Army Science Board
FY2010–2011 Summer Study

Phase 1 Report
March 2011

Strengthening Sustainability and Resiliency of a Future Force

Department of the Army
Assistant Secretary of the Army
(Acquisition, Logistics and Technology)
Washington, D.C. 20310-0103

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ARMY SCIENCE BOARD
2511 JEFFERSON DAVIS HIGHWAY
SUITE 11500
ARLINGTON, VA 22202-3911

SAAL-ASB

MEMORANDUM FOR SECRETARY OF THE ARMY

SUBJECT: Interim Report of the 2010-2011 Army Science Board (ASB) Study on Strengthening Sustainability and Resiliency of a Future Force

I am pleased to forward the interim report from Phase I of the ASB Study on Strengthening Sustainability and Resiliency of a Future Force. The Army Science Board was directed to provide findings, recommendations and feasibility relating to: technologies and innovations to reduce sustainment demand and frequency of resupply; non-organic support which could increase capabilities while reducing footprint; opportunities to use local assets to reduce demand; and other DOTMLPF changes and management methods and tools including energy and durability goals with solutions strategies and feasibility assessments.

Preliminary findings after Phase I indicate that fuel for base camp electric power and water resupply are the most demanding support areas and that technological improvements and enhanced efficiency in these areas will provide significant reductions in support requirements.

In Phase I of the study the ASB focused primarily on demand reduction. ASB provides more than twenty specific actionable recommendations in this area, in addition to findings and recommendations relating to delivery and operations. Near term tonnage reductions recommendations include accelerating fielding of existing technologies in the areas of Advanced Mobile Medium Power Source (AMMPS) generators and micro-grids; renewable energy sources (solar water treatment & battery chargers); and insulation of living facilities as well as shower water recycling and water from air. For high impact mid- and long-term reductions, study recommendations include accelerating aerial resupply initiatives and increased funding for re-engining, micro-grids, water recycling and renewable energy sources.

I endorse the study's findings and recommendations and look forward to the enhancements to this effort the ASB will provide in the second phase of this study.

Frank H. Akers, Jr.
Chair, Army Science Board

Army Science Board

2010–2011 Summer Study on

STRENGTHENING SUSTAINABILITY AND RESILIENCY OF A FUTURE FORCE

Phase 1 Interim Report

November 2010

Distribution Statement A:
Approved for public release; distribution is unlimited.

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1.0 EXECUTIVE SUMMARY

Delivering supplies and support to warfighters at all locations in a theater of operations is a complex task. Past studies by both the Army Science Board and the Defense Science Board have identified several challenges that increase the logistical difficulties associated with the sustainability and resiliency of expeditionary forces. The Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)) requested that the Army Science Board (ASB) establish a study team to make recommendations for approaches to those challenges in order to reduce sustainment requirements, logistical footprints, and other demands attendant upon deployed brigade combat teams (BCTs). The Terms of Reference (TOR) memorandum for this study is found in Appendix A. The team's objectives for this 2-year effort were to identify methods and approaches to reduce demand, make supply more efficient and effective, and increase mission-oriented use of warrior time.

The study team has gathered a database of information compiled from literature searches, interviews with subject matter experts (SMEs), and visits to installations and academic institutions. The team believes the Army can improve expeditionary force resiliency and reduce logistical burdens by adopting proposed enhancements outlined in the body of this report. Some recommendations can be implemented now and others over time as new equipment and technologies emerge from research and transition to fielded inventory. Some recommendations will require policy and organizational changes, and the process to do so will be incumbent on senior Army leadership. All of the approaches and recommendations were developed in light of doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) domains in order to reduce the risk of unintended consequences.

The study team understands the complexities as well as the secondary and tertiary effects of the issues included in this study. The team's approach includes implementations in the near term as well as in the mid term and long term. Multiple effects are expected. For example, an approach to reduce water consumption will result in less water required and fewer convoy deliveries for support. Concurrent savings will be captured in fuel since reduced delivery requirements mean fewer convoys and fewer soldiers exposed to risk. Also, the option exists either to utilize this "new capacity" for other mission-oriented operations or to reduce overall costs.

Candidate solutions were assessed tentatively utilizing a computer-based logistical model of a typical Stryker Brigade Combat Team (SBCT) as a baseline. (The second year of this study will look at the Infantry Brigade Combat Team (IBCT) and the Heavy Brigade Combat Team (HBCT) as well as the SBCT.) As different options were entered into the Army's Operational Logistics (OPLOG) Planner V7 model, the outputs were assessed and rank ordered by the team. Concurrence with the approaches and outputs was accomplished through discussions with soldiers having significant experience in both Iraq and Afghanistan. As a result, a series of metrics for assessing the various scenarios can be developed for reviewing recommendations for inclusion in this report.

The TOR challenged the team to determine the costs for the existing or baseline case as well as with the fully implemented recommendations. Again, the team utilized the Army's

OPLOG Planner 7.0 to create the base consumption data and the Army G–4's Sustain the Mission Project (SMP) tool v3.2 for its analyses. It is expected that by the end of the study in 2011, the costs of any implementation in terms of research, development, test and engineering (RDTE), procurement (PROC), and operations and maintenance (O&M) will be assessed.

Principal Conclusions

- Significant demand reductions are achievable.
- A more effective and efficient supply chain is needed, especially for environments including major areas with complex terrain and active insurgencies.
- Increases in soldier "time outside the wire" can be accomplished.

Recommendations

- Encourage the use of on-site water sources and recycling methods to help reduce the amount and the frequency of resupply.
- Implement the use of more modern and efficient (leverage commercial propulsion advancements) engines, hybrid engines, and fuel cells for energy demand reductions.
- Monitor metrics such as payload delivered per pound of fuel, tons delivered per person in the transport unit, and total number and size of convoys required for resupply to help track consumption recommendations.
- Encourage leadership and training to make concerted efforts to conserve water and fuel. This action alone could lead to a 15 percent reduction in water and fuel delivery demand and a reduction in the number of convoys necessary for resupply.
- Provide the means for soldiers to accelerate construction of the smaller unit base camps (BCs), combat outposts (COPs) and patrol bases (PBs).

Since this study is being executed over 2 years, the study team will be able to probe deeper into the identified issues, analyze alternatives with models, and conduct wider investigations for the major issues and any additional ones. The following four areas of study are being mapped out:

- BC capabilities and efficiencies.
- Impacts of airlift capability improvements, including effectiveness and efficiencies.
- Enhanced capabilities for commanders to manage energy and consumables and to recycle water.
- Future high-payoff technology improvement opportunities.

The report is organized as follows:

- Following a discussion of the TOR, study objectives, and the study methodology (Chapter 2.0), the background and statement of the problem are discussed (Chapter 3.0).
- Chapter 4.0 addresses demand reduction at all levels of BCT operations, including the smaller BCs. Issues discussed are electrical power, water, structures, security, and

ammunition for the BC BCT. Issues relevant to the smaller BCs include factors in timely mission effectiveness, electrical power, water, structures, and security.

- Chapter 5.0 analyzes more effective and efficient delivery methods. Both ground and air vehicles (manned and unmanned) are included in the analyses.
- Chapter 6.0 outlines the process of utilizing the Army's OPLOG Planner 7.0 on arriving at a baseline set of values for the study.
- Chapter 7.0 presents various notional technologies that will have impacts in future timeframes when the technology readiness levels (TRLs) reach the point of transition from research. Such topics as advanced batteries, alternative power sources, and unmanned ground and air systems will be included as part of the second year of the study.
- Chapter 8.0 summarizes the year-1 conclusions and recommendations.
- Chapter 9.0 articulates the plan for the second year of this 2-year effort.
- Appendices A–C provide a copy of the TOR, the list of study team participants, and the list of abbreviations used herein, respectively. Appendix D replicates the July 2010 briefing charts presented to the sponsors.

2.0 INTRODUCTION

2.1 Terms of Reference

In May 2010, the ASB and Army leadership came to an agreement on the direction and content of a 2-year study to improve the sustainability and resiliency of a future force. The first year was devoted to establishing the processes, identifying near term enhancements, developing the roadmap processes, and searching for new ideas and concepts. The second year will focus on the following objectives:

- Identify two or three “tier one” high-payoff recommendations that can be implemented in the near term by Army leadership. Using modeling and analysis to develop the quantitative underpinnings, the study team will include a cost-benefit analysis (CBA) and roadmap for these recommendations.
- Analyze and develop more fully the remaining year-1 recommendations as well as new ones identified through a more extensive examination of emerging technologies.

The major thrusts in the TOR are to identify the following:

- Technologies and innovations to reduce sustainment demand and frequency of unit resupply.
- Nonorganic support to reduce the burdens of deployed forces.
- Opportunities in which deployed brigades can use local assets to satisfy requirements, thus reducing logistics demands.

2.2 Study Objectives

This 2-year study is sponsored by two offices: the Deputy Chief of Staff for Logistics (G–4) and the Deputy Commanding General (DCG), Futures/Director Army Capabilities Integration Center (ARCIC), U.S. Army Training and Doctrine Command (TRADOC). The deliverables for the first year include an annotated briefing and this interim written report representing the findings during the first 7 months of the study. The second year work will result in a written report and a final briefing during the fourth quarter of 2011. Figure 1 shows a July 2010 snapshot of the study team membership and Army/DoD personnel providing support.

2.3 Visits

During year 1, the team visited or contacted the organizations listed in Figure 2. The selection of these organizations and individuals to visit was based on the team's identification of the subject-matter experts or organizations that were involved in R&D, manufacturing or applications pertinent to the study. In many cases, one visit suggested others to be made. For example, when the team wanted to better understand advanced battery concepts, a visit was made to the US Advanced Battery Consortium. There, additional resources in terms of other visits helped complete our knowledge base for this topic.

Strengthening Sustainability and Resiliency of a Future Force		
Study Members		
Study Chairs Mr. Robert Dodd Dr. Jeanette Jones BG (Ret) Robert Wynn Dr. Edward Allen Adler Mr. John R. Barnes Mr. Anthony J. Braddock Mr. William S. Crowder	Dr. Philip C. Dickinson MG (Ret) Paul L. Greenberg Ms. Helen Greiner Dr. Steven E. Kornguth Mr. Richard Ladd Dr. Thomas L. Landers Dr. Walter F. Morrison LTG (Ret) Max W. Noah	Dr. Ivan A. Somers Dr. Peter Swan Mr. David W. Swindle, Jr. COL (Ret) Charles A. Vehlow Dr. Christopher B. Wallace LTG (Ret) John W. Woodmansee, Jr.

Study Support		
Study Manager Dr. Leonard Braverman ***Study Analyst*** Mr. Bill Bryson, Dynetics	***Report Writer/Editor*** Dr. Chuck Steele, USAF Academy ***ROTC*** CDT DeLongchamp, Alabama A&M	***Army Support*** COL Paul Roege, TRADOC Liaison Mr. Tom Bruen, HQDA G4 Liaison Mr. Mark Leno, HQDA G4 Liaison MAJ Jayme Smith, ASA (ALT) MAJ J. O'Sadnick, Rock Island Arsenal 1SG (Ret) T. Haddad, Natick SSA Mr. William Fisher, AMSAA Mr. Peter Dymond, AMSAA

Figure 1. Study Team Members and Support

Army	DoD	Industry
HQDA VCSA HQDA G4/LIA HQDA OASA(I&E) TRADOC ARCIC CASCOM ARL Army Contracting Command TACOM/TARDEC PEO Integration PEO GCS NATICK PM MEP Maneuver Support CoE Rapid Equipping Force AMRDEC Army Sustainment Cmd Picatinny/ARDEC Army Geospatial Center ERDEC-CERL/GSL 249 Eng Bn (Prime Power)	JFCOM DARPA USMC JCS J4 USN TRANSCOM DLA	Honeywell Boeing Oshkosh Caterpillar LMI ITT GD Land Systems GE GM **Other** Dept of Energy ORNL

Figure 2. Visits and Contacts

2.4 Study Team Approach

The traditional approach of the 2-year effort follows the typical ASB study processes:

- Obtain agreement with sponsors on the TOR after receiving the topic from Army leadership.
- Investigate issues throughout industry and DoD-applicable organizations.
- Become familiar with current baselines associated with study topics.
- Identify anomalies and areas where greater emphasis would enhance potential benefits and savings.
- Identify, establish, and recommend goals for sustainment footprint reductions.
- Confirm assumptions and estimates through modeling and simulations.
- Lay out roadmap processes for the Army to achieve identified goals.

Year 1 of the ASB study was spent gathering information and developing recommendations based on findings. Most of the first year focused on the near term with a foundation built for analyzing the mid and long term issues. Technology forecasts, development, and insertion will play a major part of the second year's efforts. A final report will be delivered to the sponsors in October 2011.

3.0 BACKGROUND OF THE PROBLEM

Deploying a BCT introduces a logistical zero-sum game to operations planners. Since a finite amount of supplies can be taken with the deploying brigade, a balance within the makeup of the initial supply components is a continuing source of concern. Reductions in one category will allow additions in another, but this offset may reduce mission effectiveness. Figure 3 represents the distribution of the support tonnage required for a deployed SBCT. Note that fuel and water needs account for more than 82 percent of the weight necessary to sustain an SBCT.

Figure 3 also shows the distribution of water and fuel usage by application. By logic, any analysis aimed at reducing the tonnage for supplies to the BCT must begin with considering these two components. Reducing the demand for water (conservation, in situ sources, re-cycling, etc.) will have second-order positive effects on mission effectiveness as well. For example, if water demand is reduced, the requirement for resupply is reduced, meaning fewer convoys are needed to be sent in harm's way, resulting in less fuel consumption and less risk for the convoy members.

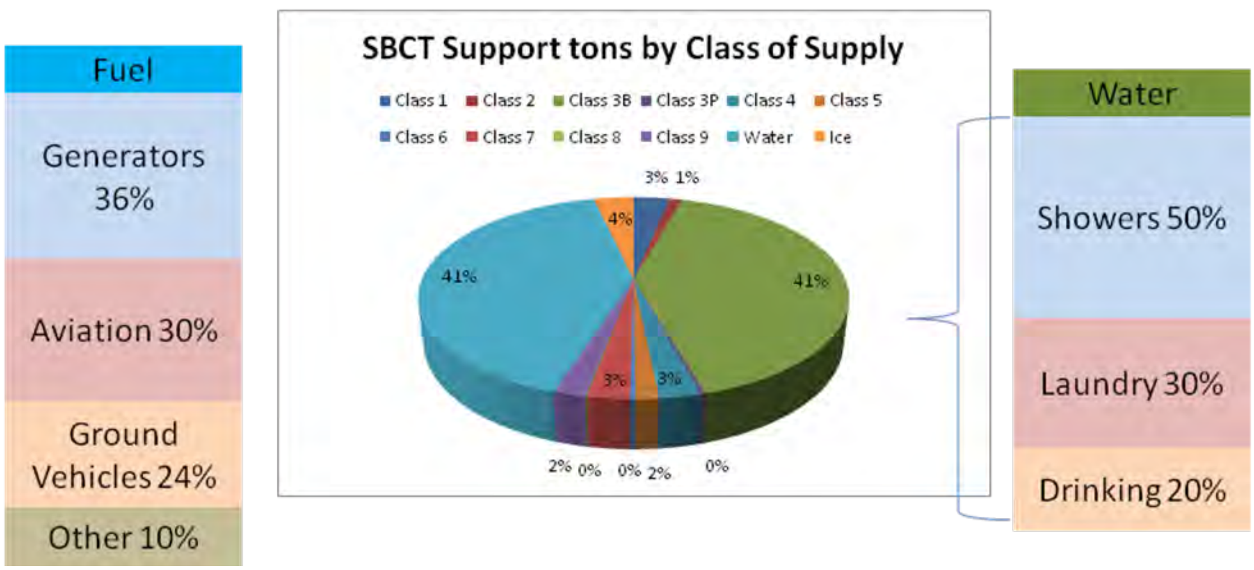


Figure 3. Logistics Tonnage

Figure 4 helps define the problem by showing the long term trend in fuel consumption in gallons per day per soldier. The cause of the growth has many sources including more mechanization, greater rotorcraft insertion into theater in both combat and support roles, more electronics and climate controls to support, and greater convoy cover roles.

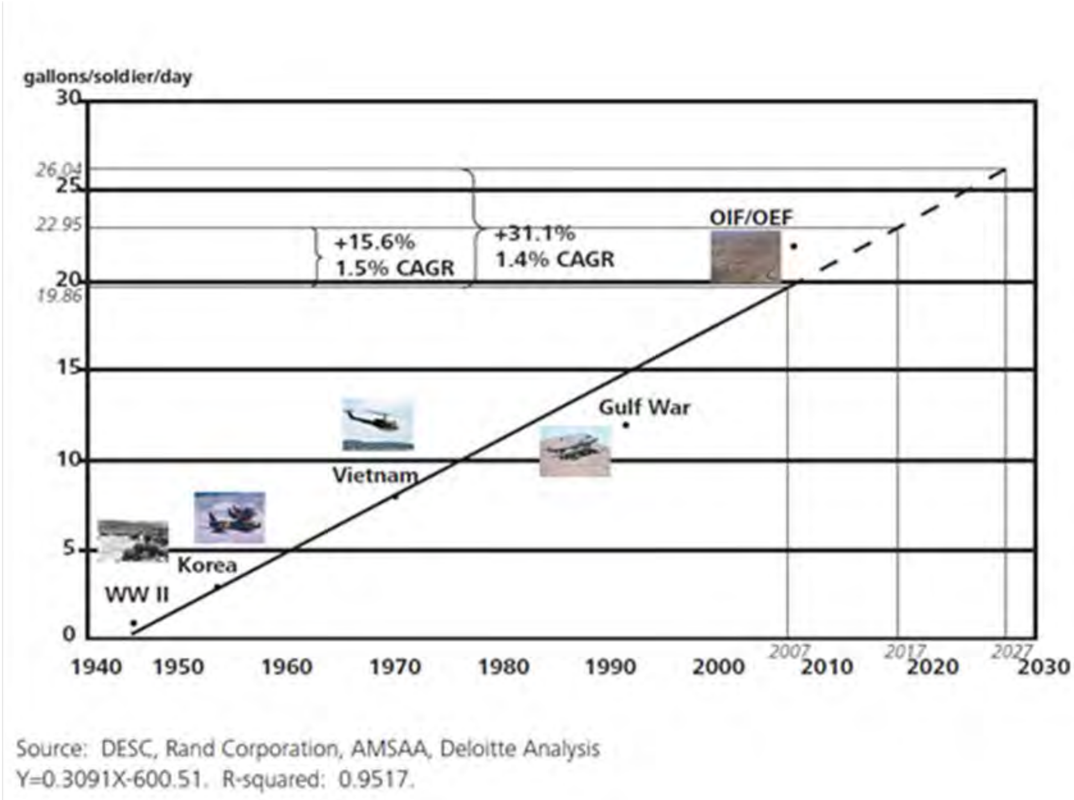


Figure 4. Historic Fuel Consumption

4.0 DEMAND REDUCTION

4.1 Base Camp for Expeditionary Forces

A BC is defined as an evolving military facility that supports the military operations of a deployed unit and provides the necessary support and services for sustained operations. BCs support the tenants and their equipment. While they are not permanent bases or installations, they develop many of the same functions and facilities the longer they exist. A BC can contain one or multiple units from joint interagency, intergovernmental, and multinational (JIIM) organizations. It has a defined perimeter and established access controls and takes advantage of natural and manmade features.

In short, a BC is any facility in theater, from a major activity center to a small outpost that provides a platform to support unit missions. BCs also provide morale, welfare, and recreation (MWR), and an acceptable habitat for the troops.

The Army's BC initiative was established by an 8 April 2008 TRADOC letter designating the Commanding General of the Maneuver Support Center of Excellence (CG MSCoE) as the Chair of a BC Integrated Concept Development Team (ICDT) to develop the concept in accordance with the Joint Capability Integration Development System (JCIDS) process for Full Spectrum Operations for Future Modular Force (2015–2024) and to conduct the cost-benefit analysis (CBA). The BC ICDT meets periodically. The latest formal action document on BCs is the initial draft version (May 26, 2010) of the Functional Solution Analysis (FSA). This ASB study recognizes and addresses the gaps cited in the FSA. There are also other ongoing BC activities within OSD and the Army acquisition community that address the gaps.

Stakeholders include all interested TRADOC centers and schools, plus research, development, and engineering centers (RDECs), program executive office/program managers (PEO/PMs), and life-cycle systems commands—in particular, the Sustainment Center of Excellence (SCoE), Fort Lee; Natick; PM Mobile Electric Power (MEP); and 249th Engineer Battalion. (The last two are primary in the electric power provision for expeditionary bases.)

The BC initiative codifies the BC in all aspects, thus giving formal recognition of the elements making up the BC and a basis for resourcing BCs and the elements that make up and support the BC.

4.1.1 *Taxonomy of Base Camps*

1. Due to different missions and personnel and materiel requirements, BCs vary widely in scale. This variability directly affects the level of support and other logistics considerations. For analytical purposes, BCs can be classified according to four categories:
2. Contingency Main Base/Contingency Operations Base ("Super Forward Operating Base (FOB)"): Brigade or larger size. Includes advanced command and control (C^2), and infrastructure and services such as coffee shops and movie theaters with contract support. May include a C130-size or greater airfield.

3. Forward Operating Base: Battalion headquarters with one or two companies. Generic term for a base that is established to extend C^2 or communications or provide support for training and tactical operations. Services are normally contracted and include most comforts such as a gymnasium, dining facility, and laundry. Also includes a helipad.
4. Combat Outpost: Company-sized unit. A well-prepared, fortified position with few services.
5. Patrol Base: Platoon-sized unit. A well-prepared, fortified position for temporary occupation (as needed) with minimal logistics footprint.

4.1.2 *Tactical Base Camp Operations*

The implementation of BCs in strategic locations is a linchpin to combat the current counter-insurgency fight in Afghanistan. A full-spectrum asymmetric fight calls for a smaller footprint of units spread out in assigned sectors. BCs in different variants have been stood up in Afghanistan to allow for the small combat unit to sustain itself in its area of operation.

Military tactical experts indicate that BCs—where soldiers are expected to interact with area residents and gather intelligence about potential enemies—are the most effective way of implementing new governance and preventing complex attacks, or other attacks such as car bombings, in the long term. Paradoxically, this approach is making U.S. soldiers more vulnerable as BC operations rely on local labor services, frequent resupply, the support of the local population for their safety, and the fact that BC soldiers are multitasked to a level of potential combat ineffectiveness.

