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FULL SPECTRUM OPERATIONS: A RUNNING START

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Successful combat operations do not ensure successful conflict resolution. Success requires convincing the populations affected by those operations to choose the US envisioned end state rather than that of its adversaries. Major combat operations (MCO) exacerbate conditions for instability. The good will and gratitude expected after liberating a population will not last unless US forces take steps to relieve the people of those destabilizing conditions. These include, in addition to lack of security, loss of power, inadequate potable water, poor waste management, food shortage, and job loss. In the aftermath of MCO in both Iraq and Afghanistan, opportunities were missed to prevent or reverse these destabilizing conditions at a critical time resulting in great cost to our nation. For success in full spectrum operations—simultaneous offense, defense and stability—US combat forces require enhanced strategic reach and endurance and the ability to immediately begin stability operations to address the population's needs. In the transition from offensive- to stability-focused operations, a critical window of opportunity exists. High threat and risk prevent other than combat units from operating effectively. However, there may be strategic consequences if the actions of those US combat forces are untimely, inadequate, or too offensively focused. Brigade combat teams (BCT) are among the few forces capable of operating during this critical, high threat period. These units must be trained and equipped to take proactive, mitigating action to address population ailments—a running start on alleviating the destabilizing conditions on the ground. Much like a combat lifesaver's quick assessment and action at the point of injury of fellow Soldier, US combat units must be able to stabilize the population with rudimentary treatment. Their actions must prop open a window of opportunity that will enable introduction of more robust reconstruction and stability capabilities to build greater momentum toward the US-desired end state. If the window of opportunity closes, a population, like an injured Soldier, may take a turn for the worse. In the case of Iraq, if outcomes and achievement of US objectives are truly measured in terms of effects on populations, the Army must better equip its combat forces to act during the critical window. Failure to do so, as we have seen, cedes the initiative to adversaries and has long-term consequences on those forces' future mission sets. Adequate local security is a primary factor in the decision for follow-on stability and reconstruction agencies when and where to arrive and begin their operations. Security and stability efforts are interdependent and simultaneous rather than sequential. In order to break the *chicken or egg* conundrum and prevent the potential downward spiraling dynamic fed by frustration, violence, and inaction, our BCTs must have the rudimentary skills and basic equipment, much like the Army's combat lifesaver program, to address the population's injuries during this transition window. This paper examines common situations BCTs are facing and will likely face in future environments and suggests equipping and training adjustments to support full spectrum operations. Simultaneously addressing the problems fomenting instability with security efforts generates a positive synergistic effect, reversing the pressure for a downward spiral. However, a BCT has finite resources—time, equipment and expertise—and its primary mission remains to be able to win the fight. Therefore, additional equipment and training must increase both reach and endurance for the offensive- and defensive-focused operations and enhance stability-focused operations. These additions must not radically modify the nature of the BCT or create a new organization. To generate a running start, I will focus on two problems faced during the critical transition window—lack of potable water and inadequate waste management—suggesting alternative and renewable resources transferable to the local population.

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Disclaimer

The views expressed in the academic research paper are those of the author and do not necessarily reflect the official policy or position of the US Government, the Department of Defense, or any of its agencies.

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For success in full spectrum operations—simultaneous offense, defense and stability—US combat forces require enhanced strategic reach and endurance and the ability to immediately begin stability operations to address the population's needs. In the transition from offensive- to stability-focused operations, a critical window of opportunity exists. High threat and risk prevent other than combat units from operating effectively. However, there may be strategic consequences if the actions of those US combat forces are untimely, inadequate, or too offensively focused. Brigade combat teams (BCT) are among the few forces capable of operating during this critical, high threat period. These units must be trained and equipped to take proactive, mitigating action to address population ailments—a running start on alleviating the destabilizing conditions on the ground. Much like a combat lifesaver's quick assessment and action at

the point of injury of fellow Soldier, US combat units must be able to stabilize the population with rudimentary treatment. Their actions must prop open a window of opportunity that will enable introduction of more robust reconstruction and stability capabilities to build greater momentum toward the US-desired end state. If the window of opportunity closes, a population, like an injured Soldier, may take a turn for the worse.

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Therefore, additional equipment and training must increase both reach and endurance for the offensive- and defensive-focused operations and enhance stability-focused operations. These additions must not radically modify the nature of the BCT or create a new organization. To generate a running start, I will focus on two problems faced during the critical transition window—lack of potable water and inadequate waste management—suggesting alternative and renewable resources transferable to the local population.

