARPA Robotics Challenge
DVIDS	Defense Video & Imagery Distribution System
ECSAPI	Enhanced Capability Small Arms Protective Inserts
EFSS	Expeditionary Fire Support System
ESAPI	Enhanced Small Arms Protective Inserts
ETK	Electrical Circuit Test Set Tool Kit
FLC	Formal Learning Centers
FoV	Family of Vehicles
FROG	Flame Resistant Organizational Gear
FSR	Field Service Representative
FY	Fiscal Year
GCEITF	Ground Combat Element Integrated Task Force
GCW	Ground Combat Element
HIMARS	High Mobility Artillery Rocket System
HIS	Human Systems Integration
HQMC	Headquarters Marine Corps
I&L	Installations and Logistics
ICD	Initial Capabilities Documents
ICE	Infantry Combat Equipment
IED	improvised explosive devices
IIF	Individual Issue Facility
IMTV	Improved Modular Tactical Vest
IPAPS	Improved PAPS
ITT	ICE Training Teams
IWS	Infantry Weapon Systems

Acronym	Definition
KPP	Key Performance Parameters
LAV	Light Armored Vehicle
LBV	Load-Bearing Vest
LCMR	Lightweight Counter Mortar Radar
LDS	Load Distribution System
LOE	Line of Effort
LS	Land Systems
LS3	Legged Squad Support System
LWH	Light-Weight Helmet
MARCORLOGCOM	Marine Corps Logistics Command
MARCORSYSCOM	Marine Corps Systems Command
MBK	Mechanical Breacher's Kit
MC-ANSUR	2010 Anthropometric Survey of U.S. Marines
MCCDC	Marine Corps Combat Development & Integration
MCFIO	Marine Corps Force Innovation Office
MCFIP	Marine Corps Force Integration Plan
MC-LEAP	Marine Corps Load Effect Assessment Program
MCOTEA	Marine Corps Operational Test and Evaluation Activity
MCWL	Marine Corps Warfighting Laboratory
MEF	Marine Expeditionary Force
MEP	Marine Enhancement Program
MERS	Marine Expeditionary Rifle Squad
MOS	Military Occupational Specialties
MSV	Modular Scalable Vest
MTV	Modular Tactical Vest
MTVR	Medium Tactical Vehicle Replacement
NATMIL	National Military Armament
NDAA	National Defense Authorization Act
NET	New Equipment Training
NHRC	Naval Health Research Center
NICE	Nylinear Individual Carrying Equipment
NIJ	National Institute of Justice
NOTM	Networking On-The-Move
NSRDEC	Natick Soldier RD&E Center
O&M	Operation & Maintenance
OAG	Operational Advisory Group
ONR	Office of Naval Research
OPFOR	Operating Forces
OTV	Outer Tactical Vest
PADS	Saber Position Attitude Determination Subsystem

Acronym	Definition
PALS	Pouch Attachment Ladder System
PAPS	PADS A/C Power Supply
PC	Plate Carrier
PdM ICE	Product Manager, Infantry Combat Equipment
PEO	Program Executive Office
PERM	Precision Extended Range Munition
PMC	Procurement, Marine Corps
PQDR	Product Quality Deficiency Reports
Qtr	Quarter
R&D	Research and Development
SAC	Study Advisory Committee
SIAT	Systems Engineering, Interoperability, Architectures & Technology
SIMK	Saber Intermediate Maintenance Kit
SME	Subject Matter Experts
SMK	Saber Maintenance Kit
SOP	standard operating procedure
SPC	Scalable Plate Carrier
SPS	Soldier Protection Systems
T&R	Training and Readiness
TCA	Task Criticality Assessments
TECOM	Training and Education Command
TEEP	Training and Exercise Employment Plan
UHMWPE	Ultra High Molecular Weight Poly-Ethylene Fiber

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