BCs require frequent resupply of all classes that result in increased enemy contact for logistical patrols. Most small combat units develop their own systems for maintaining their BCs and critical supplies inventory. More efficient systems, such as reduced use of fuel and water, conversion of solid waste to energy, renewable energy, smart local power grids, climate-controlled sleep areas, minimally manned cooking facility, unmanned and sensor monitoring for force protection, and BC training aids, would reduce the soldier task burden and allow more soldiers to stay in the fight.

4.1.3 *Base Camp Utilities*

BC utilities (BCUs) are defined as life-support systems utilizing modular construction components to provide operational support of all BC categories. BCUs are critical for mission effectiveness since soldiers depend on utilities for mission success and survival as well as to maintain the highest possible quality of life. BCUs provide levels of services according to the category of the BC. BCUs run in place and are transferred to incoming units during changes of unit or until the FOB is closed. There are four major elements of BCUs:

1. Electric power (tactical generators, prime power, commercial power).
2. Water and waste disposal (sourcing, purification, recycling, and disposal of potable/gray/black water and waste).
3. Structures (force protection; heating, ventilation, and air conditioning (HVAC); energy conservation).

4. Security (sensors and lethal/nonlethal protection systems).

BCU issues are well reflected in the initial draft version (May 26, 2010) of the FSA as gaps in DOTMLPF. This ASB analysis correlates with the FSA and presents the major issues as viewed by the ASB, facts (both nonmaterial and material) bearing on the issues, and recommendations to alleviate the issues.

There are two primary issue areas affecting the application of DOTMLPF to BCUs: proponency and logistics efficiencies.

Proponency for BCUs is critical because it drives the solutions to gaps in BCU DOTMLPF. Proponents of elements of BCUs include the following:

- HQDA Secretariat and staff.
- Requirements generators – TRADOC ARCIC, centers of excellence and schools.
- System developers – U.S. Army Materiel Command (AMC) Research, Development, and Engineering Command (RDECOM), PEOs/PMs.
- System sustainers – AMC life-cycle management commands, DoD agencies.

BCU proponents are sometimes difficult to define or can even be nonexistent. For example, electric power proponency rests at PM MEP and the 249th Engineer Battalion (Prime Power), at the SCoE as the proponent for tactical generators, and in G–8 under the communications directorate.

BCU logistics efficiencies pertain to both the efficiency of individual systems and how the systems are employed. All elements of DOTMLPF are affected in the solutions to logistics efficiency issues. BCU focus is needed to maximize mission effectiveness while gaining logistics efficiency.

4.1.4 *Electric Power*

Electric power needs on the battlefield and in BCs are increasing and are being met by units using tactical generators, which are replaced or supplemented by larger generating plants with greater capacity and commercial power provided by contractors under the direction of the 249th Prime Power Engineer Battalion. The 2008 report "DSB Task Force on DoD Energy Strategy" found that generators are the Army's single largest user of fuel on the battlefield during wartime (BCs = 35.7 percent, combat/tactical vehicles = 33.7 percent, and combat aircraft = 30.7 percent). Note that tactical fuel consumption percentages by category of equipment are highly variable. Percentages will vary significantly based upon differences in the assumptions, input variables, and characteristics of the scenarios analyzed. Therefore, the production and use of electric power at a BC is a major potential source of savings through fuel savings and efficiencies in operation of power systems and networks.

<u>Issue</u>:

- Electric power on the battlefield lacks a central proponent to prescribe and manage organizational structures, procurement, efficient employment practices, doctrine, training, and distribution of efficient generator systems.

Findings:

- TRADOC ARCIC designated SCoE as a power proponent; however, the Army Combined Arms Support Command (CASCOM) is not organized for overall power mission accomplishment.
- MSCoE is responsible for the Prime Power Program with the U.S. Army Corps of Engineers (USACE) 249th Battalion (Prime Power) acting as the battlefield power grid operator. The 249th plans, provides, or makes provisions for BCU power to replace that provided by tactical generators; the preference is always for commercial power for BC, if available.
- PM MEP is the Army systems-of-systems integrator for battlefield power integration is the DoD provider of mobile electric generating sources, and serves as Chairman of the Joint Standardization Board. PM MEP has interest in the Advanced Medium Mobile Power Source (AMMPS) high-efficiency generators, prime power sources, intelligent power distribution, hybrid power sources, and alternative energy power sources, including fuel cells and thermoelectric devices.
- Electric power as a commodity is governed by ad hoc procedures. The design and sizing of electrical generation and distribution systems for BCs need to be better supervised and implemented. In practice, tactical generators are used when no other means are available. Poor or nonexistent tactical power distribution systems and inadequate training result in inefficient power usage. Electric grid management is conducted in overseas theaters as a USACE service by the 249th Engineer Battalion (Prime Power), which is the de facto theater electric utility organization and provides the contracting officers' technical representatives (COTRs) for contracted power sources—Logistics Civil Augmentation Program (LOGCAP) and commercial. The power expertise is contained in the 120A (old military occupation specialties (MOS) 210A) construction engineering technician warrants and 21P electric power enlisted soldiers.
- There are neither 120A warrant officers nor 21P enlisted personnel assigned to BCTs. Electric power BCU depends on the capabilities of the generator repair MOS, which is not trained to plan, set up, or manage power systems. The 120As are authorized in division- and corps-level engineer staff sections, and 120As are assigned to the S5 section of maneuver enhancement brigades (MEBs), command posts at the Army service component command level, and in the Survey and design sections of an engineer brigade. Expansion of 120As continues with active Army numbers at 109 and growing. If the brigade engineer battalion (BEB) concept is approved, there will be a 120A in the vertical construction platoon in each BCT.

Recommendations:

- Establish an integrated proponency for BC power in TRADOC with two primary proponents: MSCoE for prime power and SCoE for tactical power generators.
- Ensure that the design of brigade-sized units includes 120A (old MOS 210A) construction engineering technician warrants and 21P electric power enlisted soldiers and 21P at the battalion level for the most efficient use of electric power.

<u>Issue</u>:

- Electric power on the battlefield is produced and supplied inefficiently and wastes energy.

Findings:

- The new AMMPS generator family (Figure 5) can reduce BC fuel consumption by ~21 percent The AMMPS generators in the program are ready for acquisition, but the AMMPS program has not achieved enough priority to make the Program Objective Memorandum (POM).

Figure 5. AMMPS Generators

- The benefits of micro-grids in BCs include reduced fuel consumption, reduced sustainment demand, reduced security personnel, reduced number of convoys, improved power reliability, improved power availability, enhanced operator safety, and an adaptive, resilient power network. Over the years, the Army has recognized the potential for micro-grids to improve electrical power distribution and efficiencies. The Army Materiel Systems Analysis Activity (AMSAA) and the Air Force are currently conducting studies to examine the possible benefits of micro-grid technology for military applications.
- In 2009, AMSAA was contracted by the Communications–Electronics Research, Development, and Engineering Center (CERDEC) to investigate the use of micro-grid technologies and document the methodology to determine the logistical and financial impact of implementing the architecture for the baseline SBCT tactical operations center (TOC).

- The U.S. Air Force Research Laboratory (AFRL) is in the beginning stages of their Advanced Integrated Power System (AIPS) micro-grid test bed study. Scheduled for completion in April 2012, the study will create an experimental micro-grid that integrates multiple power sources that supply all airbase activities.
- The Logistics Innovation Agency (LIA) is working with Army Central Command (ARCENT) on a smart-grid design effort for medium-sized BCs capable of reducing JP–8 demand by 30 to 60 percent. This effort addresses the BC space for midsized camps; it complements RDECOM's micro-grid work in the "tactical/mobile" space and Installation Management Command's (IMCOM's) smart-grid efforts in the "installation" space. The goal is to develop a government-owned, open-source design specification for an energy-saving smart micro-grid for theater BCs where grid construction can be (1) built by military engineers, or (2) built through LOGCAP. The initial design phase (Phase I/$250,000) is ~3 months and focuses on a 150-man camp baseline. Phase II is a hardware validation demonstration allowing ARCENT design tweaks before finalizing the design within 12 months. LIA is seeking additional funding to run a follow-on hardware validation and grid demonstration. This project will use a systems engineering approach and commercial-grade utility industry hardware optimized to the BC operating environment and associated requirements. LIA is partnered with a Department of Energy laboratory on this project, which leverages $178 million of DOE national smart grid development expertise to minimize risk and reduce learning-curve difficulty and project time.
- In addition to currently fielded generators, solar, wind, and fuel cell power technologies will be implemented. In 2001, AMSAA conducted a limited study examining the effects of employing micro-grid technology to power a TOC. The results were a 10–20 percent savings in fuel consumption, assuming 10 percent of power was coming from renewable sources. Besides efficient power management, micro-grid technology could provide other benefits for an Army BC. Currently, Army bases rely solely on JP–8-fueled generators for electric power. Opportunities to enhance security by creating a more robust power grid are possible. A successful attack on a class-3 bulk storage area could severely limit or destroy a base's power generation capabilities. By incorporating diverse power sources (wind, solar, microhydro) and energy storage devices, the Army could meet critical power needs while primary power generators are restored. Also, during periods of high demand or low supply, devices exist that could divert power from lower priority (HVAC, etc.) to higher priority users.

Recommendations:

- Raise priority for acquisition of AMMPS generators for programming in the POM.
- Proceed with micro-grid designs for use in BCs.
- Conduct fuel consumption analyses to assess benefits of micro-grid technology insertion into BC, to include determination of electric power users (e.g., MWR, mission and habitat users in BCs) and range of fuel savings possible within the users.

4.1.5 *Water Supply*

Increasingly, the Army will be facing operations in the "arc of instability," which includes arid to semiarid areas where water is a coveted commodity. Typically, the provisioning of water has been effective but grossly inefficient, with hasty planning, excessive stockages, little recycling, and limited local (onsite) production. Although this mode of operation is still a possibility in some regions, operations in a very different hydrologic environment will become a critical challenge. With water making up 38 percent of the logistics tonnage moving into theater, substantial potential savings lie in alternative ways to produce, conserve, and use water onsite.

Issue:

- Water recycling capability is not being sufficiently pushed to reduce water demand.

Findings:

- Meeting an expeditionary force's demand for water is a major challenge, especially in the early stages of deployment before a logistics support base or structure is established.
- A particular problem is the supply convoy exposure on the nonlinear operating environment, where one of the two largest jobs is delivering water to forward locations.
- Recycling reduces new water demand for kitchens, showers, laundries, and lavatories, but not new drinking water demand. Concurrently, recycling reduces demand for delivered water.
- There are three categories of water: (1) potable drinking water; (2) "gray water" that has been used for showers, cooking, or laundry; and (3) black water, which can contain human waste.
- Gray shower water recycling is going to the field as part of the Force Provider (FP) program with a 65–70 percent recovery rate.
- Gray water (laundry/mess hall) recycling is at TRL 3. Black water treatment and disposition need additional research and development and proof of concept. With further development and acquisition funding, additional gray water recycling can be added to FP sets and extended to equipment in brigade support battalions.

Discussion:

Tactical or early entry water requirements expand rapidly from about 6 to 7 gallons/day per soldier for drinking and personal hygiene to nearly 40 gallons/day as operating bases become established and more permanent. Table 1 shows a typical "water day" for a 600-man FOB (a base with shower and laundry services). It is also representative or scalable to smaller COPs and PBs. The table shows how an objective 80 percent recovery rate of kitchen wash (some consider this black water), shower (FP currently 70 percent), and laundry water (roughly 15,000 gallons out of 24,000 gallons daily) can reduce demand for new water by up to 63 percent.

Table 1. Potential Water Demand Reduction Through Recycling (gallons)

600 man Force Provider Base Camp	Daily Req'd	Daily Out	Recycled Yield	Recycled Use	New Water Needed
Drinking (3+ g/d)	1,925	----	----	----	1,925
Food Service 80%	1,925	1,375	1,100	----	1,925
Shower 80%	12,000	12,000	9,680	9,740	2,260
Laundry 80%	5,200	5,200	4,160	5,200	----
Latrine 78%	2,700	3,465			2,700
Total	23,750	22,140	14,940	14,940	8,810

Source: Force Provider

The application or reuse of the recycled water has some restrictions based on public health policy. Table 1 shows that the recycled water is retained for shower and laundry uses. Note that new drinking water will always be needed whether or not the FOB recycles. The reclaimed water could just as well be used for flush water in the latrines with appropriate transfer means—placing new water into the showers and laundry rather than into the latrines. One consideration in water reuse is the means to reposition the water from the point of use/recycling to the point of reuse.

Reclaiming black water is a complicated and important process of waste stream management that will be considered in the second phase of the study along with R&D advances on higher gray water recovery rates.

Recommendation:

- ASA(ALT) provideS additional research and development funding to increase the fighting force's water recycling capability within existing programs of record.

Issue:

- Transportation of water is a major logistical burden.

Findings:

- There are five general water sources: surface, water from air, recycled, ground/well, and delivered (either locally purchased or organically sourced elsewhere). The first four are all potentially onsite sources. Considering exposure to risk, delivered water is the least preferred method.
- Onsite water sourcing (acquire, purify, recycle, package) is the best solution in terms of improved security, given that the source site can be secured.
- Well drilling is frequently the only option to long-haul delivery of large volumes of water, especially when combined with onsite packaging for mobile missions. Today, the Army depends largely on contractor drilling that, without careful planning, can be

inherently time consuming (weeks) for a deep well. Further, drilling is often delayed until after base security has been established—60+ days at least.

- Deep wells are needed to avoid draining local water supplies. (Local contractors can be used, but they tend to drill down to the sources (aquifer) used by the local community and can potentially be a source of "collateral damage" from our high consumption rates.) Company outposts, PBs, and early arriving units will need alternatives to well drilling. Small-unit water purification systems onsite and disposable packaging for water shipped to remote sites are needed.
- Subject to favorable humidity conditions, water-from-air capability can immediately upon arrival provide for or mitigate the need for water delivery, pending completion of a well. Ongoing tests of the 500-gallon Gator water-from-air system may open the door to a near-term alternative to delivered water. Two Gators could provide for a PB or COP.
- As the 249th Engineer Battalion (Prime Power) provides an example of a viable enterprise sourcing and acquisition model for the electric power, so: Could a 249th Water Battalion provide for theater water acquisition and sourcing? A company of the 249th Water Battalion in every Army Force Generation (ARFORGEN) cycle could execute the appropriate theater water plan using a specific mix of teams to provide contracting and management support.
- An Expeditionary Water Packaging System (EWPS) has been successfully tested and used in Iraq to reduce convoy traffic bringing bottled water in theater. However, anecdotal information suggests that alternative disposable packages, such as the camelback, are preferred in many situations and would also simplify bottle disposal.

Discussion:

On-site sourcing of water and water products is the best way to reduce the water burden on the transportation network. The capability to produce or acquire water in the absence of easily accessible surface water is virtually nonexistent in the force today. Such an expeditionary capability must be established within the ARFORGEN process.

Recommendations:

- ASA(ALT) establish commercial off-the-shelf (COTS) nondevelopment item (NDI) water sourcing capabilities in ARFORGEN ready force to reduce convoys. The capabilities should have both well-drilling teams and water from air teams.
- Establish EWPS program and evaluate alternative disposable packaging, such as sleeves for camelback, in lieu of water bottles.

<u>Issue:</u>

- Water management and planning are lacking.

Findings:

- The key to a theater water system is good water management and planning. Recently, the Army TAA 12–17 process dropped the last four Petroleum and Water Group Headquarters, leaving no water management capability in the force. This is a strategic weakness that will lead to more "brute force," inefficient provisioning of water.
- As the 249th Engineer Battalion (Prime Power) provides an example of a viable enterprise management model for the electric power BCU, so: Could a 249th Water Battalion (active or reserve component (AC/RC)) provide theater water management? A company of the 249th Water Battalion in every ARFORGEN cycle could execute the appropriate theater water plan using a specific mix of teams to provide well drilling, water from air, contracting, and management support.
- The Army Geospatial Center (AGC) maps water sources to support water sourcing planning. AGC should continue to develop this tool in conjunction with the Army component commands as part of a total review of theater water support plans.
- Figure 6 displays an improved water sourcing tool for the Arghandab District, Kandahar Province, Afghanistan Water Resource Availability Layer: Perennial Surface Water Resources over AGC's Water Resource Database (WRDB) Ground Water Potential Layer. In addition, elevation data have been used to show that all slopes exceeding 33 percent have been included into the Unsuitable for Water Resource layer—best solution to date in terms of predicting actual conditions for water planning. It gives estimates of daily water availability and time to drill a well. In addition, a relative humidity graphic has been included for reference to guide the use of water-from-air equipment.

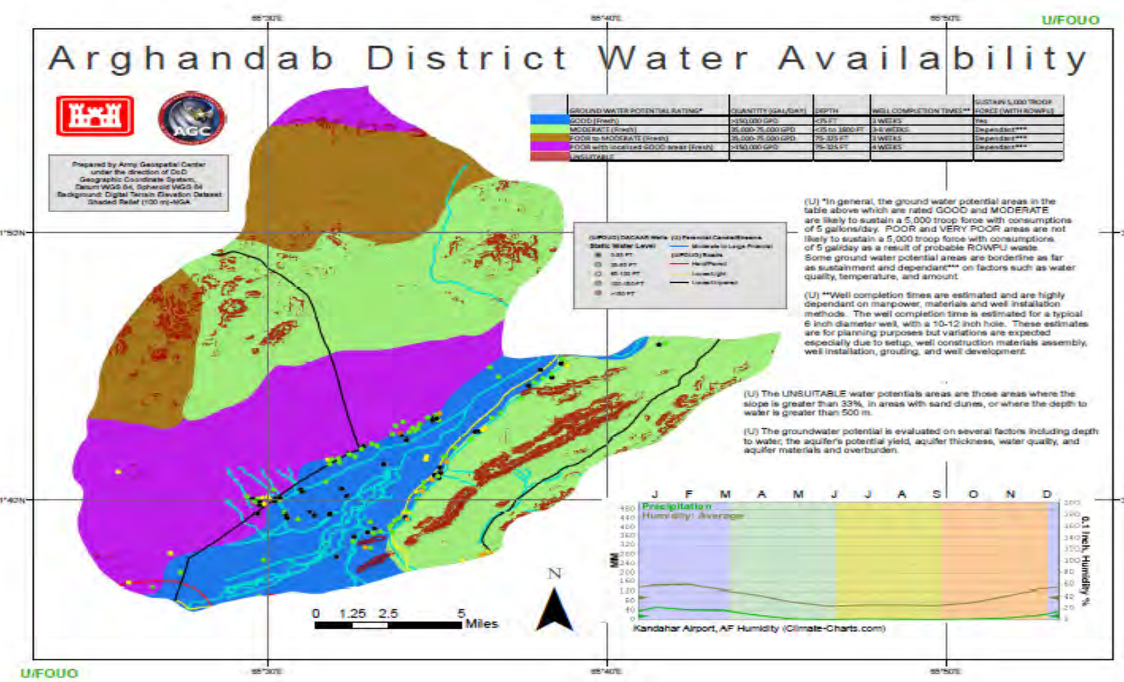


Figure 6. Example of a Hydrology Map

Discussion:

The expectation for a combatant commander to provide adequate, high-quality water to the force with nearly 100 percent certainty is unquestionable. This provisioning capability appears to be at serious risk of disappearing at a time when future operational environments are becoming increasingly inhospitable. The need to have tailored water support plans that can be sustained in each ARFORGEN cycle should be equally unquestionable. The need for a variety of capabilities and skill sets suggests a virtual organization of teams and equipment sets that, functionally, is very close to the successful model developed for another commodity, electric power, the 249th Engineer Battalion (Prime Power).

Recommendations:

- Establish 249th Water Battalion (AC/RC) to provide an ARFORGEN ready force water services organization: well-drilling, water-from-air, contracting, and managing the process.
- Army component commands (with AGC advice) review theater plans to ensure water is adequately addressed.

<u>Issue</u>:

- There is not a clear overall proponent for water.

Finding:

- The Logistics Corps is the supply and distribution proponent, but it is not apparent which organization is responsible for sourcing and acquisition. The study team has not been able to determine a single proponent for water for the operational Army.

Recommendation:

∇ Vice Chief of Staff Army designate an overall proponent for water if there is not one.

4.1.6 *Structures*

In all four categories of BCs, structures are a primary concern. They provide shelter from the natural environment, protection from enemy attacks, and the physical infrastructure to support mission, MWR, and habitat activities.

BCs in Afghanistan are located where soldiers are expected to interact with area residents, gather intelligence about potential enemies, and utilize the available facilities or build suitable structures. These can vary from rehabbing and occupying existing buildings, to b-huts (erected wooden structures), to Force Provider (Figure 7) (a fully engineered and complete 600-person complex containing full support for the soldier—air conditioned canvas buildings, showers, latrines, kitchens, mess halls, etc.) to tents/shelters.

Company- and platoon-sized units build the COP and PB BCs either from the ground up or from existing local structures. Both processes are time consuming and create immediate threats and challenges. BC creation increases the workload on the small combat unit by

Figure 7. Example of a Base Camp

having to provide its own soldiers to sustain unit internal force protection, medical care, feeding, hygiene facilities, and latrines.

BCs are marginally constructed due to their ad hoc nature with immediate force protection challenges, manpower issues, and eventual sustainment of the BC. Typically, company-level infantry units in Afghanistan building a BC spend an average 67 days building a COP properly fortified with HESCO barriers and minimal tentage. During the construction period, combat effectiveness is decreased with soldiers quickly fatigued from additional tasks that increase unit risk. Improvement in support BCU systems, force protection measures, and sustainment measures during this period must be sought to allow more soldiers to be applied to their primary missions.

Issue:

- BC structure design lacks consideration for energy conservation.

Findings:

- BC structures generally lack insulation for energy conservation. Fuel savings of 30–50 percent can be achieved by foaming tents. In one example, an 8-to-1 savings of fuel was achieved in foaming a large maintenance tent. Lightweight modular structures that can be assembled in a few hours that provide significant insulation and offer some protection from shrapnel and small arms fire are also available.
- At the request of the Department of the Army G–4 Director of Operations and Logistics Readiness, AMSAA conducted an independent analysis of potential HVAC energy savings resulting from the use of closed cell foam insulation on nonexpeditionary tent structures in Iraq. In an October 2009 briefing, AMSAA concluded that

"using closed-cell foam to insulate nonexpeditionary tent structures in Iraq results in greater than 50 percent fuel savings annually."

- In parallel, it was recommended that "safety concerns relative to the foaming process and foam itself (e.g., proper quality control implemented for materials applied)" be thoroughly addressed. Assuming that HVAC accounts for 75 percent of electrical power usage at BCs in Iraq, shelter insulation would reduce BC power demand by roughly 40 percent, with a proportional fuel savings.