ACRONYMS

AO	Area of operations
ARS	Armed reconnaissance squadron
ASA ALT	Assistant Secretary of the Army for Acquisition, Logistics, and Technology
BCT	Brigade combat team
Big 5	Power, water, waste management, food, jobs
BSB	Brigade support battalion
BTU	British thermal unit
CAB	Combined arms battalion
CERP	Commander's emergency response program
CLS	Combat lifesaver
CONUS	Continental United States
COTS	Commercial off the shelf
DoD	Department of Defense
EPA	Environmental Protection Agency
FAC	Free available chlorine
FOB	Forward operating base
GPD	Gallons per day
GPH	Gallons per hour
GWOT	Global War on Terrorism
HA	Humanitarian assistance
HMMWV	High mobility multi-purpose wheeled vehicle
IA	Iraqi Army

IED	Improvised explosive device
IO	Information operations
JP8	Jet fuel propellant
kW	Kilowatt
LWP	Lightweight water purifier
MCO	Major combat operations
METL	Mission essential task list
MTOE	Modified table of organization and equipment
NGOs	Non-governmental organizations
NBC	Nuclear, biological, and chemical
PPM	Particles per million
RES	Renewable energy system
RO	Reverse osmosis
S&R	Stabilization and reconstruction
TDS	Total dissolved solids
TGER	Tactical garbage to energy refinery
TWPS	Tactical water purification system
US	United States
UV	Ultra-violet
WPU	Water purification unit
WTE	Waste to energy

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FULL SPECTRUM OPERATIONS: A RUNNING START

> One of the most important lessons of the wars in Iraq and Afghanistan is that military success is not sufficient to win: economic development, institution-building and rule of law, promoting internal reconciliation, good governance, providing basic services to the people, training and equipping indigenous military and police forces, strategic communications, and more—these, along with security, are essential ingredients for long-term success.
>
> —Defense Secretary Robert Gates, 27 NOV 2007, Manhattan, KS [1]

America's future wars and interventions as part of the long war against violent extremism will see an increase in military forces conducting operations among foreign populations.[2] Success will be measured not just by military objectives set and achieved, but ultimately by the effect these operations have on those populations and the choices they make.[3] In our future efforts to support global security, through the Global War on Terrorism (GWOT) or in opposition to destabilizing rogue nations, we will have multiple foes: nation-state armies, nonstate transnational terrorist organizations, and regional and local extremist groups. While we face an extended series of campaigns against these extremist groups, use of force will likely be subordinate to measures addressing the underlying causes of conflict.[2]

The real foe in the long war is the poverty, backwardness, and misgovernance that perpetuate the frustration and hopelessness upon which extremist organizations thrive.[4] Success in transforming US combat forces to execute rapid, joint, decisive operations against conventional forces must be matched by a transformation enabling full spectrum operations appropriately and sufficiently balanced among offense, defense, and stability to defeat this foe, so that after winning a war we may win a peace.[5]

The US Army exists to prevail over America's enemies, either by deterrence or successful armed conflict. Many of America's current and future adversaries are failing states, held together by force, with simmering instability fueled by internal corruption, economic stagnation, and social unrest. These future battlegrounds have vulnerable infrastructures suffering from years of internal decay, neglect, ill effects of international sanctions, or combat damage. From an unstable peace requiring US intervention that escalates to major combat operations, US forces, as the only agents of control and hope,

will inherit and fill the ensuing power vacuum and humanitarian abyss.[6] Most immediately, populations will be frustrated by the Big 5: lack of electrical power; inadequate waste disposal; unhealthy drinking water; potential food shortages; and rampant unemployment.[7] Big 5 problems aggravated by disenfranchisement and rampant threat of violence will assault helpless populations. US forces' quick military successes will rapidly transition to the need for stability-focused efforts to counter these conditions, while brutal and adaptive adversaries seek to sustain or instigate instability and hopelessness for their own gain.[8]

A running start for stability requires immediate security efforts integrated with providing humanitarian assistance and essential services to prevent a downward spiral of instability, which discourages and prohibits rebuilding.[4] US combat forces will need the proper equipment and experience to generate a running start for conditions supporting longer term solutions. *Minimal additional equipping can enhance a brigade combat team's (BCT's) ability to conduct full spectrum operations, whether they are focused on offense or stability.* Such full spectrum capability would support the security and progress required to reduce threat levels at the critical time to enable better equipped, more expert follow-on stabilization and reconstruction (S&R) forces and elements to operate.

As demonstrated in Iraq and Afghanistan, security and progress toward stability are not sequential, but interdependent and simultaneous. Forces capitalizing on this interdependence must be able to operate regardless of threat, generating increased security and progress, which ultimately enable more comprehensive S&R efforts. These efforts must begin without the long delay awaiting the arrival of follow-on forces and agencies or the security levels they require to operate.[9]

In Iraq, after the rapid, stunning victory, the slow pace of reconstruction fueled the fires of the population's discontent. The US was slow to act; its adversaries were not. The population, caught in the downward spiral of instability, tacitly or overtly sided with opponents of US objectives. The resulting unacceptable lack of security further delayed rebuilding and progress. In this high-risk operational environment, US Soldiers and Marines, the only ones available to run most of Iraq, found themselves ill equipped and unprepared to address issues other than security.[10]

The Stabilization and Reconstruction Gap

Figure 1 shows threat over time during the phases of joint US military operations. As shaping and deterrence efforts fail, threat rises. The US must resort to employing the full extent of joint force capabilities. Threat peaks as US forces seize the initiative and subsequently dominate the adversary and operational environment. Ideally, threat declines during stabilization operations enabling transfer to civil authority.[3]