Recommendations:

- Develop standards for energy conservation to include HVAC design, foaming of tents and design of future tents, prefabricated shelters, and Force Provider structures.
- Include energy conservation as a key performance parameter (KPP) in all structure designs.

Issue:

- BC force protection is cumbersome and requires inordinate troop labor and time to build, thereby severely impacting the unit mission.

Findings:

- The Natick Soldier RDEC (NSRDEC) conducted a study and found that construction of a company-sized small combat unit base camp (SCUBC) (100 m × 150 m) takes an average of 67 days. During this time, the unit is living in mine-resistant ambush-protected (MRAP) vehicles (constantly running), and 60–70 percent of the unit's strength is occupied in construction and force protection, leaving a relatively small percentage available for operations. Most of this time is spent filling HESCO bastions with dirt, which are main components of BC force protection. One small front-end loader (Bobcat) is provided to assist in this task (Figure 8). Even simple sandbag filling takes two soldiers per bag.

Figure 8. Example of a HESCO Bastion

- The Engineer Research and Development Center (ERDEC) has developed a Modular Protective System (MPS) concept for a force protection barrier that can be rapidly assembled to replace the HESCO bastion. Modules are 5 ft long × 5 ft wide × 4 ft high. Two modules, a wall section 5 ft long and 8 ft high, can be assembled by five troops at a rate of about 1.2 min/section. Depending on the number of five-man teams assigned and the number of shifts, the perimeter of the SCUBC could be completed in an estimated 2–5 days, greatly reducing construction time. MPS modules are heavier and cost more than unfilled HESCO bastions, but savings in both fuel and time are expected to be significant.
- Currently, little or no engineering equipment is used to build COP and PB fortifications, resulting in very slow building time.

Recommendations:

- Include force protection as KPPs in all structure designs.
- Develop rapid erectable barriers for COPs to include sandbag fillers.
- Provide engineering support to forward infantry units to build fortifications faster with larger equipment.

Issue:

- No standards exist for design and operation of HVAC.

Findings:

- HVAC is a major electrical load ranging from 40 percent to as high as 75 percent of the total BC energy usage.
- Standards on shelter and habitat insulation could reduce HVAC usage by 30–55 percent depending on the size and type of shelter. AMSAA concluded in a study that "using closed-cell foam to insulate nonexpeditionary tent structures in Iraq results in greater than 50 percent fuel savings annually."

Recommendation:

- Develop standards for energy conservation to include HVAC design, foaming of tents, and design of future tents and Force Provider structures.

4.1.7 *Security*

BC security is critical to successful Army operations in a country. The security operation should be tied into a network of various sensors and active protection devices that supplement manned weapons and allow complete compliance with rules of engagement (ROE), hence minimizing civilian casualties while ensuring maximum protection of the BC. An example of a base camp security schema is shown in Figure 9.

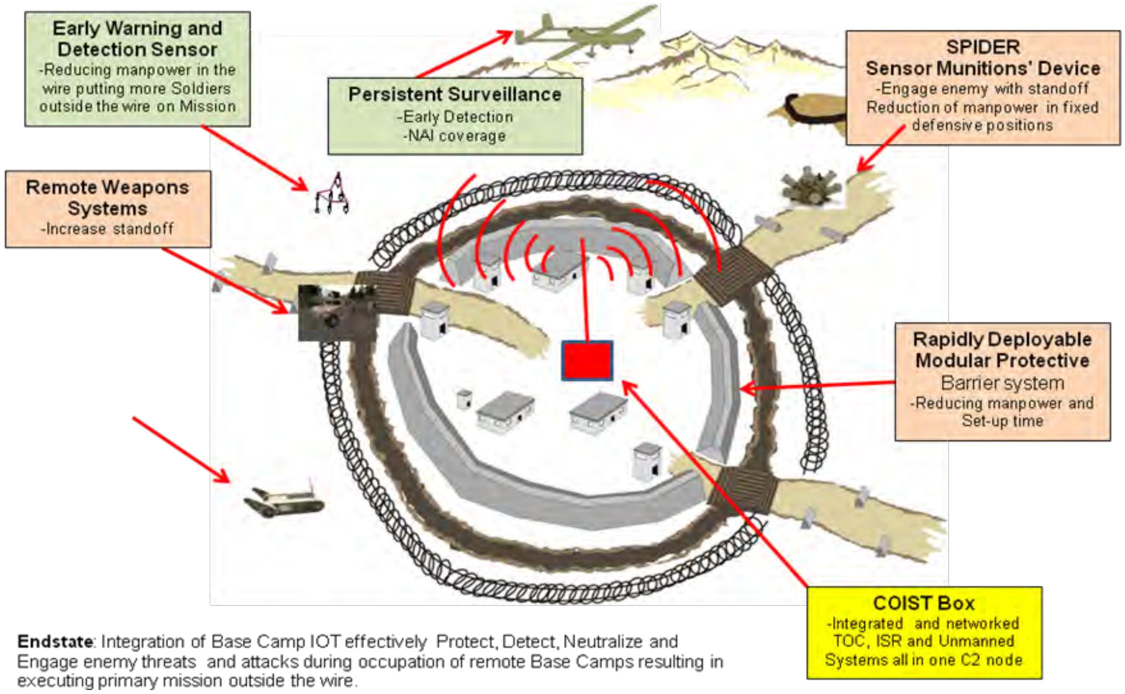


Figure 9. Base Camp Perimeter Security

Issue:

- BC security lacks proponency and has no recognized Army concept of operations (CONOPS).

Findings:

- BC security procedures are devised ad hoc in theater, and local security is manpower intensive, with units using manned direct and indirect fire (mortars) to protect the BC.
- BC security tactics, techniques and procedures (TTP) have been essentially tied to the defense tactics of the small unit in the field. For large FOBs, security has depended on roving patrols and guards.

Recommendation:

- Designate MSCoE as BC proponent for BCU security to include JCIDS development of requirements and CONOPS.

Issue:

- BC force protection concepts for equipment development have been disjointed.

Findings:

- Integrated protection systems containing sensors tied into lethal and nonlethal protection devices for protection of a BC are not available. Pieces of a full system, such as the surveillance program RAID (rapid aerostat initial deployment) towers and sensors, have been used with some success, but Army commitments to deploy an integrated system have been lacking.

- Sensor systems exist, which are provided under the Base Expeditionary Targeting and Surveillance Systems–Combined (BETSS–C) onboard navigation system—a 3-year-old system designed to rapidly provide the warfighter with a flexible, moveable, adjustable, scalable, and expeditionary base defense system for persistent ground targeting and surveillance with standoff capability and links to key battle command systems to allow response against a full spectrum of targets. Joint Rapid Acquisition Cell (JRAC) validated 2 November 2007, 3 September 2008, and intensive work is ongoing setting up BC security demonstration sites at Forts Bragg, Leonard Wood, Hood, and Lewis. However, the equipment in the BETSS–C system is complex and is not integrated to communicate with each other. When it breaks down, field repair is not available according to experience from theater.
- Active force protection must be included in BC protection and tied in with network communications, tying all systems together to be useful. The use of lethal and non-lethal systems, such as ground munitions systems Spider and Scorpion, must be tied into BC security. Employing this capability will reduce manpower requirements for security from a couple of squads for a COP to a control group of three to four selected operators looking over up to 40 Spiders interfaced with sensors. With the man-in-the-loop feature, Spider will meet ROE requirements.

Recommendation:

- Develop an integrated BC security package that includes sensors, active force protection, and integrated communications, all with high reliability requiring minimal maintenance (Figure 10).

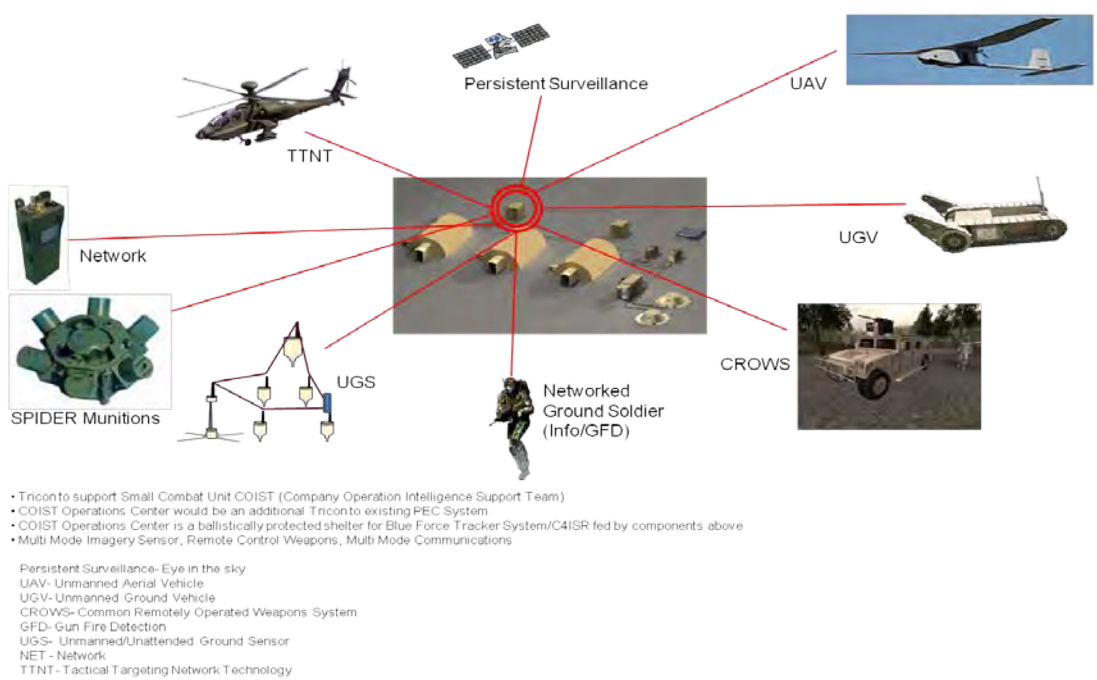


Figure 10. Components of an Integrated Base Camp Security System

4.1.8 *Ammunition Stockpiles*

Issue:

- Planning and management of ammunition stockpiles for expeditionary force missions will challenge the current structure because of dispersed field locations, distribution, and weight.

Findings:

- Ammunition is a high-tonnage commodity in excess of 3,200 discrete line items.
- There are two dedicated munitions ships in Iraq and Afghanistan.
- Cargo composition was determined by a Rand-calculated stockage objective in the two theaters, based upon weapons densities, historical planning factors, anticipated consumption data, and the ability to resupply.
- With few exceptions, the quality, quantity, and mix of missiles—conventional and precision munitions, for the most part—appear to be adequate.

Discussion:

Ammunition is a high-tonnage commodity in excess of 3,200 discrete line items. As DoD's single manager for ammunition, the Army is responsible for providing munitions for all services. During Desert Storm, more than 560,000 short tons of ammunition and missiles were shipped for all services from a prepositioned munitions ship. Because of the short duration of the conflict, only 7 percent was consumed. The situation in Operation Iraqi Freedom (OIF) was not much better. Shortages of some types of training ammunition may still exist now that each soldier is required to qualify twice a year.

Recommendations:

- Periodically analyze prepositioned munitions and missile stocks to ensure balance with weapons densities and develop predictive models that incorporate the future force.
- Size footprint in theater in relation to anticipated demand.
- Periodically analyze prepositioned munitions and missile stocks to ensure balance with weapons density.
- Establish "available supply rate" controls when necessary.
- Stockpile a mixture of conventional weapons, precision munitions, and missiles.
- Develop predictive models that incorporate the future "new" expeditionary forces vs. historic models.

Reduce ammo consumption by having expeditionary BCTs use reachback forces with precision munitions (such as unmanned aerial vehicle (UAV) strikes).

4.2 Ground Vehicles

4.2.1 *Combat and Tactical Vehicle Engines*

Issue:

- The Army is not capitalizing on the latest industry engine improvements.

Findings:

- Growing power and thermal management demands are being added to new and current vehicles.
  - More equipment, armor, silent overwatch, and tactical power capabilities increase fuel demand.
  - Silent overwatch power requirements exceed reasonable battery storage capacity.
  - Use for power export and as "hotel power" (e.g., MRAP vehicle used as a shelter during forward base construction) also increases fuel demand.
- Modern diesel engines offer improved performance effectiveness and fuel efficiency over current systems.
- Savings potential examples in the M1 include the following:
  - Save ~10 percent by replacement with modern common rail diesel engines.
  - Save ~50 percent by converting to diesel power with integral dynamo.

Discussion:

In this report, the term *dynamo* is used to describe the electrical device that converts mechanical energy to electrical energy and, in some cases, back to mechanical energy. In the literature, one may see this apparatus described as an alternator, a generator, a motor, or a motor/generator set.

Many of the Army's combat vehicles were developed years ago. Since the initial fielding of those vehicles, technology has changed significantly, with greater emphasis placed on improved fuel efficiencies and reduced emissions. Over this same period, Army combat platforms have gained add-on armor that has stressed both vehicle suspensions and power trains. As the Army fields LandWarNet (LWN), operating requirements will increase both persistent awareness capabilities and self-protective equipment on its combat platforms, thereby adding to power and cooling demands.

In the past, batteries and auxiliary power units (APUs) have been seen as the answer to these power needs. As the auxiliary load grows, there comes a point where the space claim of batteries or an APU exceeds the available physical space on the already crowded combat platform. The path ahead in many applications is to incorporate a dynamo in the primary power train, powered by the main engine. This is the common practice today in hybrid vehicles, for both automotive and heavy construction equipment.

With the advent of electronically managed common rail (CR) diesel engines, the problems associated with long periods of idle operation have been largely resolved, allowing the primary engine/generator to serve as the standby power system. In addition, modern diesel engines offer fuel savings of about 10 percent over the older engines in the current vehicle fleet.

One additional factor impacts tactical vehicle fuel consumption. Diesel engines with electronic controls optimized for diesel fuel can burn JP–8, but the power output typically suffers due to a difference in energy density between the two fuels. Development at the U.S. Army Tank–Automotive RDEC (TARDEC) has shown that with electronic controls, which monitor the exhaust gasses, it is possible to have the engines produce comparable power levels.

Recommendations:

- Replace older diesels in both combat and support tactical vehicles, during reset, including the M1. This change can reduce fuel burn significantly. In most instances, these engines should include integral dynamo/generators.
- Continue to evaluate the tradeoffs between an integral dynamo on the engine and an APU for increasing the range of missions and platforms.

4.2.2 *Diesel Hybrid Technology*

Issue:

- Diesel hybrid technology may offer a substantial reduction in fuel demands for ground combat vehicles.

Findings:

The private sector is leading the hybrid engine technology in both innovation and fuel economy gains. Opportunities for reductions in fuel demands by ground vehicles are offered by the following characteristics of diesel hybrid operation:

- Fuel efficiencies of advanced diesel engines.
- Reliability and reduced maintenance of electric drive (reduced number of parts for inventory and increased mean time to fail).
- Flexible and robust fuel control system.
- Tailored energy storage techniques (flywheel, capacitor, battery).
- Increased capacity for onboard and export power demands.
- Reduction in pollutants emitted.
- Potential savings and costs identified:
    - ~10–25 percent in fuel for hybrid construction equipment.
    - ~20 percent in fuel for Heavy Expanded Mobility Tactical Truck (HEMMT) hybrid in Aberdeen Proving Grounds (APG) trials.
    - ~20–25 percent more investment for acquisition of hybrids.

Discussion:

The automotive, trucking, and construction equipment industries are capitalizing on the availability of improved technologies, including efficient CR diesels with smart, electronically controlled fuel injection management and a choice of energy storage systems. Storage devices include batteries (numerous users), ultra capacitors (Oshkosh and Ford), and mechanical flywheels (Porsche). Electric/hybrid vehicles are demonstrating savings in fuel as well as reduced maintenance (in very limited samples) in a variety of applications, including heavy construction equipment, transit buses, and the hybrid HEMTT.

Hybrid city busses in operation today are demonstrating fuel savings of about 10 percent, with lower maintenance costs than the same bus without hybrid drive. HEMMTs running at APG today are showing a 20 percent improvement over conventional HEMMT platforms. And finally, Caterpillar is marketing an electric drive dozer, the D7E, with advertised savings of about 25 percent in fuel used for a given task and with maintenance expected to be reduced by 60 percent. The price premium for an electric dozer is about 20 percent.

The current cost to implement a small number of these vehicles is considerably higher than a mechanical drive system, but these costs will come down as industry increases production quantities. Projections from one Joint Light Tactical Vehicle (JLTV) vendor indicate that in expected production quantities the cost penalty will be a few percent at most.

Recommendation:

- The Army needs to capitalize on the innovation ongoing in U.S. industry. TARDEC is aware of the potential but is not resourced currently to fully harvest this important technology.

4.2.3 *Auxiliary Power Units*

Issue:

- Gains in effectiveness and efficiency in selected ground combat vehicles would be realized by adding onboard APUs.

Findings:

- Silent overwatch increases power demands. Examples include the following:
- Cycling between battery and main engine generator is inefficient.
- Electronics will increase overwatch power demands (e.g., M1A2 (~15 kW) and M1A3 (~45 kW)).
- Integral dynamo avoids APU complexity.
- Save >40 percent fuel by retrofitting an APU on the turbine-powered M1.
- Needs science and technology (S&T) for silent overwatch powering.

Fuel cells show promise, but the current architecture is not compatible with JP8 fuel because of the sulfur contaminants. This incompatibility would require an additional fuel to be transported with the vehicle.

Discussion:

In the past, APUs or battery banks have been seen as the answer to the power needs for overwatch. As the auxiliary load grows, the space claim of an APU or batteries exceeds the available space, and the path ahead in many applications is to incorporate a dynamo in the primary power train, powered by the main engine.

The fielding of LWN with the Joint Tactical Radio System (JTRS) Ground Mobile Radio (GMR), Warrior Information Network–Tactical (WIN–T), and elements of Future Combat System (FCS) Battle Command will increase the power demand on combat vehicles significantly. As an example, the High-Mobility Multipurpose Wheeled Vehicle (HMMWV) with Single-Channel Ground and Airborne Radio System (SINCGARS) has an electric load of a few kilowatts—the current M1A2 supplies about 15 kW to the onboard systems, while the proposed M1A3 is estimated to need 45 kW. This trend continues with the Ground Combat Vehicle (GCV) with an estimated power demand of about 60 kW. This level of power exceeds the capacity of available battery sources, and an APU capable of providing this power will need ~100 hp to drive the generator.

A class of vehicle with relatively modest "hotel" power demands includes many MRAP vehicles that are employed as protected troop shelters during BC construction. For these platforms, an onboard APU will be a much more efficient source of power than operating the main engine. These vehicles can also benefit from the provision to accept power from BC generators or from a sister vehicle.

Fuel cell technology to provide 10 kW from JP–8 is in early development and is expected to reach TRL 5 in 3 years, TRL 6 in 3 more years, with a fieldable unit years later. These devices operate at very high temperatures, as much as 1,000ºC, and will cause severe problems in both thermal signature and energy management in a densely packed combat vehicle.

The M1 is a special case in that the turbine engine is very inefficient at idle, as it would operate in overwatch. In a typical Opearational Mode Summary (OPMODSUM) consisting of 5 hours of maneuver and 19 hours in overwatch, the tank burns 200 gallons in maneuver and 240 gallons in overwatch. If the M1 is not repowered with a diesel, then an adequate APU should be developed and fielded, with the potential to reduce fuel consumption by half in a typical OPMODSUM.

The only apparent solution for the high-demand platforms (50 kW) is to produce the electric power from the main powerplant. Industry has moved to integral dynamo/starter/generators for most applications with high electric power demands. In this configuration, the dynamo is mounted within the bell housing of the engine, offering a better capability for cooling and eliminating highly stressed belt drives with their high-bearing sideloads both on the crankshaft and on the alternator.

If sufficient focus is put on reducing the size, weight and power, and cooling (SWaP C) in the development of future combat systems, an APU may be the correct engineering solution, employing internal combustion engine-driven alternators, or perhaps fuel cells will be mature by then.

Recommendations:

ASA(ALT) and PEO Ground Combat Support System (GCSS) direct that these vehicles:

- Meet power demands by utilizing integral dynamo technology for high electronic loads.
- Are repowered combat vehicles in modification schedule, including integral alternators.
- Rapidly install APUs on the M1 tank (if not repowered with diesel).

4.3 Feasibility for Demand Reduction

4.3.1 *SWaP C*

The Army continues to move to a fully networked combat force. With the added focus on troop protection, ground combat vehicles are evolving with a very high demand for electrical power for onboard systems. The option of providing this power with an APU is considered in many applications. The trade space is illustrated in Figure 11. The colored arrows at the bottom of the figure represent the needs of a HMMWV with SINCGARS, the current M1A2, the proposed M1A3 with a much more complex battle command suite, and finally the TARDEC estimate of the GCV requirement. Figure 11 illustrates the results of two potential solutions to the problem.

An APU powered by an internal combustion engine will need to produce about 2 hp for every kilowatt of output (this option is shown by the yellow-labeled line). The APU for the GCV will require about 100 hp. A quiet diesel engine capable of producing this power is not small—think of a Honda Civic engine. The space claim for an APU of this size will challenge placement on a densely packed combat vehicle.

To better understand the battery option, a curve is shown for a Macintosh laptop battery, which produces 70 Wh of energy with a volume of about 12 in^3, netting about 100 batteries/ft^3. The curve shows the number of batteries required for 1 hour of operation. To go the 15–20-hour overwatch required of combat vehicles, this number must be multiplied by the number of hours. For example, the number of batteries required for 15 hours is 15 times the quantity shown. At the level of the HMMWV, 1 hour requires about 20 batteries and to run for 15 hours, a 300-battery stack would be required. In the case of the GCV, the 1-hour battery pack will need nearly 1,000 cells, and the 15-hour mission would require 15,000 batteries. For this particular battery, the GCV package would be on the order of 150 cubic feet (5 ft × 3 ft × 10 ft).

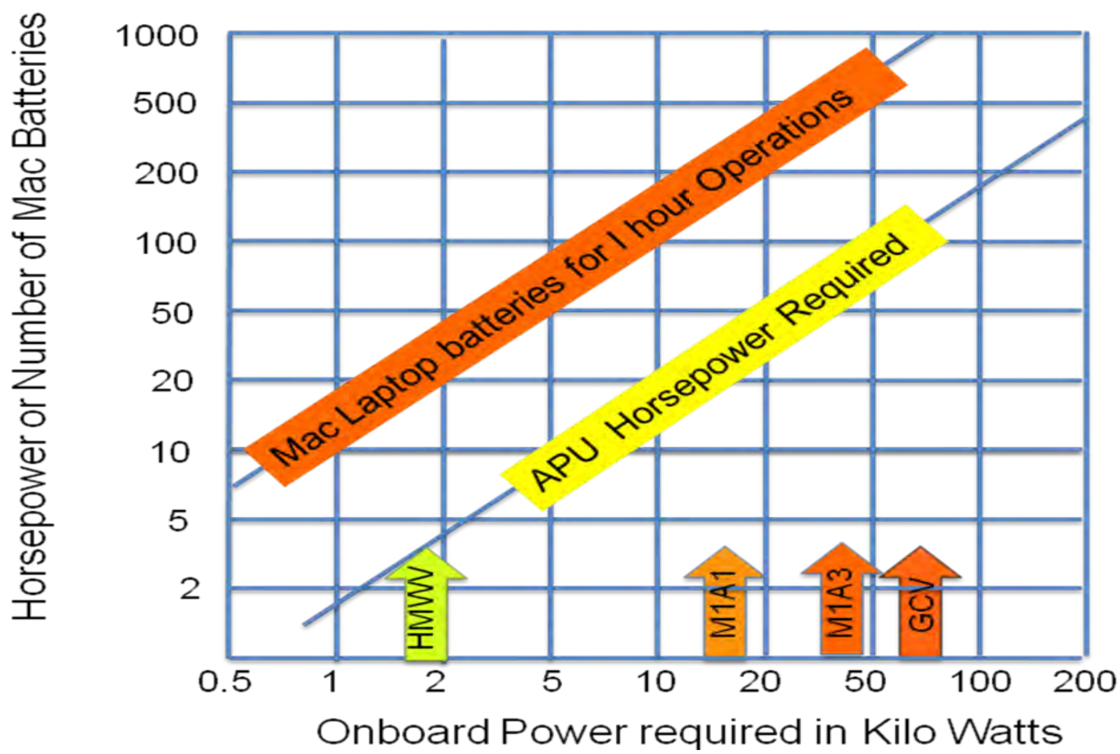


Figure 11. SWaP C Problem Defined

There is no obvious solution to meet the power demands of these platforms. The consensus today is to employ an integral dynamo on the primary powerplant and utilize it for all missions. This will mean that research will be needed to quiet high-powered diesel engines for these platforms, particularly under idle conditions during overwatch.

4.3.2 *Recognizing SWaP C Is a Problem*

Findings:

- Fielding of LWN on combat vehicles will include JTRS GMR, WIN–T, FCS-integrated computer system, and Force XXI Battle Command Brigade and Below (FBCB2).
- Results in an increase in SWaP from ~10 kW to 40 kW, with concomitant increased demands for cooling.
- Overwatch SWaP C demands on combat vehicles is growing too large for practical batteries or an APU.

Discussion:

The fielding of complex electronics on ground combat vehicles has grown significantly in the past decade. Over the next few years, demand will continue to grow with the fielding of JTRS; WIN-T; additional intelligence, surveillance, and reconnaissance (ISR); and self-protect capabilities. This growing electronic load brings the attendant challenge of cooling both the devices and the crew members. Since this HVAC system is usually electrically powered, the total hotel load on future combat vehicles is estimated to exceed 50 kW, as contrasted to perhaps 2 kW on a HMMWV and 10–15 kW on the M1A2. In an overwatch mission, these increased demands exceed any reasonable battery storage capability, as illustrated on the previous figure. In addition, the primary power required to drive an APU will approach 100 hp. Durable diesel engines producing this level of power are neither small nor quiet.

Today, nearly all the electronic systems being installed on these vehicles have been developed independently, with little or no constraint on power demands, size, or cooling. The vehicle developer is then faced with the problem of incorporating multiple black boxes into their already crowded combat platform and linking them into a coherent system. These demands have now grown such that a much more systematic approach is required.

The ASA(ALT) should convene a panel composed of vehicle developers and electronics system developers, from both the PM organizations and the RDECs. This group should be tasked to develop a set of bounds for SWaP C for combat vehicles and for combat support and combat service support (CS/CSS) platforms as well. The group should also establish a set of bounds for size, weight, power demand, and cooling requirements.

Recommendations:

- Establish standards to manage SWaP C on tactical vehicles.
- Should be a KPP for new platforms.
- Place constraints on SWaP C available for electronics.
- The following values are potential SWaP C limits:
    - Volume : 10 ft^3
    - Weight : 1,000 lb
    - Power : 20 kW input
    - Cooling : 20,000 BTU

4.3.3 *Reduced Fuel Consumption*

Findings:

Table 2 lists existing and emerging technologies that appear to have an impact on reducing fuel consumption.

Discussion:

The ASB Strengthening Sustainability and Resiliency of a Future Force study group is charged with identifying and assessing enhancements to future expeditionary brigades and their associated support elements to reduce the logistics requirements and provide sustainment options to support full-spectrum military operations. Through fuel economies at all echelons (particularly those further downrange where savings multiply through each stage of

Table 2. Available and Emerging Technologies

Vehicle Technology	Impact	Upper Bound Fuel Savings (percent)
Modern Diesel Engine	Common rail and integrated control	10
Closed-Loop ECUs	Reduce JP–8 power loss	8
Advanced Transmissions	Reduce torque conversion losses (many speeds available)	20
Hybrid Drive	Energy conservation	25
Active Suspension	Store and regenerate damping energy	2

the supply chain), one of the top two commodities of the expeditionary logistics tail is significantly reduced.

The private sector and federal government are leading the emergence of heavy vehicle technologies to enhance both functional performance and fuel economy. Through private investment and competition, the commercial vehicle industry is rapidly advancing diesel hybrid power transmissions, energy storage, digital control, and active chassis suspension technologies. Test and field experiences are building a record of improvements in savings of 2 to 25 percent per innovation. Combinations of these design innovations should produce greater savings, depending upon each case of application, duty cycle, design approach, and maintenance practice.

TARDEC should continue to develop and assess candidate technologies. TARDEC can challenge the industry to innovate through prototype competition and by setting bold goals (e.g., KPP of 50 percent fuel savings for the HMMWV). Fuel metering at the pump and on the vehicle should be demonstrated in the test environment and then deployed throughout the operational Army to promote efficient management of the fuel resource. O&M best practices should be identified, benchmarked, and trained. For example, long-haul truckers indicate a 30 percent spread in driver-to-driver fuel economy. Fuel management best practices, such as supply and demand information tracking, will support both operations and future planning and procurement decisionmaking.

Recommendations:

- TARDEC conduct a competitive "economy derby" to modify the existing military vehicles heavy equipment transporter (HET), HEMMT, Stryker, Bradley, and family of medium tactical vehicles (FMTV) to minimize fuel demand:

- Two programs for each type of vehicle.
- Vendor to provide a price to modify ~1,000 vehicles of that class to match the fuel savings demonstrated.

- Require (KPP) for HMMWV replacement to show ~50 percent mile per gallon improvement.
- Army adopt and train best practices of vehicle operation, maintenance, and fuel management throughout the supply chain.

4.3.4 *Single Fuel Policy Reduces Options*

Issue:

- The Army's policies on fuel may degrade overall effectiveness.

Findings:

- The single fuel policy restricts the Army in capitalizing on advances in fuel cells and engine technology.
- JP–8 has a lower energy density than commercial diesel, resulting in a lower miles per gallon and reduced power output.
- JP–8 specification allows much higher sulfur than U.S./Europe commercial diesel.
- Commercial diesel engines modified to burn both JP–8 and diesel often produce much lower power on JP–8.
- Sulfur presence in JP–8 introduces a severe problem for fuel cells.
- JP–8 is not as good a lubricant as diesel, reducing the service life of precision fuel system components.
- JP–8 should be retained for aviation.
- Commercial tankers routinely delivery multiple fuel types.

Discussion:

The DoD policy on JP–8 as the single DoD fuel impacts the design and operation of ground vehicles. The need to convert COTS diesel engines to burn JP–8, a nonstandard fuel, increases unit cost and overall reliability.

The specifications for JP–8 allow sulfur contamination as high as 30,000 parts per million. Sulfur is a poison for most fuel cells, requiring fuel reformation systems to convert the JP–8 to a lighter hydrocarbon and to strip the sulfur from the resulting product. Prototype devices being developed at TARDEC will have to operate at very high temperatures (as high as 1,000°C) to accommodate this fuel.

Water obtained from JP8-fueled engines is not suitable for drinking because of its high sulfur content. Water obtained from commercial diesel fuel engines is a suitable source for human consumption. The recovery rate of water from fuel is above 80 percent and would represent a significant source of potable water for motorized/mechanized forces.

In addition, JP–8 has a lower power density than diesel D2, netting about 8 percent lower miles per gallon. Many diesel engines converted to operate on JP–8 may demonstrate significantly lower fuel economy. The diesel on the HMMWV, which can produce 180 hp in a cool, low-altitude environment, nets less than 150 hp in the desert environment.

An additional factor is the reduced lubrication capability of JP–8 as compared to D2, which reduces the component life of some elements of the fuel delivery system.

Recommendations:

The Army should open a dialog with DoD for relief of the single-fuel mandate. Since this fuel is optimized for turbine engines and should continue to power Army aircraft, the need for JP–8 will continue. The Army should lead the effort to develop an updated version of JP–8 that has a sulfur content similar to commercial diesel. The Army with DoD should consider allowing D2 for use in all ground vehicles. This action would allow the direct purchase of commercial diesel engines and reduce the challenge of producing fuel cells operating on combat fuels.

4.3.5 *Evaluate DOTMLPF for an Expeditionary BCT*

Findings:

- Doctrine related to aerial logistic delivery, unmanned platforms, and the establishment of BCs is unproven.
- Vehicle drive technology is changing rapidly and is unproven in military applications.
- Robotic systems have reached a level of maturity that can support additional military missions.
- Leadership focus may reduce consumption of water and fuel.

Discussion:

As the Army moves to a more mobile, expeditionary posture, every element of the DOTMLPF will be impacted. In the past, some of the most dramatic shifts in the force have been facilitated by field exercises, including the Louisiana maneuvers that preceded WWII, the 11th Air Assault division exercises in the early ‘60s, and Task Force XXI in the ‘70s. Today, the Army is experiencing a flood of new technology, a very different enemy, and a radically different mission.

Much of the transition today is driven by the desire to minimize the loss of life, both U.S. soldiers and collateral damage to the civilian population. This has led to the increased use of aerial resupply, which takes convoys off the road, but the full potential of this capability has not been tapped. By exploiting both manned and unmanned aerial resupply, the logistic system can be streamlined to support delivery from fewer central supply points directly to the outpost, thereby eliminating the touch labor at the intermediate nodes and the attendant overhead associated with those troops.

Modern diesel engines and hybrid/electric drive systems show promise to reduce fuel consumption in the battlefield. Today, these technologies are unproven under field conditions. Their utility may be impacted by the TTP developed for their operation.

Small robotic systems have proven their value in countering improvised explosive devices (IEDs), but larger, smarter systems are available and need to be evaluated in a variety of roles, including logistics, scout and armed reconnaissance, and route clearance.

A major burden on the troops today is the time and effort required to establish a new BC. Troops are diverted into construction labor, reducing the combat power available for the primary mission. A more effective, systematic approach needs to be taken to develop the tools and procedures to expedite this process, freeing the troops to execute their primary mission.

A series of experiments should be planned to address these examples and many others that impact the deployability, effectiveness, and supportability of the expeditionary brigade. These exercises can produce the hard data critical to modeling the force, allowing excursions into other concepts.

Given the Army's missions and the flood of new technology available to the force, refinement of the DOTMLPF through operationally relevant field exercises can lead to a much more effective force and minimize the sustainability burden.

Recommendations:

Conduct a series of experiments to support the rapid adoption of new technology. For example, the following concepts should be evaluated:

- Hybrid vehicles, unmanned systems, and generators.
- Aerial delivery to point of need, both manned and unmanned.
- Learning to "build a BC."
- Hard field data that support realistic unit modeling.

5.0 DELIVERY ENHANCEMENTS: A KEY CHALLENGE FOR EXPEDITIONARY ENVIRONMENTS

5.1 Point-of-Need Delivery Capability and Capacity Are Lacking To Support Approved Joint CONOPS

Issue:

- U.S. Air Force fixed-wing transport resupply capability is severely constrained in forward operational areas due to maximum on ground (MOG) and constrained transportation infrastructure.

Findings:

- Efficient and responsive point-of-need delivery is a key capability for future expeditionary operations, especially in complex terrain with active insurgency or in areas where active access denial efforts are employed by the enemy.
- Future environments will often include limited availability of adequate airfields across the joint operational areas (JOAs).
- Current military aerial sustainment throughput is often constrained by limited airfield availability, MOG limitations, cargo-handling complexity, physical security conditions and airfield ground congestion due in part to limitations of ground transportation infrastructure.
- USAF capability to deliver supplies is further exacerbated by the size of the land area in which the forces may be distributed.
- Many future JOAs will likely lack adequate road or railroad networks to support high operations tempo (OPTEMPO) operations.
- The Joint Precision Airdrop System (JPADS) and precision low-cost, low-altitude airdrop capabilities are useful for small amounts of supplies, but total throughput limitations, drop aircraft survivability, and retrograde of the hardware are major challenges.
- Recent experiences (Haiti, Katrina, and the deployment of a Stryker BCT to Operation Enduring Freedom) have shown that the Army's joint and national capability to generate required aerial throughput lacks capacity and responsiveness.
- Technology is available and feasible for the development of long-range vertical takeoff and landing (VTOL) transports, which offer solutions to both access and throughput limitations.

Discussion:

Given the current emphasis within DoD for globally responsive expeditionary warfare capabilities, a daunting challenge for land power is assured access to the JOA and sustainment of widely dispersed forces operating in complex terrain at high OPTEMPO. These challenges include the following issues:

- Political access (the ability to obtain port access, overflight and basing rights, etc.).
- Geography (remoteness, infrastructure limitations, etc.).
- Increasing enemy capability to deny access at strategic to tactical levels.

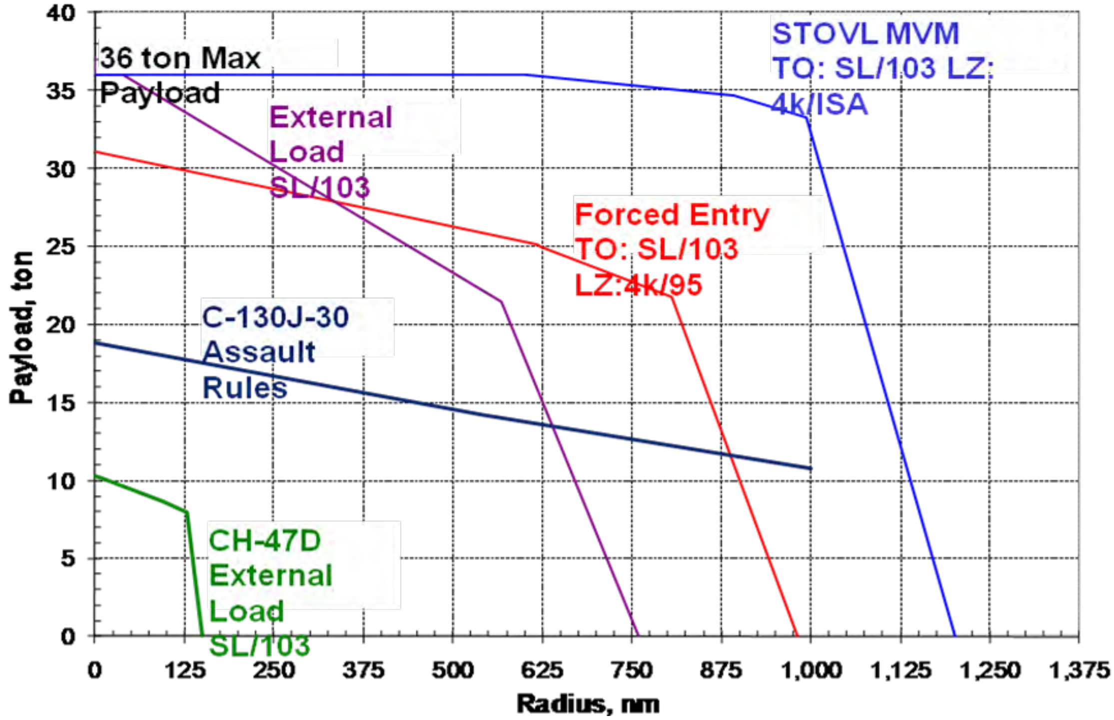
The challenge is further complicated by the fact that U.S. air and sealift rely heavily on world-class (mostly deep water) seaports and large commercial/military airports and airfields that can be heavily defended and easily denied by the enemy. Advanced mobility platforms are required to liberate U.S. forces from these constraints.

Senior combatant commanders (COCOMs) recognize the operational benefits of VTOL platforms as a means of vastly expanding access into and throughout the theaters of operations. [Source: formal letters to the CJCS/VCJCS.] Multiple studies by the government and industry agree that a heavy-lift VTOL solution is technologically feasible with acceptable risk.

The primary finding is that a host of new technologies and advanced capabilities are ready for flight demonstration. Together these available technologies offer a revolutionary advance in VTOL aviation. Technology maturity supports a competitive technology demonstration.

Figure 12 compares a joint heavy-lift (JHL), high-efficiency tilt-rotor (HETR) mission capability with the CH–47D Chinook and the C–130J-30 for selected mission conditions. As shown, the C–130 can lift a 15-ton load under the conditions specified to a mission radius of around 450 nmi. JHL can carry the same load to a mission radius of ~850 nmi (i.e., nearly 2× the range performance with the same load). Likewise, the JHL can transport a 30-ton load (2× the 15-ton load) to a mission radius of more than 1,000 nmi (i.e., 2× the payload and ~2× the mission radius) using an initial short takeoff at sea level/103°F conditions and a vertical landing at 4,000-foot pressure altitude (PA)/International Standard Atmosphere conditions at the mission midpoint. This improves mission productivity while enabling point-of-need delivery and a viable means to minimize ground convoy operations in high-risk environments.

The mission performance enhancement is even greater when JHL is compared to the Army's CH–47D Chinook. At a takeoff condition of sea level/103 °F, the CH–47D can carry an 8-ton load ~125 nmi radius. In comparison (using the red curve in Figure 12), the JHL can carry this same load to ~925 nmi, a 7× increase. A better comparison is when the JHL carries twice the CH–47 load (16 tons) to ~850 nmi or 24 tons to ~700 nmi (i.e., 2–3× greater payloads and more than 5–6× the mission radius equates to 10–15× increase in mission productivity compared to today's capability). The potential payoff is even more advantageous when the JHL can be employed using a short takeoff with a vertical landing at the mission midpoint (the blue curve) (i.e., 32-ton load at 1,000 nmi radius equates to a 32× mission productivity improvement. These levels of mission performance can provide U.S. forces with a new airlift capability to operate dispersed and at OPTEMPOs that can lead to dominant maneuvers and high, efficient sustainment, even in areas with limited or no transportation infrastructure.



Notes:
C–130J-30: hard runway takeoff

- Assault landing/takeoff rules: At mission midpoint the aircraft gross weight is limited to 135,000 lb.
- Takeoff distance at 4,000-ft PA/95° conditions: 4,150 ft to clear 50-ft obstacle.

CH–47D: external load, sea level (PA)/103°F conditions at takeoff, 3,000-ft PA/91.5°F conditions at mission midpoint

Figure 12. Payload Moved as a Function of Aircraft

Recommendation:

- DA/ASA(ALT) should pursue a technology demonstration for a long-range VTOL solution to the Joint Future Theater Lift (JFTL) requirement.

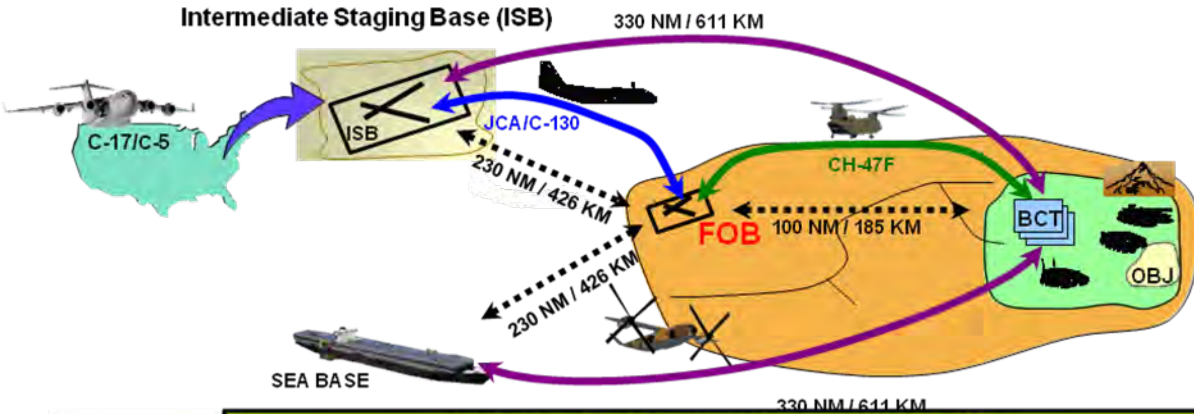
5.2 Delivery Efficiency and Throughput Enhancements

Issue:

- Major advancements in delivery efficiency are available for demonstration of high-payoff improvements in aerial sustainment and maneuver.

Finding:

- JHL is substantially more responsive and efficient than the current capabilities. Figure 13 describes and compares the mission performance of various options for delivery to point of need.



	2,215 S-Ton Resupply from ISB to BCT							
	Block Speed	Payload / Sortie	No. Sorties	Total Fuel	Total No. Flt Hours	% Increase Fuel	% Increase Flt Hours	Payload / Fuel
	(kt)	(s-ton)		(lb)	(hr)	(%)	(%)	(lb/lb)
JCA + CH-47	280 / 130	6.0 / 8.0	370 / 277	1,908,869	604 + 432	132%	469%	2.3
C-130 + CH-47	248 / 130	21.0 / 8.0	106 / 277	2,017,306	197 + 432	145%	246%	2.2
JHL VTOL	274	26.5	84	905,352	202	10%	11%	4.9
JHL STOVL	272	29.7	75	821,775	182	Baseline	Baseline	5.4

Figure 13. Comparisons of Delivery to Points of Need

Discussion:

Figure 13 illustrates an envisioned future mission to resupply an Army maneuver BCT from either a seabase or an intermediate staging base (ISB) located 330 nmi from the BCT's support base. The 3-day resupply requirements of the BCT are assumed to be 2,215 short tons (a prior estimate for the FCS BCT but also within the range needed for a Stryker BCT operating at high OPTEMPO). When JHL a short takeoff/vertical landing mode is utilized from the airfield, JHL uses a little over 40 percent of the fuel consumed by the combined C–130 and CH–47 fleets. When JHL is required to fly VTOL from the seabase with a smaller payload, the fuel requirements go up about 10 percent to almost 45 percent of the current C–130 plus CH–47 fuel requirements. JHL resulted in a reduction of flight-hours by two-thirds—a major reduction in the exposure time for the crews—and delivered around 5 pounds of payload per pound of fuel, which was over twice that of the C–130 plus CH–47 team.

Using fewer transfer nodes has a very positive impact on productivity. A movement strategy that takes cargo directly from the ISB or seabase to the point of need eliminates transloading latency, reduces movement complexity, and reduces vulnerability to threat interdiction or disruption.

Since many, if not most, of the supplies from the FOB are transported by ground convoy, security is required, often with Apache or Kiowa helicopters. Most importantly, the risk of exposure to an IED attack is significant and increases with distance, terrain complexity, and insurgency activity levels.

Recommendation:

- DA should pursue a technology demonstration for a long-range VTOL solution to the JFTL requirement.

5.3 Intra BCT Aerial Resupply

Issue:

- Growing demand for airborne resupply. Additional means are needed to support efficient point-of-need delivery and provide a lower risk option to minimize high-risk convoy operations in complex terrain with insurgency/IED hazards.

Findings:

- Convoys have greater exposure and can consume as much fuel as delivered.
- Aerial resupply offers reduced touch labor and may be the sole means of support for remotely dispersed combat outposts.
- Recent analysis indicates that in complex terrain with insurgencies, aerial resupply is often competitive and potentially more responsive than ground convoys.
- Unmanned aerial system (UAS) platforms have demonstrated the ability to deliver payloads up to 5,000 pounds.
- Fuel consumption is reduced by greater than 20 percent to deliver to a given outpost.
- Casualties and exposure are reduced compared to ground convoy operations.
- Increased aerial delivery can enhance combat power and reduce forward area support footprint and sustainment demand (fewer personnel forward equates to reduced water, fuel, and food consumption with associated requirements for medical, shelters, HVAC, etc.).

Discussion:

Current experience in OEF has shown the versatility of aerial-delivered logistics. Increased aerial delivery has reduced troop exposure and soldier losses by eliminating the need for ground convoys in high-risk areas, especially areas with complex terrain and active insurgencies. If emerging UAS capabilities are utilized, new aerial delivery options can further reduce the risk to manned aircraft crews and increase support OPTEMPO and supply throughput. In addition, an aerial delivery system could reduce the density of supply points (movement nodes), thus eliminating the complexity, delay time, and manpower needed to operate node transfer points. The source of these estimated savings is a U.S. Marine Corps study (cargo UAS) "Fuel Consumption Analysis," 2 December 2009, presented at the MORS Power and Energy Specialist Meeting. Several comparisons, with the following results, were used for this estimate: Cargo UAS K (Kamax UAS) (9,033 gallons); Cargo UAS H (A–160 Hummingbird) (9,101 gallons) versus medium security convoy (11,388 gallons).

Recommendation:

- VCSA direct RDECOM, TRADOC, and PEO Aviation to evaluate utility and suitability of existing and future UAS platforms based on results, field COTS/NDI systems as an interim capability, and develop a strategy for long-term solutions.

5.4 Delivery Improvement – Packaging

Issue:

- Supplies should be packed to optimize the receiving party rather than shipping efficiency.

Findings:

- Packing for shipping efficiency can induce additional handling at intermediate stages or at a headquarters destination.
- Delays in shipments can result from waiting for "full containers."
- The metric "pounds delivered per gallon of fuel" can result in unintended consequences.
- Packing for recipients may improve asset tracking.

Discussion:

A key to reducing the logistics structure is improved packaging of inbound supplies. For example, if Transportation Command (TRANSCOM) were to package inbound cargo in standard packs for 20, 50, and 100 troops, then the Army ground element could tailor packages for forward outposts by choosing suitable TRANSCOM packs and augmenting them with fuel, water, and ammo as necessary. The elimination of touch labor can reduce manpower directly involved in the logistics operations as well as the personnel that support them.

Recommendation:

- HQDA G–4 direct LIA to study the cost benefit of alternative packing concepts focused on the receiving unit/mission to determine if it is more effective for soldiers in the operational area.

6.0 MODELING AND ANALYSIS

6.1 Modeling Methodology

Any approach to modeling is only as good as the data entered into the process. To set the structure and scenario, the Army's OPLOG Planner 7.0 was used, which produces the full complement of equipment and consumption for the force structure. A Stryker brigade was chosen as the principal unit, and the approach was then discussed with SMEs that have recent Afghanistan experience.

Figure 14 depicts the modeling methodology utilized by the study team. The combination of both models, OPLOG Planner 7.0 and the SMP tool, allows for sensitivity analyses. When the scenarios and relevant inputs are varied, changes in cost-benefit outputs can be observed.

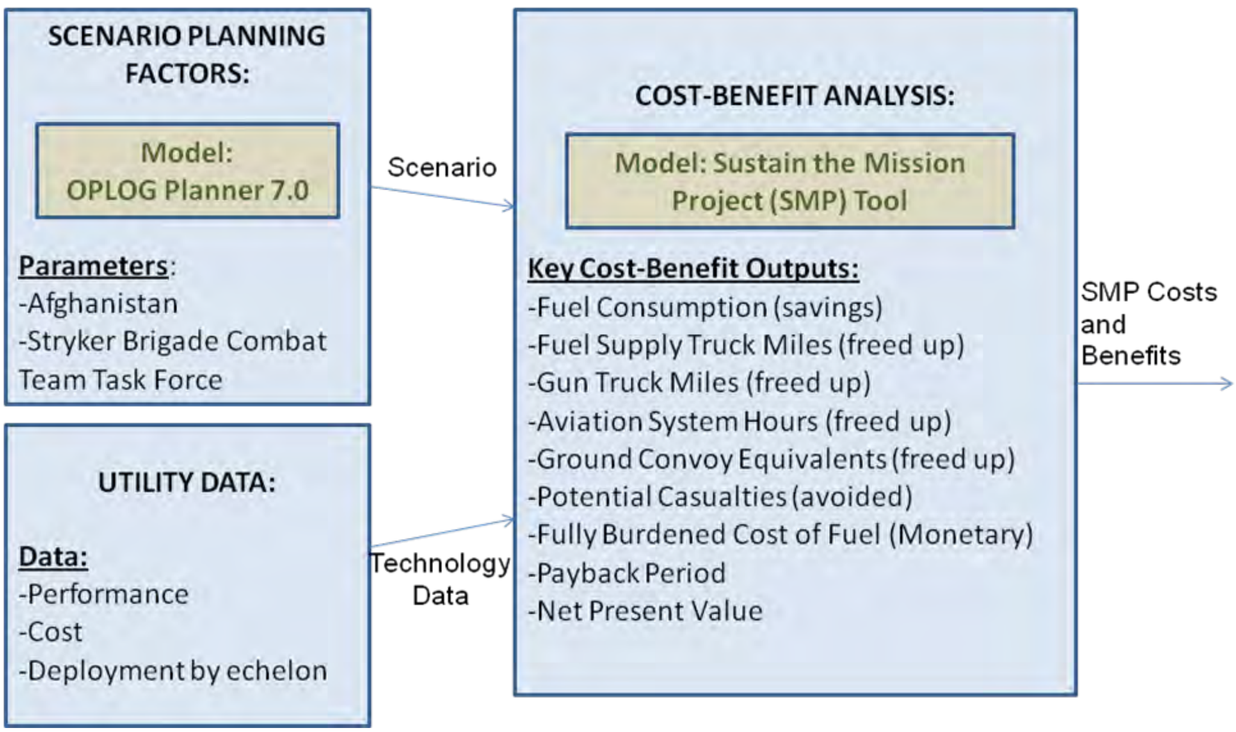


Figure 14. Modeling Methodology

As utility data are gathered about candidate technologies, the team sought performance, cost, and deployment information. The Army's SMP tool was then used to set the baseline and to assess the cost-benefit impacts of the specific technology. A revision to the OPLOG Planner will be published in fall 2010, and the study will have to be updated in year 2 using that version.

6.2 Elements of Sustainability

To measure the sustainability and resiliency of a future force, the ASB study team chose an SBCT task force to model as a notional unit in the OPLOG Planner. This unit is positioned at various echelons and locations on the battlefield and requires that its operation be sustained for defined periods of time. OPLOG Planner estimates the support requirements for each class of supply and displays the number of tons needed at each node on the battlefield.

To fulfill these requirements, the SMP decision support tool configured the number of convoys that would be needed to ship the required tonnage between the operating bases. Each convoy was configured with aviation security and gun truck support, based on assumptions about the level of force protection needed to conduct the mission. If a technology insertion resulted in reduced demand or improved the efficiency of delivery, the costs and benefits were calculated and the impacts displayed as depicted in the top left portion of Figure 15.

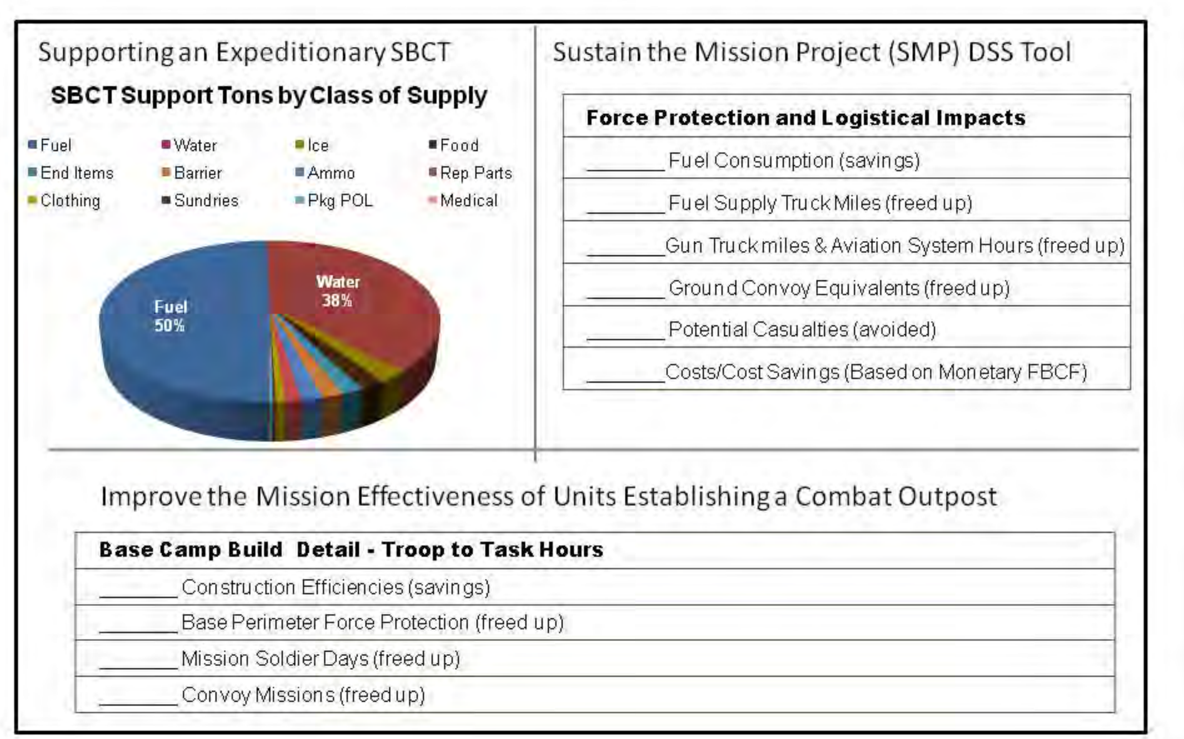


Figure 15. Elements of Sustainability

There is currently no model to measure the troop-to-task hour improvement for building combat outposts. As part of the second year of the study, the team will investigate adding this to the modeling construct.

6.3 Using OPLOG Planner 7.0 To Estimate Consumption Rates for an Expeditionary SBCT

The Army CASCOM Planning Data Branch has released OPLOG Planner 7.0. CASCOM has refined the OPLOG Planner into a premier planning tool specifically designed to support operations typically associated with plans and orders for multiphase operations. The OPLOG Planner enables users to estimate mission requirements for water, ice, mail, and all classes of supply using the latest modular force structures and planning rates approved by the Deputy Chief of Staff, G–4, DA. No other planning tool gives users this Army-approved and updated logistics estimate planning data.

The ASB study team took the SBCT organization and capabilities specified in Figure 16 and assigned standard requirement codes (SRCs) to each. These SRCs were validated by CASCOM.

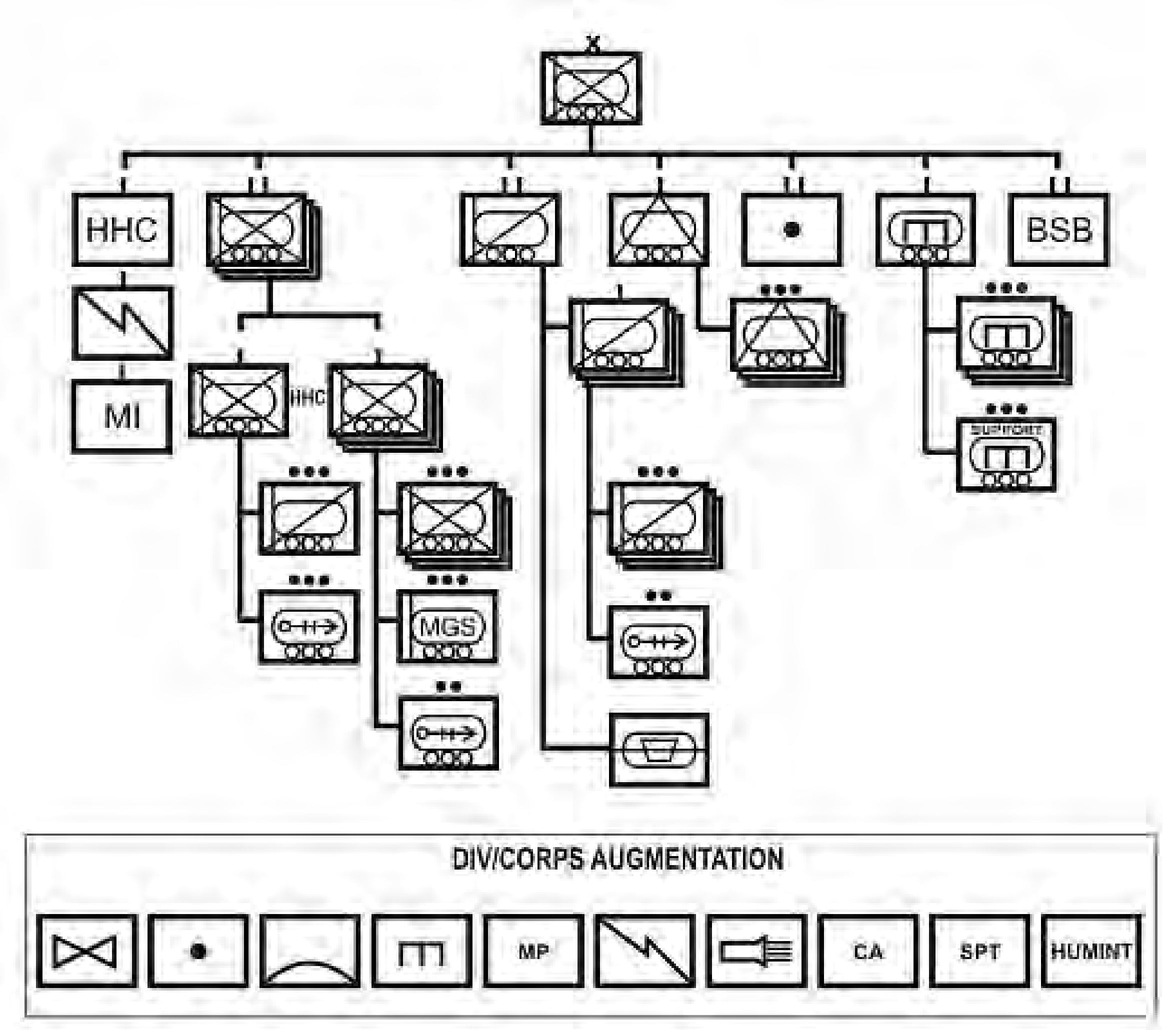


Figure 16. SBCT Organization and Capabilities

The OPLOG Planner allows the user to build multiple task organizations by using a pre-loaded list of units and equipment or by importing custom-built units that the user creates from scratch. The OPLOG Planner assigns each task organization a consumption parameter set, which establishes the rates, climate, joint phases (deter, seize initiative, or dominate) and Army operations (offense, defense, stability, or mission staging) necessary for the mission. The planner can use predefined default planning rates or customized rates based on unit experiences. These consumption parameter sets and task organizations form an order. The OPLOG Planner generates the logistics supply requirements that users can view for the entire operation by operational phase, by task organization, by unit, or by individual unit equipment. Each subordinate unit is then set at specific battlefield locations and distances apart.

The planner can enter specific assumptions and operating conditions for the consumption of fuel: vehicles, power generation, materiel handling, and other equipment. These will impact the required supply of class–III bulk at each node on the battlefield (Figure 17).

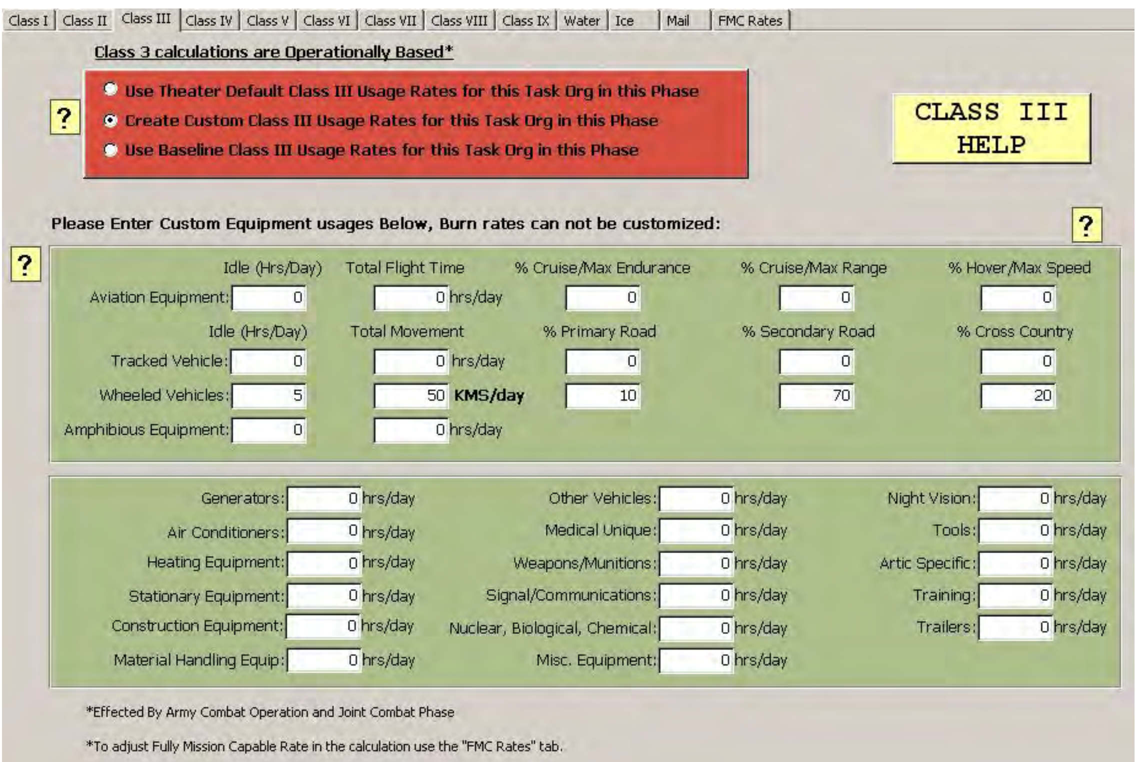


Figure 17. User Interface Data Entry Screen

Similarly, each tab enables the customization of meal cycles, bottled water consumption, shower and laundry usage, barrier equipment, and fully mission-capable rates. Water demand parameters, for example, are shown in Figure 18.

Based on the chosen parameters and baseline modeling factors, OPLOG Planner reports on the consumption at each unit and battlefield location, down to each type of equipment, if necessary. This level of detail is useful for the ASB study team to isolate the demand for power generators, aviation, and tactical vehicles from other types of equipment.

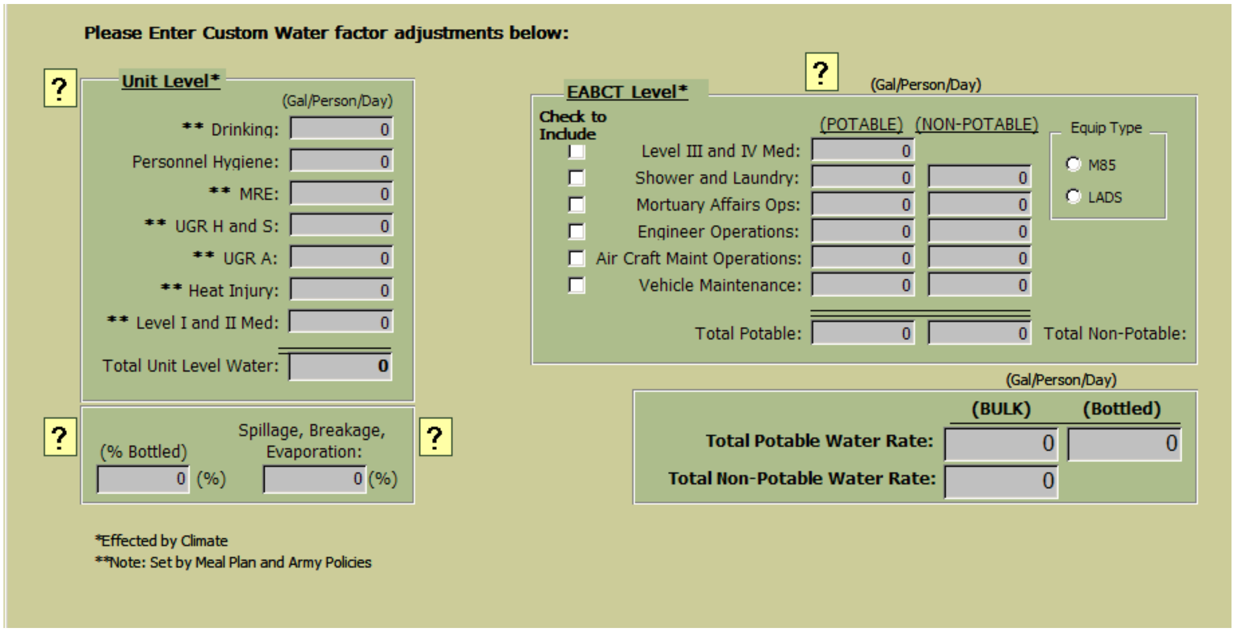


Figure 18. Data Entry Screen

Additional consumption factors include mine-resistant ambush-protected (MRAP) vehicles. Since MRAP vehicles are operating in theater but are not currently part of the structure of OPLOG Planner, these assets could be added to the SBCT based on the specific equipment density issued.

6.4 Combat Augmentation for the Stryker Brigade Combat Team Task Force

The force structure is based on adding a division-level aviation support slice from an air cavalry squadron (ACS) and general support aviation battalion (GSAB). The ACS "minus" includes one air cavalry troop (ACT), one attack helicopter troop (ATKHT), and an assault aviation troop. The squadron is dependent on the SBCT, division, or higher for Army air-space command and control (A2C2), weather, legal, finance, and sustainment functions as shown in Figure 19.

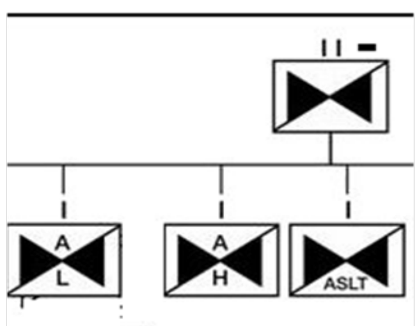


Figure 19. Air Cavalry Squadron "Minus" as Configured in ASB SBCT Task Force Model

An ACT consists of a headquarters section and two attack reconnaissance platoons of five OH–58Ds each. The ATKHT consists of a headquarters section and two attack helicopter platoons of four AH–64s each. The assault helicopter troop consists of a headquarters section, a general support platoon with seven UH–60s and a C^2 platoon with three UH–60s and two Army airborne C^2 system mission kits. The ACS gathers information about the enemy and terrain, maintains surveillance, and provides early warning of enemy contact. It provides reconnaissance, surveillance, and security of lines of communications to enhance C^2, and target acquisition for field artillery, naval surface fire support, attack helicopters, and ACS.

The GSAB minus consists of a forward support company, a heavy helicopter company, and a medical evacuation (MEDEVAC) company. The FSC has a headquarters section, a distribution platoon, and a ground maintenance platoon. The FSC provides field feeding, transportation, refueling, and ground maintenance support, and coordinates with the ASB (aviation support brigade) for additional support as required. The heavy helicopter company consists of a company headquarters and three flight platoons with four CH–47s each. The MEDEVAC company consists of a company headquarters and four air ambulance platoons. Each air ambulance platoon consists of three HH–60 aircraft and a platoon headquarters that can support 24-hour operations following the structure in Figure 20.

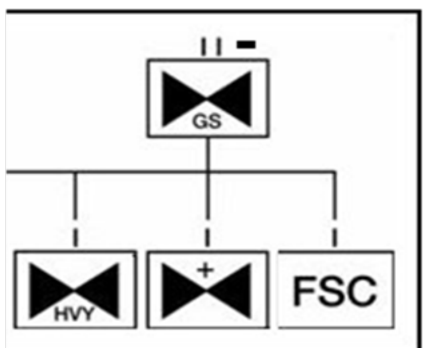


Figure 20. General Support Aviation Battalion "Minus" as Configured in ASB SBCT Task Force Model

The mission of the GSAB minus is to conduct air transport of personnel, equipment, and supplies; aerial sustainment operations; air assault operations support as required; and MEDEVAC support throughout its area of responsibility. The missions performed include:

- Air assault
- Air movement
- Aerial MEDEVAC
- Casualty evacuation
- Personnel recovery
- Downed aircraft recovery
- Air traffic services
- Forward arming and refueling point (FARP) operations

Because of the CH–47's characteristics, heavy helicopter units can perform two unique sub-missions: high-altitude operations and oversized, heavy, and special munitions movement.

6.5 Sustain the Mission Project Decision Support Tool

The SMP decision support tool is capable of calculating the fully burdened cost of fuel (FBCF) and energy to sustain Army missions in theaters of operation and the training base, and for conducting the CBA of investments in energy technologies (and energy-impacting technologies) based on FBCFs. The SMP methodology includes the costs of fuel, equipment, personnel, inter- and intra-theater transportation, force protection, and other costs related to providing fuel to a consuming Army unit. Using the FBCF will enable more informed decisions regarding investments in sustainable energy technologies that provide essential support to Army missions. The SMP fully burdened cost of fuel and fully burdened cost of energy methodology has been validated by the Deputy Assistant Secretary of the Army for Cost and Economics (DASA–CE) and also complies with OSD and Army policy on the FBCF.

The key cost-benefit outputs from the G–4 SMP tool include the following:

- FBCF (monetary)
- Fuel consumption (savings)
- Potential casualties (avoided)
- Fuel supply truck miles (freed up)
- Gun truck miles (freed up)
- Aviation system hours (freed up)
- Ground convoy equivalents (freed up)
- Greenhouse gas emissions (avoided)
    - Payback period
    - Net present value

In the SMP tool, the monetary FBCF is presented using two metrics. The first is the total cost of fuel per year using the FBCF methodology for each technology being compared. The second is a dollar-per-gallon cost of fuel for each technology being compared using the FBCF. The following are SMP cost components for the monetary FBCF:

- Force protection from ground (e.g., MRAP) and aviation systems (e.g., Apache).
- Transport on an inter-theater basis (initial deployment from an installation to a theater and return), intra-theater basis (fuel resupply convoys in theater), and ports of embarkation (usually in the continental United States (CONUS) and debarkation (in theater).
- Energy support military personnel (e.g., quartermaster) in BCT or unit.
- Energy support materiel (e.g., fuel storage, distribution) in BCT or unit.
- Sustainment brigade/theater support command (theater-level assets that support several BCTs or units).

- Energy commodity (the actual fuel itself) and garrison facilities (fuel storage and distribution facilities at installations).

SMP provides an analytic capability for collectively evaluating the costs and benefits of investing in an energy technology for applications in support of operational missions based upon FBCFs. It does not address key cost-benefit factors such as combat or operational effectiveness (e.g., lethality), logistics performance (e.g., maintainability), and safety or environmental factors (e.g., stealth). But SMP does provide the potential linkages for some of the benefit factors to be incorporated into a combat/combat support model. For example, an energy technology that consumes less fuel reduces fuel resupply convoys and therefore frees up convoy force protection assets, such as gun trucks and Apaches, which could then be reapplied to other mission requirements in a combat/combat support model.

6.6 Illustrative Preliminary Outputs

The notional scenario seen in Figure 21 was used to depict consumption demands at each organizational level. The daily tonnage numbers in the SBCT brigade area include the tonnage that then has to flow down to the battalion area. The battalion includes the tonnage that has to flow to the company area, and the company area includes the tonnage that has to flow to the lowest level element, the outpost. That flow has not been modeled from CONUS to the SBCT. This SBCT flow was then taken into the SMP model to determine the fully burdened cost of fuel throughout the SBCT. In the second year, this model will show the cost of moving the consumables in terms of the assets required to move the commodity and the security

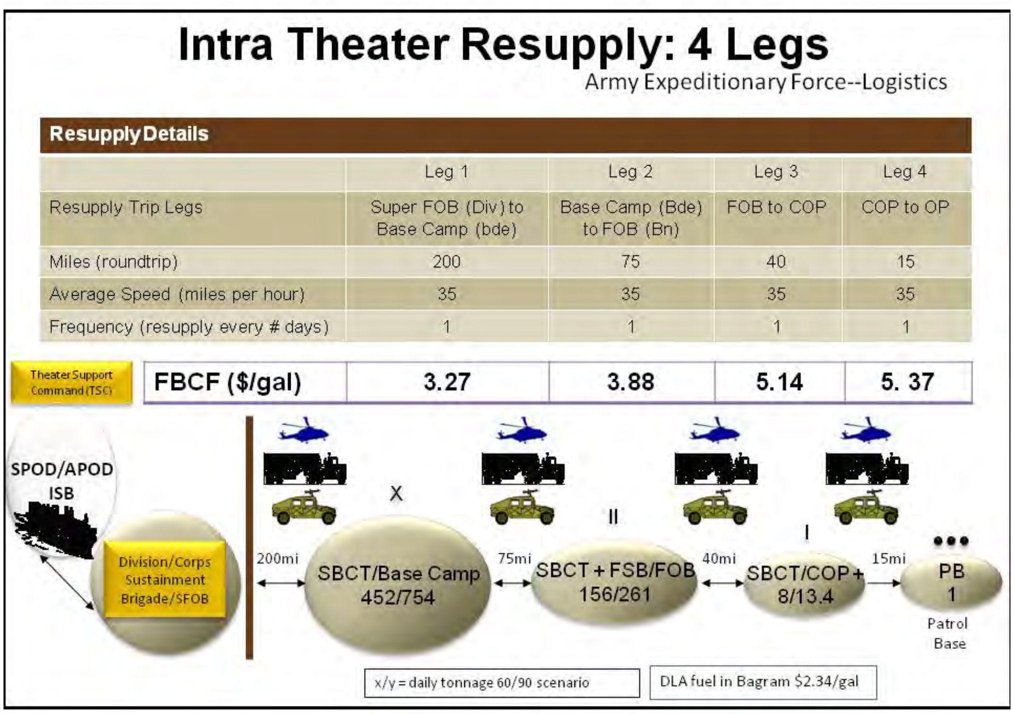


Figure 21. Resupply Problem Defined

of the assets, surface and air. The model will also reflect the impacts of specific technologies in each operational area. The FBCF in this scenario is 2.3× the cost of fuel at the farthest point from the DLA delivery point in Bagram. That multiplier would increase in other more stressful scenarios. The second year should expand this to other brigade-level scenarios to further illustrate impacts.

7.0 FUTURE TECHNOLOGIES

In year 2 of this study, a team will investigate potential future technologies that could enable increased force sustainability in the mid term (6–15 years) and far term (16–25 years). This chapter describes several candidate technologies that will be addressed in greater detail as the study progresses (Table 3).

Table 3. Example Technology Areas for Further Study

Technology Area	Application Example	Objectives, Status
Advanced battery power	Radios, sensors, computers	Significant increase in storage densities
Fuel cells	Vehicles, replace generators	Use of JP–8
Unmanned systems	Security, resupply, situational awareness, robotic tasks	Integration into operational systems
Hybrid technology	Vehicles	Cost reductions
Water sources	Reduce convoy resupply	Recycling, In situ development
Micro-grid	BC power	In development
Modular construction	BC construction	Various methodologies and concepts
Alternative sources including solar and APUs	BC power, vehicles, combat outposts	Need technological breakthroughs

For ease of discussion, the technology areas will be studied and reported in the final report (August 2011) as follows:

- Battery power sources for the soldier
- Fuel cells
- Hybrid propulsion systems
- Unmanned systems
- Power and energy control systems
- Water supply
- BC construction
- Logistics

Key needs have been identified in a number of areas. Since petroleum (power generation) and water account for more than 80 percent of unit resupply volume after initial combat, these are two of the more important areas for identifying future technologies to increase force sustainment. Other areas to which future technologies can contribute include air resupply, ground platforms, unmanned systems, BC construction, and logistics systems (e.g. tagging, tracking, automation).

It's important, however, that future technologies not be addressed in isolation, but in the context of the overall system in which they will be employed. For example, fuel cells offer a quiet and fuel-efficient alternative to JP–8-powered generators. They have been installed as part of demonstration programs at several Army installations and have proven successful. However, current-generation fuel cells utilize simple fuels, such as hydrogen, methanol, or propane, and reformer technology that would permit use of JP–8 is immature. Until reformer technology is advanced to the point that it is compatible with the Army's common fuel, BC-class fuel cell generators will most likely not be adopted for Army use. Other examples might include reduced water resupply due to water generated as a byproduct of fuel cell operation; reduced resupply resulting from waste management technologies (e.g., recycling water, using waste for power generation); and robotics to handle routine tasks, potentially reducing manpower and thus logistics.

8.0 YEAR 1 CONCLUSIONS AND RECOMMENDATIONS

In completing the initial year of the 2-year study, the following principal conclusions and recommendations are suggested for this interim report:

Principal Conclusions

- Significant demand reductions are achievable.
- A more effective and efficient supply chain is needed, especially for environments including major areas with complex terrain and active insurgencies.
- Increases in soldier "time outside the wire" without an increase in COP personnel can be accomplished.

Recommendations

- Encourage the use of onsite water sources and recycling methods to help reduce the amount and the frequency of resupply.
- Implement the use of more modern and efficient (leverage commercial propulsion advancements) engines, hybrid engines, and fuel cells for energy demand reductions.
- Monitor metrics, such as payload delivered per pound of fuel, tons delivered per person in the transport unit, and total number and size of convoys required for resupply, to help track consumption recommendations.
- Encourage leadership and training to make concerted efforts to conserve water and fuel. This action alone could lead to a 15 percent reduction in water and fuel delivery demand and a reduction in the number of convoys necessary for resupply.
- Provide the means for soldiers to accelerate construction of the smaller unit base camps, combat outposts, and patrol bases.

Discussion

The Army can improve the resiliency and reduce the size of the sustainment effort needed for its current expeditionary forces. Many of the actions recommended above can begin now with little or no cost impact and will reduce the tonnage demand of the two largest consumable commodities: fuel and water. Figures 22 and 23 illustrate potential aggregate tonnage savings in the near and mid terms.

Although most of the recommendations focus on efficiencies and consumption savings to some segment of the BCT, there are secondary and tertiary—or "aggregating" effects—that can be realized. For example, recycling of shower water reduces water demand, which potentially reduces water trucks, truck drivers, number of convoys and their associated security and risks to the warfighters. A similar analogy can be made for fuel. Again, less consumptions equates to fewer tanker convoys and less risk to the personnel. Also, with reduced requirements for convoys of fuel and water, fewer support personnel are needed in theater.

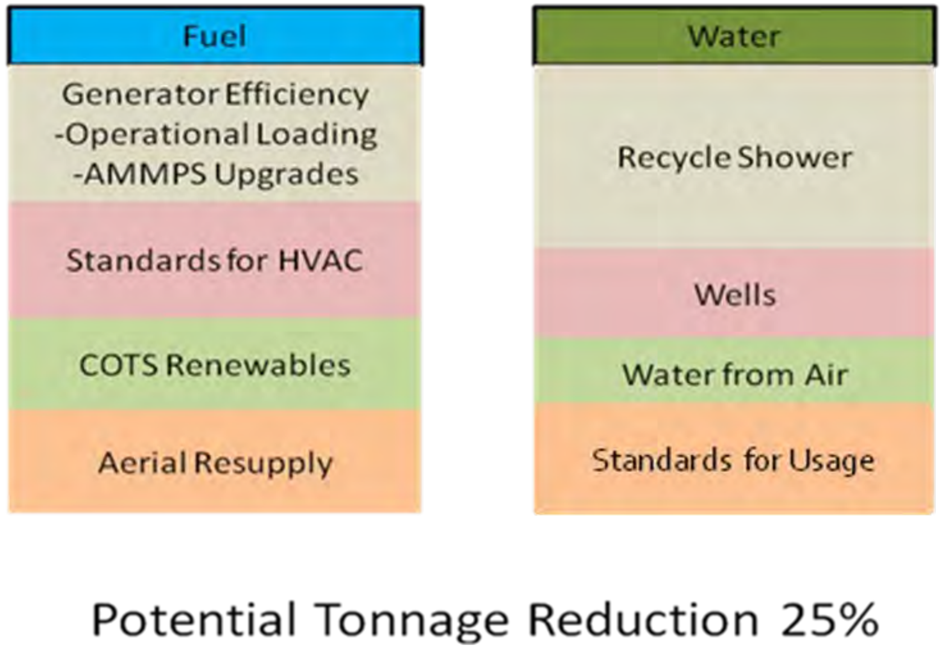


Figure 22. Near Term Fuel and Water Uses That Offer Potential Weight Savings

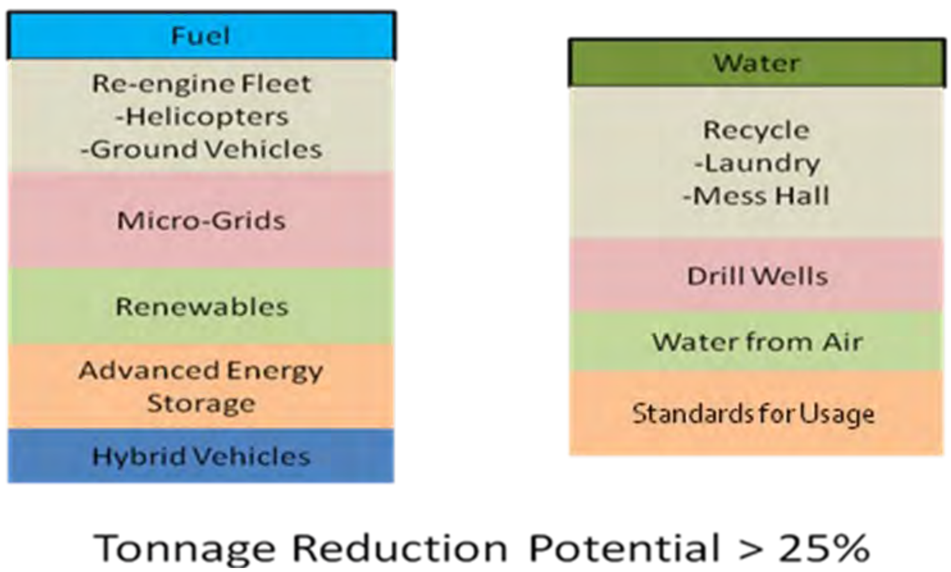


Figure 23. Mid Term Fuel and Water Uses That Offer Potential Weight Savings

Improvements in the effectiveness and efficiency of delivery of supplies will also reduce the sustainment tonnage required for expeditionary forces. However, the impact of delivery efficiency on sustainment tonnage is significantly less in size and benefit than demand reduction for the near term. Even so, enhancements in delivery efficiency such as longer range VTOL aerial resupply and robotics will provide disruptive benefits to future combat effectiveness in the mid and long term. More investment appears needed to accelerate these technologies and will be discussed in the final report.

Prototype kits for renewal energy and to recycle and purify water are ready to be deployed. Continued improvements in these technologies will potentially reduce frequency and size of routine resupply shipments to the smaller patrol bases.

Year 2 will focus on new technology that is or will become ready to move from the laboratories to the theater. There is need to understand which technologies will be the enablers to improving the overall resilience of the Army's small units when deployed in combat outposts or patrol bases. Significant progress is being made in renewable energy efficiencies, affordability, and packaging as well as improvements in energy storage. Along with unit cost and weight reductions these are expected to reduce the sustainability requirements as they become available.

9.0 THE WAY FORWARD

Since this study is being executed over 2 years, the board will be able to probe deeper, analyze alternatives with models, and conduct wider investigations into the major issues. Traditionally, the ASB conducts studies from January to July, as accomplished for the first part of our study. This study will also have additional study periods: fall/winter (August–December) and spring/summer (January–July). Five areas of study are being mapped out:

- A closer look at BCs capabilities and efficiencies.
- Significant airlift capability improvements.
- Enhanced situational awareness options for commanders to manage energy and consumables.
- Investigation of future high-payoff technology improvement opportunities.
- Exercise experimental expeditionary BCT for technology insertions.

From the TOR, there are deliverables due at the end of the study:

- Present recommendations enhancing future expeditionary brigades and their associated support elements by reducing logistical requirements and options for improving sustainment for full-spectrum military operations.
- For two or three "tier 1 recommendations," create top-level implementation roadmaps (with timeframes) for future expeditionary brigades (and associated support):
    - Reduce logistics requirements
    - Provide sustainment options
    - Support full-spectrum military operations

The key to the next effort is that the study team is focusing on the expected deliverables and looking into the future for potential savings. The first new task is to understand, develop, and refine roadmaps to implement the recommendations. Each area of detailed study will present a roadmap that shows activities, broken out by timeframes, leading to the goals established early in the next 6-month period. Figure 24 shows the thrusts that are being accomplished and the focused efforts in the March–May 2011 time period.

During the next 12 months, the current teams will work to define the year-1 results and refine the analysis on those topics. In addition, the modeling team will go from the initial "runs" during year 1 to the stage where the model is validated for the "problem" of reducing the logistics footprint for an expeditionary BCT. Once the second-year efforts are initiated, two teams will be established to fulfill the requirements of the study and ensure that the mid and long term years are the focus of the efforts.

In order to address the year-2 issues and plan, the team has formed the following subteams:

- Roadmap Development Team (oriented around major benefit goals)
- Future Technology Assessment Team (oriented toward the 6–25-year technologies)

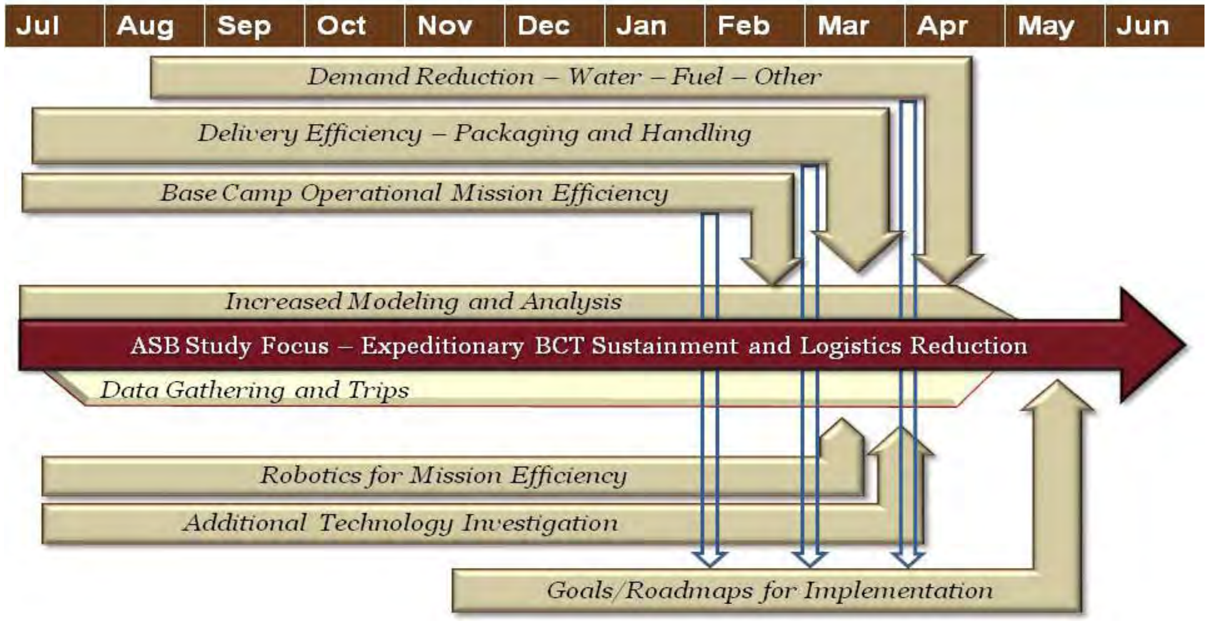


Figure 24. Activity Chart

APPENDIX A: TERMS OF REFERENCE

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY OF THE ARMY
ACQUISITION LOGISTICS AND TECHNOLOGY
103 ARMY PENTAGON
WASHINGTON, DC 20310-0103

MAY 18 2010

Dr. Frank H. Akers, Jr.
Chairman, Army Science Board
2511 Jefferson Davis Highway
Arlington, Virginia 22202

Dear Dr. Akers:

I request that the Army Science Board conduct a study entitled "Strengthening Sustainability and Resiliency of a Future Force." The study should be guided by, but not necessarily limited by, the Terms of Reference described below.

The purpose of the study is to provide findings, recommendations, and feasibility (including top-level technical, operational and investment/funding considerations) on the following topics:

a. High payoff technologies and innovations to reduce sustainment demand and the frequency a unit needs resupply.

b. Nonorganic support (e.g., joint, allied or commercial reach-back capabilities), which could increase tactical unit capabilities and robustness while reducing personnel footprint in forward areas;

c. Opportunities in which the deployed brigade can use local assets to satisfy requirements, thus reducing logistics demand; and

d. Other Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities changes and management methods and tools including "time-phased/progressive" energy and "tactical unit" durability goals with solutions strategies and feasibility assessments (including top-level technical, operational and investments/funding considerations).

Background: Forward deployed Army units invoke a substantial sustainment demand for fuel, water, and other classes of supply. Any improvement in forward demand rates would have a strong impact on the sustainment system and act as an enabler to enhance future force agility and flexibility in uncertain complex environments. Large sustainment requirements generate associated costs in terms of both funding and human casualties, and effectively limit options, thus, reducing resiliency and flexibility, while increasing vulnerability. The Army has an array of opportunities to improve the operational endurance, effectiveness, and tactical flexibility of future forces. These improvements can be implemented incrementally in a time phased plan or roadmap. Each improvement in the logistical endurance of tactical forces will reduce the amount of consumables needed and the amount of high risk exposure time of forces involved in resupply efforts. Further, these improvements will increase the operational reach and independence of the tactical forces; i.e., increase the maneuver commander's freedom of operations across the Joint Operational Area 2010.

Recent strategic analyses predict a future era of persistent conflict with a high degree of complexity and uncertainty. The Joint Forces Command and U.S. Army Training and Doctrine Command Operational Environments investigations indicate an array of conflict possibilities that include a potential mix of simultaneous actions including innovative hybrid threats. Analysis of future global operations across the "Arc of Instability" point toward distributed operations involving full spectrum operations in under-developed regions or in complex terrain conditions. These strategic assessments predict a continued trend away from major combat operations conducted within reach of major seaports–historically enjoying generous deployment schedules-to distributed operations involving lower intensity conflict and stability operations "in urban settings or harsh, inaccessible lawless areas." (Operational Environment 2009-2025, U.S. Army Training and Doctrine Command, v6, p. 8, January 2009) the Army must establish capabilities to deploy quickly and operate reliably in areas with little existing transportation and logistics infrastructure, such as sub-Saharan Africa, Central Asia and South America.

Scope: This study will identify and assess enhancements to future expeditionary brigades and their associated support elements to reduce the logistics requirements and provide sustainment options to support full-spectrum military operations. The report will outline for each recommendation a top level implementation roadmap and estimated timeframe (near-term 0-6 years (Budget and Program Objective Memorandum); mid-term (7-15 years) and far-term (16-25 years)) for incorporation into the force. Changes will draw from all DOTMLPF domains.

Study Sponsorship: Sponsors for this study are the Deputy Chief of Staff, G4 of the Army and the Deputy Commanding General, Futures/Director, Army Capabilities Integration Center, U.S. Army Training and Doctrine Command.

Study Duration: The study is expected to conclude in 2011. An interim briefing will be provided by August 31, 2010, after adoption by the full committee. A subsequent briefing with all findings and recommendations will be provided by August 31, 2011. The final written report will be provided by October 15, 2011.

The study will operate in accordance with the Federal Advisory Committee Act, and Department of Defense (DoD) Directive 5105.4, the "DoD Federal Advisory Committee Management program." It is not anticipated that this study will need to go into any "particular matters" within the meaning of Title 18 United States Code Section 208, nor will it cause any member to be placed in the position of acting as a procurement official.

Sincerely,

Malcolm R. O'Neill
Assistant Secretary of the Army
(Acquisition, Logistics and Technology)

APPENDIX B: PARTICIPANTS LIST

APPENDIX B – PARTICIPANT LIST

Army Science Board

2010 Summer Study

Strengthening Sustainability and Resiliency of a Future Force

Study Participants

Study Chairs

Mr. Robert Dodd

Dr. Jeanette Jones

BG (Ret) Robert Wynn

Panel Members

Dr. Edward Allen Adler
Mr. John R. Barnes
Mr. Anthony J. Braddock
Mr. William S. Crowder
Dr. Philip C. Dickinson
MG (Ret) Paul L. Greenberg

Ms. Helen Greiner
Dr. Steven E. Kornguth
Mr. Richard Ladd
Dr. Thomas L. Landers
Dr. Walter F. Morrison
LTG (Ret) Max W. Noah

Dr. Ivan A. Somers
Dr. Peter Swan
Mr. David W. Swindle, Jr.
COL (Ret) Charles A. Vehlow
Dr. Christopher B. Wallace
LTG (Ret) John W. Woodmansee, Jr.

Study Support

Study Manager
Dr. Leonard Braverman
Army Science Board Staff

Report Writer/Editor
Dr. Chuck Steele
USAF Academy

ROTC Support
CDT Paul DeLongchamp, Alabama A&M

Study Analyst
Mr. Bill Bryson, Dynetics

Analysis Support
Mr. Steve Siegel, ESG
Mr. Scott Dicke, ESG

Army Support
COL Paul Roege, TRADOC Liaison
Mr. Tom Bruen, HQDA G4 Liaison
Mr. Mark Leno, HQDA G4 Liaison
MAJ Jayme Smith, ASA(ALT)
MAJ J. O'Sadnick, Rock Island Arsenal
1SG (Ret) T. Haddad, Natick SSA
Mr. William Fisher, AMSAA
Mr. Peter Dymond, AMSAA

APPENDIX C: ABBREVIATIONS

APPENDIX C – ABBREVIATIONS

A

A2C2	Army Airspace Command and Control
AC	active component
ACS	air cavalry squadron
ACT	air cavalry troop
AFRL	Air Force Research Laboratory
AGC	Army Geospatial Center
AH–64	Attack Helicopter 64; Boeing Apache
AIPS	Advanced Integrated Power System
AMC	Army Materiel Command
AMMPS	Advanced Mobile Medium Power Sources (generator class)
AMSAA	Army Materiel Systems Analysis Activity
APG	Aberdeen Proving Ground
APOD	aerial port of debarkation
APU	auxiliary power unit
ARCENT	Army Central Command
ARCIC	Army Capabilities Integration Center
ARDEC	Armament Research, Development and Engineering Center
ARFORGEN	Army Force Generation
ARL	Army Research Laboratory
ARMDEC	
ASA(ALT)	Assistant Secretary of the Army for Acquisition, Logistics and Technology
ASA(I&E)	Assistant Secretary of the Army for Installations and the Environment
ASB	Army Science Board; Aviation Support Brigade
ATHKT	attack helicopter troop

B

BC	base camp
BCT	brigade combat team
BCU	base camp utility
Bde	brigade
BEB	brigade engineer battalion
BETSS–C	Base Expeditionary Targeting and Surveillance Systems–Combined
BLUF	bottom-line up front
Bn	battalion
BTU	British thermal unit

C

C	Celsius
C^2	command and control
CASCOM	Combined Arms Support Command
CBA	cost-benefit analysis
CERDEC	Communications–Electronics Research and Development Center
CERL	Construction Engineering Research Laboratory
CG	commanding general
CH–47	Cargo Helicopter 47; Boeing Chinook
CJCS	Chairman of the Joint Chiefs of Staff
COCOM	combatant commander
CoE	center of excellence
CONOPS	concept of operations
CONUS	continental United States
COP	combat outpost
COTR	contracting officer's technical representative
COTS	commercial off the shelf
CR	common rail (modern variant of direct fuel injection system)
CROWS	Common Remotely Operated Weapon System
CS/CSS	combat support/combat service support

D

D2	A class of diesel fuel with a much lower sulfur content than JP–8
DA	Department of the Army
DARPA	Defense Advanced Research Projects Agency
DASA–CE	Deputy Assistant Secretary of the Army for Cost and Economics
DCG	deputy commanding general
DLA	Defense Logistics Agency
DoD	Department of Defense
DOE	Department of Energy
DOTMLPF	doctrine, organization, training, materiel, leadership and education, personnel, and facilities
DSB	Defense Science Board
DSS	DLA Support Services

E

ECU	
ERDEC	Edgewood Research, Development and Engineering Center
EWPS	Expeditionary Water Packaging System

F

F	Fahrenheit
FARP	forward arming and refueling point
FBCB2	Force XXI Battle Command Brigade and Below
FBCF	fully burdened cost of fuel
FCS	Future Combat System
FMTV	family of medium tactical vehicles
FOB	forward operating base
FP	Force Provider (program)
FSA	Functional Solution Analysis
FSC	Forward Support Company (subset of Aviation Brigade)
ft^3	cubic foot

G

G–4	Deputy Chief of Staff for Logistics
GCSS	Ground Combat Support System
GCV	Ground Combat Vehicle
GD	General Dynamics
GE	General Electric
GM	General Motors
GMR	Ground Mobile Radio
GSAB	general support aviation battalion
GSL	Geotechnical and Structures Laboratory

H

HBCT	Heavy Brigade Combat Team
HEMTT	Heavy Expanded Mobility Tactical Truck
HESCO	HESCO Bastion Ltd. produces Concertainer, a barrier for flood control and military fortification
HET	heavy equipment transporter
HETR	high efficiency tilt-rotor
HH–60	MEDEVAC company "air ambulance" helicopter; Sikorsky Pave Hawk
HMMWV	High Mobility Multipurpose Wheeled Vehicle
hp	horsepower
HQDA	Headquarters, Department of the Army
HVAC	heating, ventilating, and air conditioning

I

IBCT	Infantry Brigade Combat Team
ICDT	Integrated Concept Development Team
IED	improvised explosive device
IMCOM	Installation Management Command
in^3	cubic inch
ISA	International Standard Atmosphere
ISB	intermediate staging base
ISR	intelligence, surveillance and reconnaissance

J

JCA	joint cargo aircraft
JCIDS	Joint Capability Integration Development System
JCS J4	Joint Chiefs of Staff, Logistics
JFCOM	Joint Forces Command
JFTL	Joint Future Theater Lift
JHL	joint heavy lift
JIIM	joint, interagency, inter-governmental, and multinational
JLTV	Joint Light Tactical Vehicle
JOA	joint operational area
JP–8	jet propellant 8; used as a fuel for heaters, stoves, tanks, by the U.S. military as a replacement for diesel fuel in the engines of nearly all tactical ground vehicles and electrical generators, and as a coolant in engines and some other aircraft components
JPADS	Joint Precision Airdrop System
JRAC	Joint Rapid Acquisition Cell
JTRS	Joint Tactical Radio System

K

KPP	key performance parameter
kW	kilowatt

L

LIA	Logistics Innovation Agency
LMI	Logistics Management Institute
LOGCAP	Logistics Civil Augmentation Program

LWN	LandWarNet
LZ	landing zone

M

MEB	maneuver enhancement brigade
MEDEVAC	medical evacuation
MEP	Mobile Electric Power
MOG	maximum on ground
MORS	Military Operations Research Society
MOS	Military Occupational Specialty
MPS	Modular Protective System
MRAP	mine-resistant ambush-protected (vehicle)
MSCoE	Maneuver Support Center of Excellence
MVM	mounted vertical maneuver
MW	megawatt
MWR	morale, welfare, and recreation

N

NCOES	Noncommissioned Officer Education System
NDI	nondevelopmental item(s)
nmi	nautical mile
NSRDEC	Natick Soldier Research, Development and Engineering Center

O

O&M	operations and maintenance
OASD (I&E)	Office of the Assistant Secretary of Defense for Installations and the Environment
OEF	Operation Enduring Freedom
OH–58	Observation Helicopter 58; Bell Kiowa
OIF	Operation Iraqi Freedom
OPLOG	Operational Logistics
OPMODSUM	Operational Mode Summary
OPTEMPO	operations tempo
ORNL	Oak Ridge National Laboratory
OSD	Office of the Secretary of Defense

P

PA	pressure altitude
PAWS	petroleum and water systems
PB	patrol base
PEO	program executive office
PM	program manager
POL	petroleum, oil and lubricants
POM	Program Objective Memorandum

R

R&D	research and development
RAID	Rapid Aerostat Initial Deployment (tower)
RC	reserve component
RDA	research, development, and acquisition
RDEC	research, development and engineering center
RDECOM	Research, Development, and Engineering Command
RDTE	research, development, testing and engineering
ROE	rules of engagement

S

S&T	science and technology
SBCT	Stryker Brigade Combat Team
SCoE	Sustainment Center of Excellence
SCUBC	small combat unit base camp
SFOB	Special Forces operational base
SINCGARS	Single-Channel Ground and Airborne Radio System
SL	sea level
SME	subject-matter expert
SMP	Sustain the Mission (Project)
SPOD	seaport of debarkation
STOVL	short takeoff/vertical landing
SWaP C	size, weight and power, cooling

T

TAA	Total Army Analysis
TACOM	Tank–Automotive Command
TARDEC	Tank–Automotive Research, Development and Engineering Center
TOC	tactical operations center
TOE	table of organization and equipment
TOR	Terms of Reference
TRADOC	Training and Doctrine Command
TRANSCOM	Transportation Command
TRL	technology readiness levelTSC
TTP	tactics, techniques and procedures

U

UAS	unmanned aerial system
UAV	unmanned aerial vehicle
UH–60	Utility Helicopter 60; Sikorsky Black Hawk/Pave Hawk
USACE	U.S. Army Corps of Engineers

V

VCJCS	Vice Chairman of the Joint Chiefs of Staff
VCSA	Vice Chief of Staff, Army
VTOL	vertical takeoff and landing

W

Wh	watthour
WIN–T	Warfighter Information Network–Tactical
WO	warrant officer
WRDB	Water Resource Database

APPENDIX D: JULY 2010 STUDY BRIEFING TO SPONSORS

2010 Army Science Board Summer Studies

Strengthening Sustainability and Resiliency of a Future Force

Study Co-Chairs
Mr. Robert Dodd
Dr. Jeanette Jones
BG (Ret) Robert Wynn

22 July 2010

Briefing Outline

- ***Introduction***
- BLUF & Outline of Process
- Issues – Findings – Recommendations
  - Demand Reduction
  - Delivery Improvement
  - Operations Improvement
- Modeling and Analysis
- Way Ahead – Year 2

Terms of Reference (Extract)

- Provide findings, recommendations, feasibility on following topics by timeframe (0-6 yr, 7-15 yr, 16-25 yr):
  - Technologies and innovations to reduce sustainment demand and frequency of resupply
  - Nonorganic support that could increase capabilities while reducing footprint
  - Opportunities to use local assets to reduce demand
  - Other (DOTMLPF) changes and management methods and tools including "time-phased/progressive" energy and "tactical unit" durability goals with solutions strategies and feasibility assessments

2010 Army Science Board Summer Study 3

Study Parameters

- Study Sponsors:
  - Deputy Chief of Staff G-4 of the Army
  - Deputy CG, Futures/Director, ARCIC, US Army TRADOC
  - Deliverables:
- Year 1: Approved, Interim Annotated Briefing and Written Report
  - Preliminary findings and recommendations
  - Recommended areas to be further developed in Year 2
- Receive Guidance from Study Sponsors for Year 2 Work
- Year 2: Final Briefing and Written Report
  - Updated methodology to include metrics and processes used for feasibility
  - Updated findings and recommendations w/analytical underpinnings
    - Time-phased/progressive energy and tactical unit durability goals
    - Solutions strategies, feasibility assessments, and roadmaps

2010 Army Science Board Summer Study 4

Study Members

Strengthening Sustainability and Resiliency of a Future Force

Study Members		
Study Chairs Mr. Robert Dodd Dr. Jeanette Jones BG (Ret) Robert Wynn Dr. Edward Allen Adler Mr. John R. Barnes Mr. Anthony J. Braddock Mr. William S. Crowder	Dr. Philip C. Dickinson MG (Ret) Paul L. Greenberg Ms. Helen Greiner Dr. Steven E. Kornguth Mr. Richard Ladd Dr. Thomas L. Landers Dr. Walter F. Morrison LTG (Ret) Max W. Noah	Dr. Ivan A. Somers Dr. Peter Swan Mr. David W. Swindle, Jr. COL (Ret) Charles A. Vehlow Dr. Christopher B. Wallace LTG (Ret) John W. Woodmansee, Jr.

Study Support		
Study Manager Dr. Leonard Braverman	***Report Writer/Editor*** Dr. Chuck Steele, USAF Academy ***ROTC*** CDT Paul DeLongchamp, Alabama A&M ***Study Analyst*** Mr. Bill Bryson, Dynetics ***Analysis Support*** Mr. Steve Siegel, ESG Mr. Scott Dicke, ESG	***Army Support*** COL Paul Roege, TRADOC Liaison Mr. Tom Bruen, HQDA G4 Liaison Mr. Mark Leno, HQDA G4 Liaison MAJ Jayme Smith, ASA(ALT) MAJ J. O'Sadnick, Rock Island Arsenal 1SG (Ret) T. Haddad, Natick SSA Mr. William Fisher, AMSAA Mr. Peter Dymond, AMSAA

Information Sources

Army
HQDA VCSA
HQDA G-4/LIA
HQDA OASA(I&E)
TRADOC ARCIC
CASCOM
ARL
Army Contracting Command
TACOM/TARDEC/PM PAWS
PEO Integration
PEO GCS
Natick (NSRDEC/PH-FSS)
PM MEP
Maneuver Support CoE
Rapid Equipping Force
AMRDEC

Army Cont.
Army Sustainment Cmd
Picatinny/ARDEC
Army Geospatial Center
ERDEC-CERL/GSL
249 Eng Bn (Prime Power)

DoD
JFCOM
DARPA
USMC
JCS J-4
USN
TRANSCOM
DLA

Industry
Honeywell
Boeing
Oshkosh
Caterpillar
LMI
ITT
GD Land Systems
GE
GM

Other
Dept of Energy
ORNL

Briefing Outline

- Introduction
- ***BLUF & Outline of Process***
- Issues – Findings – Recommendations
  - Demand Reduction
  - Delivery Improvement
  - Operations Improvement
- Modeling and Analysis
- Way Ahead – Year 2

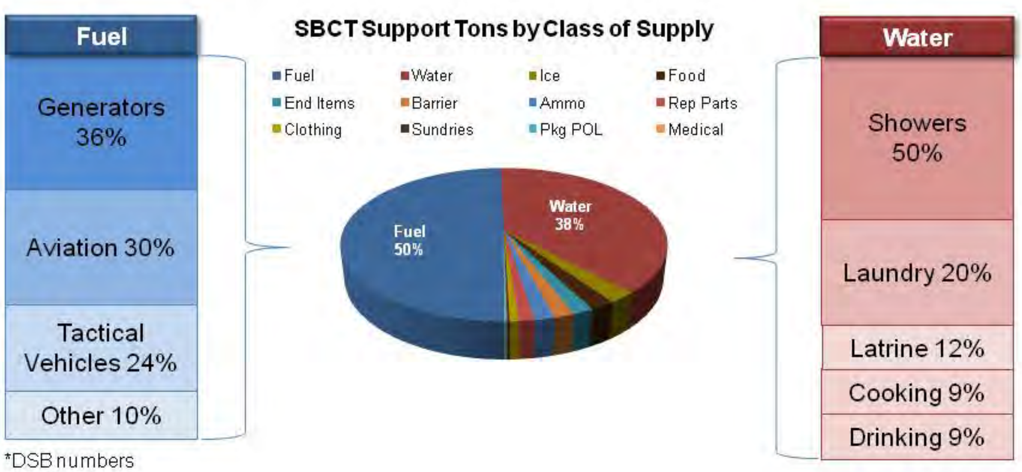
Study Team's Approach

- Review similar studies
- Review Operational Army's activity and plans
  - Comment on areas of substantial difference
  - Comment on areas requiring increased emphasis
  - Silent when in agreement
  - Recommend technologies/innovations not found thus far in Army's activities
- Evaluate via modeling (year 2)

Logistics Analysis Dimensions

- Three Timeframes
  - Near Term 0-6 years
  - Mid Term 7-15 years
  - Long Term 16-25 years
- Four Echelons
  - Super Forward Operating Base 2,000+ people
  - Forward Operating Base 600+ people
  - Combat Outpost 150+ people
  - Patrol Base ~60 people
- All DOTMLPF Domains

Logistics Tonnage



*DSB numbers

Near Term Opportunities

Fuel	Water
Generator Efficiency - Operational Loading - AMMPS Upgrades	Recycle Shower
Standards for HVAC	Wells
Shelter Insulation	Water from Air
COTS Renewables	Standards for Usage

Potential Tonnage Reduction 25%

Mid/Long Term Prospects

Fuel	Water
Re-engine Fleet - Helicopters - Ground Vehicles	Recycle - Laundry - Dining Hall
Micro-Grids	Water From Exhaust
Renewables	Black Water Reuse
Aerial Resupply	Advanced Filtration and Purification
Hybrid Vehicles	

Tonnage Reduction Potential >25%

BLUF Actions for Immediate Implementation

Near Term Tonnage Reductions 25%

- Accelerate fielding of existing technologies (ASA(ALT))
  - Fuel: AMMPS generators and micro-grids; renewables (solar water treatment and battery chargers); insulation of living facilities
  - Water: Shower recycling and water from air
- Develop standards/measures for conservation of water and fuel, train conservation awareness and ensure compliance (TRADOC)
- Increase drilling and water recycling capability (ASA(ALT))

High Impact for Mid/Long Term Reductions

- Accelerate aerial resupply initiatives (UAS, Heavy-Lift VTOL, enhanced UH-60 performance) (ASA(ALT))
- Increase funding for re-engine, micro-grids, water recycling and renewable sources of energy

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Base Camps Are "Platforms" To Support Unit Missions

- The Army has made significant progress in the base camp domain
- There are four basic levels of base camps:
  - Contingency main base/contingency operations base – "Super FOB"
  - Forward operating base – "FOB"
  - Combat outpost – "COP"
  - Patrol base – "PB"
- Two primary issues:
  - Proponency for base camp utility (BCU)
  - Logistics efficiencies in BCUs
- Base camp utilities include:
  - Electrical Power
  - Water
  - Structures
  - Security

More Efficient Utilities a Key Factor

Base Camp Electric Power

Findings
DSB cited generators as largest user of fuel (36%)
Current design and sizing for power is ad hoc
Maneuver Support Center of Excellence responsible for Prime Power Program with USACE 249th Bn (Prime Power)
ARCIC designated Sustainment Center of Excellence as power proponent
Advanced Medium Mobile Power Sources (AMMPS) reduce fuel consumption by ~21%
PM MEP is overall responsible in DoD for battlefield electric power systems

Recommendations
Incorporate MOS 210 WOs or 21P "Utility" experts into BCT TOE organizations for electric power management
VCSA assign integrated proponency for base camp power
ASA(ALT) lead acceleration of AMMPS and micro-grid systems to field

Water Recycling Capability

Findings

Recycling reduces new water demand for base camp kitchens, showers, laundries, and lavatories

New drinking water is always needed

Force Provider (FP) has shower water recycling capability
- Gray water (laundry/dining hall) recycling in RDA (TRL 3)
- Black water treatment and disposition needs RDA

Recommendations

TRADOC/ASA(ALT) Lead acceleration of fielding Force Provider

ASA(ALT) Review for adequacy RDA funding for other gray water

ASA(ALT) Determine if RDA funds should be formally provided to black water treatment and disposition

Recycling at Base Camps Saves Significantly!

Demand Reduction – Water Recycling

600-Man Force Provider Base Camp	Daily Req'd	Daily Out	Recycled Yield	Recycled Use	New Water Needed
Drinking (3+ gal/d)	1,925	----	----	----	1,925
Food Service 80%	1,925	1,375	1,100	----	1,925
Shower 80%	12,000	12,000	9,680	9,740	2,260
Laundry 80%	5,200	5,200	4,160	5,200	----
Latrine 78%	2,700	3,465			2,700
Total	23,750	22,140	14,940	14,940	8,810

Source: Force Provider

Recycling can cut new water demand by 63%

Transportation of Water Is a Major Logistical Burden

Findings
Onsite water sourcing (provision, purify, package) is best solution
Well drilling is frequently only choice to stop long-haul delivery
Army largely depends upon contractors with associated delay
Need deep well capability
Company outposts and patrol bases will likely need alternative to well drilling Water from air can immediately provide or mitigate delivery demand Provide BCTs access to small-unit water purification systems and disposable packaging Water packaging forward shortens supply chain

Recommendations
TRADOC/ASA(ALT) establish COTS water sourcing capability in the ARFORGEN-ready force to reduce convoys
Test and employ where feasible disposable packaging, such as sleeves for camelback, in lieu of water bottles

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Improve Water Management and Planning

Findings
Anecdotal evidence suggests water provisioning is "grossly effective"
Petroleum and Water Groups being deleted in TAA 12-17 Theater water management capability lost
Army Geospatial Center (AGC) maps water sources globally AGC information and staff available to help planning

Recommendations
Establish "249th-type water battalion (AC/RC)" to provide an ARFORGEN-ready force water services organization: Well drilling, Water from air, contracting and managing teams
Army component commands (w/AGC advice) review theater plans to ensure water is adequately addressed

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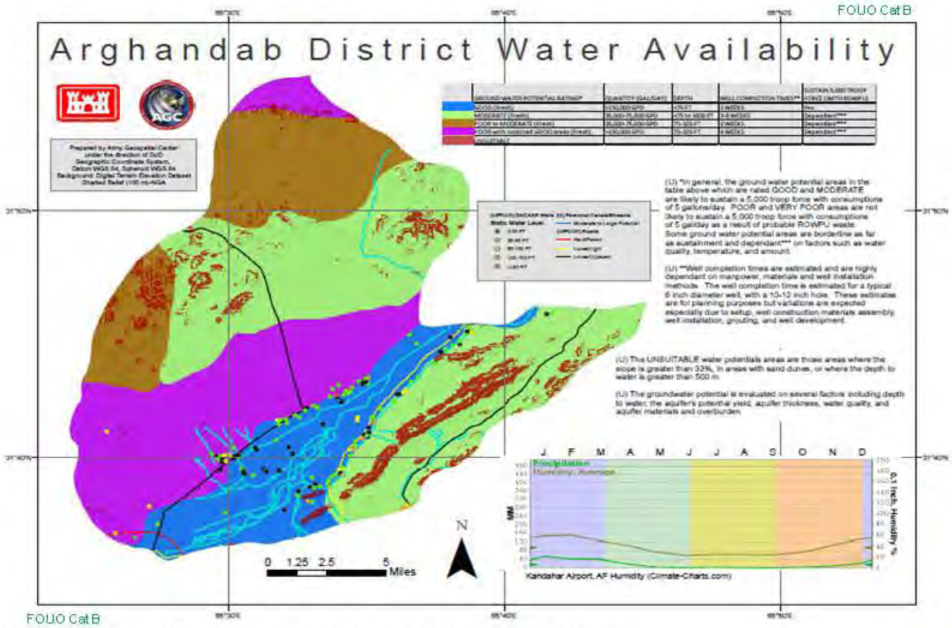
Example of Hydrological Information

FOUO Cat B



FOUO Cat B

Arghandab District, Kandahar Province, Afghanistan Water

Water Proponency

Findings
Logistics Corps is supply/distribution proponent
Today, no water production/acquisition proponent Formerly, Corps of Engineers
Others approve purity

Recommendations
VCSA designate an overall proponent for water
Designate others to participate in Integrated Capability Development Team

Base Camp Structures

Findings
Design needs consideration for energy conservation
Foaming tents save 30% to 50% in fuel consumption
No standards for HVAC design
HVAC consumes 40%-75% of electrical load
Combat outpost and patrol base barrier structure development is time consuming

Recommendations
Develop standards for energy conservation to include HVAC design, foaming of tents and design of future tents, Force Provider structures
Include force protection and energy conservation as KPPs in all structure designs
Develop rapid erectable barriers for COPs to include sandbag fillers

Base Camp Security

Findings
No CONOPS nor Proponency exists
ASA(ALT) IPT recently (May 2010) established to address Base Camp Security
Various sensor and sensor systems currently employed Existing sensor systems often fail and are useless as repair is not at hand Lack of integrated approach Must be linked with communications
Proper employment of sensors can save manpower
Force Protection measures (lethal and non-lethal) have to be integrated

Recommendations
Designate Maneuver Support Center of Excellence as BC proponent for BCU Security to include JCIDS development of requirements and CONOPS
Develop a BC security package that includes sensors, active force protection and integrated communications, all with high reliability requiring minimal maintenance

Army Should Capitalize on "Latest Industry" Engine Improvements

Findings

Growing power and thermal management demands
- More equipment, armor, overwatch and tactical power demand

Modern diesel engines offer improved performance and fuel efficiency
- Save ~10% by replacement with modern common rail diesel engines
- Save ~38% by converting M1 to diesel power with integral dynamo

Recommendations
The ASA(ALT) establish programs to re-engine tactical vehicles

Migrate to modern diesel engines as part of the modernization strategy to improve operational performance and fuel efficiency, especially M1

Continue to evaluate the trade between an integral dynamo on the engine and an auxiliary power unit

Include new engines in RECAP/reset for all tactical vehicles

Exploit Hybrid Technology

Findings

Private sector is leading in innovation and economy
- Advanced diesel engine efficiencies
- Electric drive reliability (reduced parts count) and maintainability
- Fuel Control System – robustness and flexibility
- Tailored energy storage techniques (flywheel, capacitor, battery)
- Increased capacity for onboard and export power demands
- Save ~10%-25% in fuel for hybrid construction equipment
- Save ~20% in fuel for HEMTT hybrid in APG trials – complete August 2010
- Cost ~20%-25% more investment for acquisition of hybrids

Recommendations

ASA(ALT) direct efforts to exploit private sector innovation with priority for hybrid systems whose mission profiles leverage these capabilities

Auxiliary Power Units

Findings
Overwatch power demands
Cycling between battery and main engine generator is inefficient
Electronics will increase overwatch power demands; e.g., M1A2 (~15 kW) and M1A3 (~45 kW)
Integral dynamo avoids APU complexity
Save >40% fuel by retrofit of APU on the turbine powered M1
There is no easy solution for powering silent overwatch

Recommendations
ASA(ALT) and PEO GCSS direct
For high electronic loads, meet power demands by integral dynamo
Repower combat vehicles in mod schedule including integral alternators
Install APUs on the M1 tank rapidly (if not repowered with diesel)

Focus S&T community on reducing/eliminating silent watch fuel consumption

BCT Aerial Resupply

Findings
Convoys have greater exposure and can consume as much fuel as delivered
Aerial resupply offers reduced touch labor and may be sole means of support
USMC analysis indicates aerial resupply is competitive with land resupply and more responsive
UAS platforms have demonstrated the ability to deliver payloads of 1,000 to 5,000 pounds
Reduction in casualties compared to ground convoy operations
Increased aerial delivery increases valuable combat power and reduces footprint

Recommendations
VCSA direct RDECOM, TRADOC and PEO Aviation to establish a program to evaluate utility and suitability of NDI UAS platforms; based on results, field COTS/NDI systems as an interim capability, and develop strategy for long term solutions

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Aerial Resupply

Findings
Limited availability of adequate airfields in operational areas
Throughput is highly constrained by maximum on ground (MOG) limitations
Distributed operations exacerbates air delivery issues
Precision delivery systems reduce the airfield requirements
Technology is available to consider development of longer range VTOL transports
Many potential operational areas in the arc of instability have limited access to seaports

Recommendations
HQDA establish a program to extend the reach of vertical lift

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Fuel and Water

Findings

Insufficient awareness of the operational benefits of conserving

Need standards and training in techniques that reduce consumption

Need to "connect the dots":

> HVAC = > Power = > Fuel = > Convoys (> Exposure + > Security (troops + equipment)) = < Effectiveness

> Recycle $H_2 0$ = < $H_2 0$ need = < Convoys (< Exposure + < Security (troops + equipment)) + < Fuel = > Effectiveness

Recommendations

TRADOC establish standards and embed training in NCOES on benefits and techniques to conserve water and fuel

Company Outposts

Findings

For a new patrol base, a majority of the troops are allocated to "inside the wire" functions for weeks

Once established, 35%-40% of force remain in support role

Resupply to patrol bases is typically difficult and inefficient

Solutions exist to reduce:

- Demand for fuel and water
- Time to establish patrol base
- Force protection personnel demands

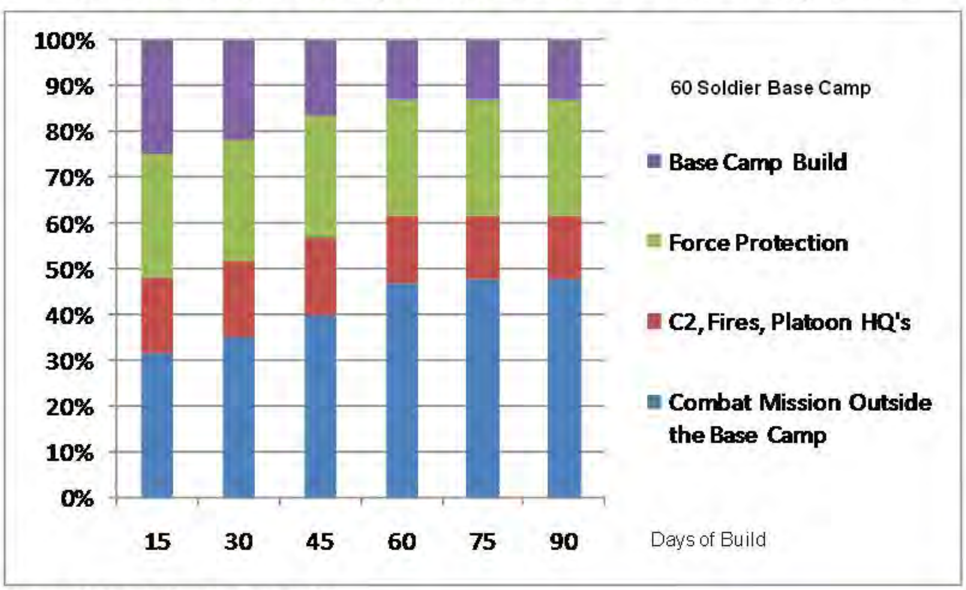
Recommendations

VCSA direct TRADOC and ASA(ALT) to:

- Develop and field new barrier material
- Acquire and provide perimeter security sensor packages
- Provide solar blankets, wind turbines, water-from-air devices for small units

Troop to Task

Conduct Combat Operations and Base Camp Build



Source: Natick Soldier Systems Center

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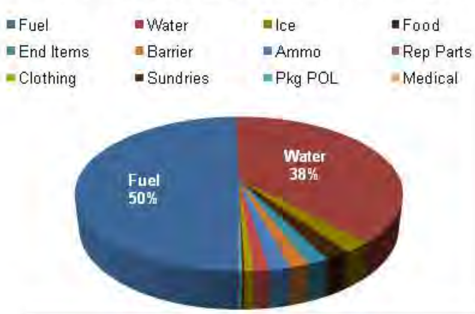
Elements of Sustainability

Supporting an Expeditionary SBCT

SBCT Support Tons by Class of Supply



Sustain the Mission Project (SMP) DSS Tool

Force Protection and Logistical Impacts
_______ Fuel Consumption (savings)
_______ Fuel Supply Truck Miles (freed up)
_______ Gun Truck miles & Aviation System Hours (freed up)
_______ Ground Convoy Equivalents (freed up)
_______ Potential Casualties (avoided)
_______ Costs/Cost Savings (Based on Monetary FBCF)

Improve the Mission Effectiveness of Units Establishing a Combat Outpost

Base Camp Build Detail - Troop to Task Hours
_______ Construction Efficiencies (savings)
_______ Base Perimeter Force Protection (freed up)
_______ Mission Soldier Days (freed up)
_______ Convoy Missions (freed up)

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Modeling Tools

SCENARIO PLANNING FACTORS:

Model: OPLOG Planner 7.0

Parameters:
- Afghanistan
- Stryker Brigade Combat Team Task Force

→ Scenario →

UTILITY DATA:

Data:
- Performance
- Cost
- Deployment by Echelon

→ Technology Data →

COST-BENEFIT ANALYSIS:

Model: Sustain the Mission Project (SMP) Tool

Key Cost-Benefit Outputs:
- Fuel Consumption (savings)
- Fuel Supply Truck Miles (freed up)
- Gun Truck Miles (freed up)
- Aviation System Hours (freed up)
- Ground Convoy Equivalents (freed up)
- Potential Casualties (avoided)
- Fully Burdened Cost of Fuel (Monetary)
- Payback Period
- Net Present Value

→ SMP Costs and Benefits →

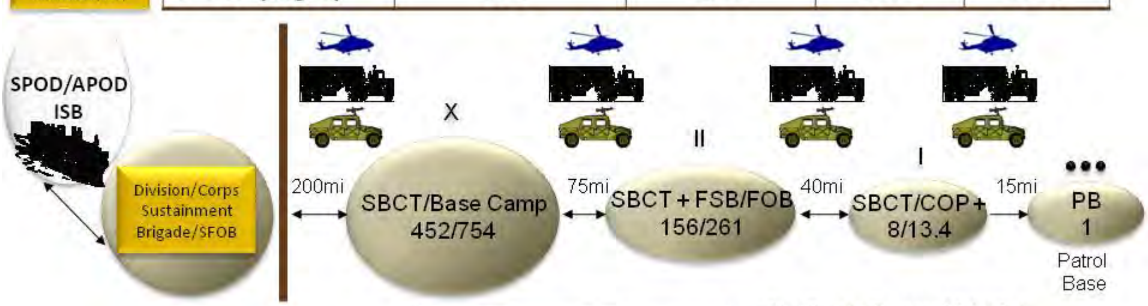
Theater Resupply: 4 Legs

Resupply Details

	Leg 1	Leg 2	Leg 3	Leg 4
Re-supply Trip Legs	Super FOB (Div) to Base Camp (bde)	Base Camp (Bde) to FOB (Bn)	FOB to COP	COP to OP
Miles (roundtrip)	200	75	40	15
Average Speed (miles per hour)	35	35	35	35
Frequency (resupply every # days)	1	1	1	1

Theater Support Command (TSC)

FBCF ($/gal)	3.27	3.88	5.14	5. 37



x/y = daily tonnage 60/90 scenario

DLA Fuel in Bagram $2.34/Gal

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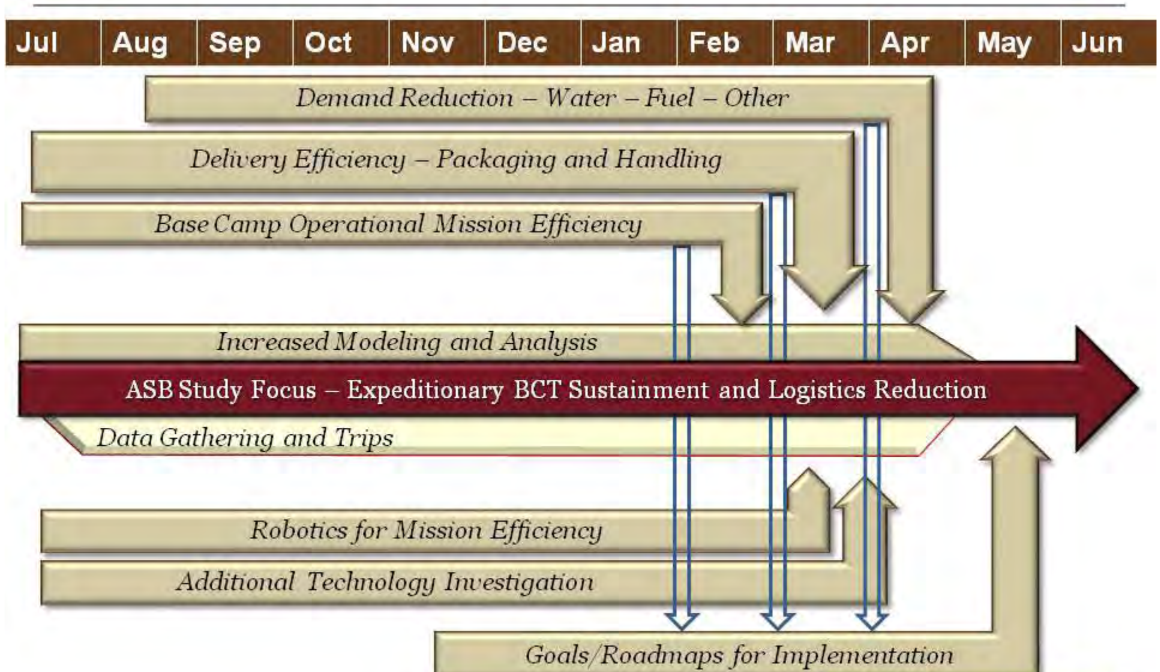
Way Ahead -Year 2



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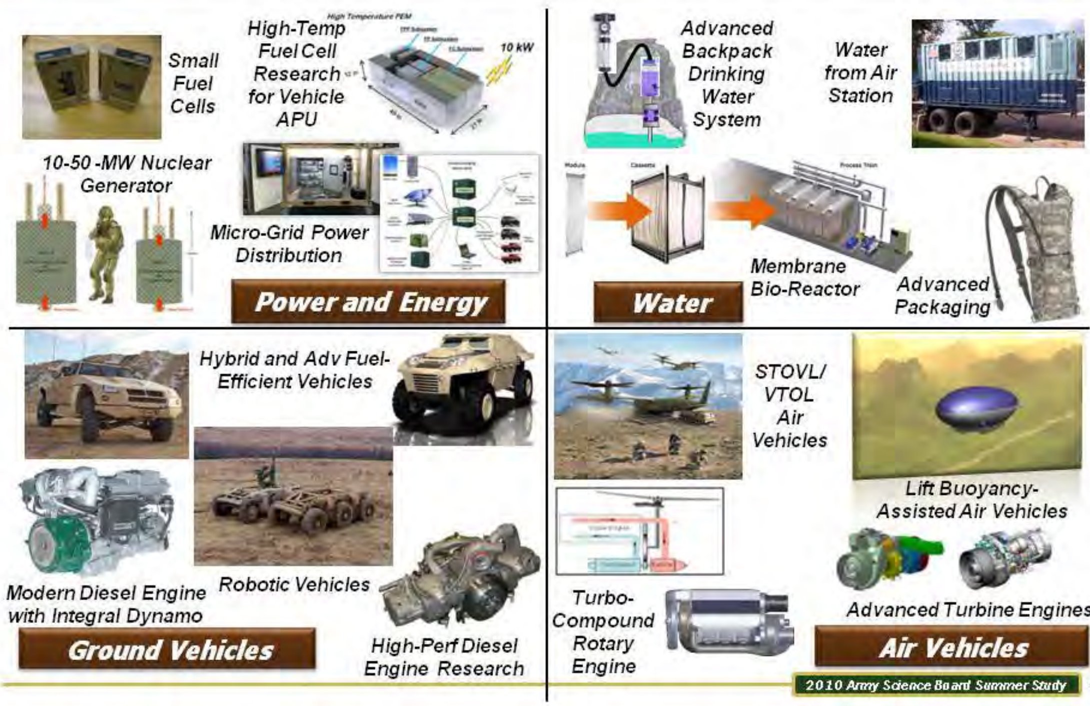
Future Technology (6-25 Years)



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Take Aways

Near Term Tonnage Reductions 25%

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  - Fuel: AMMPS generators and micro-grids; renewables (solar water treatment and battery chargers); insulation of living facilities
  - Water: Shower recycling and water from air
- Develop standards/measures for conservation of water and fuel, train conservation awareness and ensure compliance (TRADOC)
- Increase drilling and water recycling capability (ASA(ALT))

High Impact for Mid/Long Term Reductions

- Accelerate aerial resupply initiatives (UAS, heavy-lift VTOL, enhanced UH-60 performance) (ASA(ALT))
- Increase funding for re-engine, micro-grids, water recycling and renewable sources of energy

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