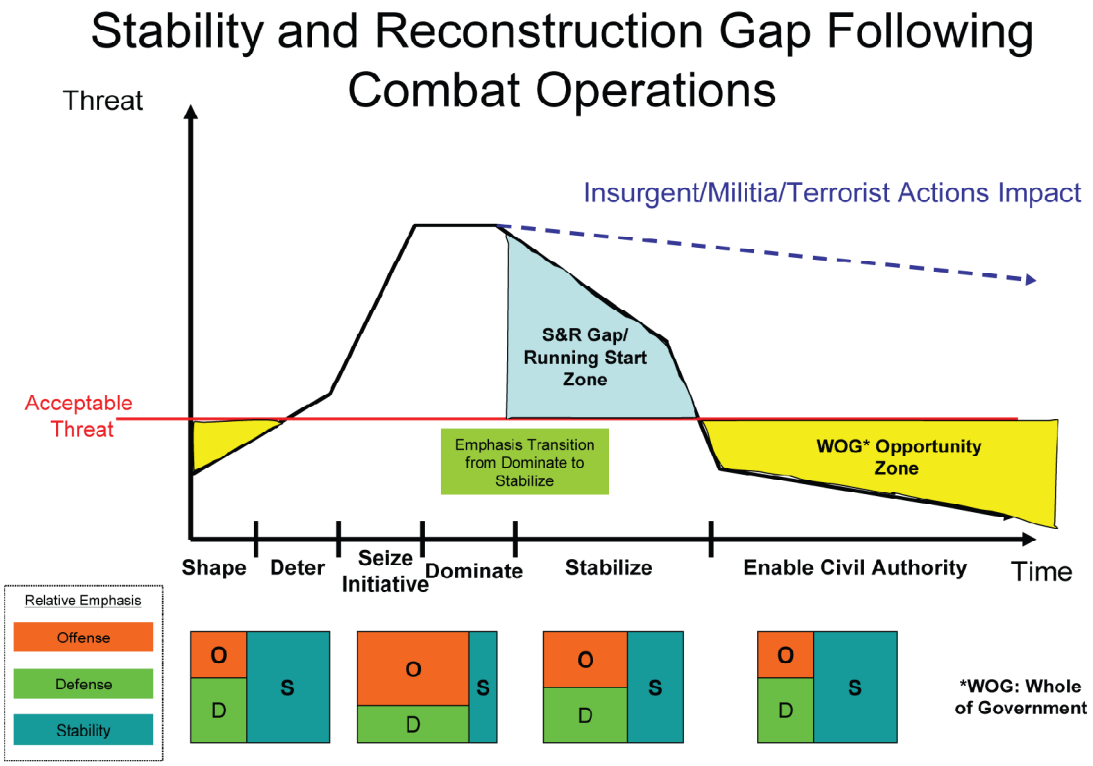

Figure 1. Stability and reconstruction gap following combat operations (compilation from chart[5] and document[3]).

As in Iraq and Afghanistan, threat may remain high as military forces transition to stabilization. Full spectrum operations are balanced as combat units simultaneously conduct offense, defense, and stability operations to reduce the threat. If the threat

remains above the acceptable threshold (red line), S&R units and agencies must delay or limit their entry and participation, and combat units will remain the primary stabilization executors.[5] It is combat Soldiers who will provide security, humanitarian assistance, and essential services to set conditions so that US whole of government (WOG) and international agencies can take over long-term nation building.[3] This threat threshold does not impugn the courage or capability of more S&R-capable elements. However willing, other-than-combat forces are unable to effectively operate above certain threat levels; full spectrum operations, specifically stability-focused operations, default to the BCTs, creating the S&R gap (shaded blue).

The S&R gap is that transition period between offense- and stability-focused operations, where time is most critical and available forces least capable. BCTs are well-trained and equipped to win the fight. They can self-secure while they conduct civil-military operations. US Soldiers and leaders have an amazing capacity to adapt and respond to the population's needs in the aftermath of combat operations. They are well-suited to working with local security forces. BCTs are, however, only partially equipped and trained to address a comprehensive, interdependent, full spectrum problem. Efforts to restore essential services are hampered by lack of vital tools as well as Soldiers trained and experienced to best employ those tools. Equipment and experience shortfalls during the S&R gap delay achieving conditions, as measured by threat, required to enable transition to civil authority.

The Big 5 predict what BCTs will likely inherit when the major fighting stops. The Army must acknowledge them and rectify the equipment and experience shortfalls to enable a running start during the S&R gap. BCTs must have some additional nonlethal equipment and experience for full spectrum operations if positive security and progress are to be achieved and the acceptable threat threshold met. The Army should, however, avoid overcorrecting by overspecializing a portion of the force or in any way reducing the lethality of our combat units.

Nonstate adversaries of the US—including insurgents, militias, and terrorists—are likely to act during the S&R gap to deny US forces from reducing the threat level to support large-scale nation building. They will, if able, prevent follow-on S&R elements

and agencies from arriving and operating effectively. Their goals will be to keep the threat level high (blue dotted line), deny progress, promote instability, eliminate the population's hope, and sap US will. Closing this S&R gap is more than a matter of timing for follow-on forces to arrive with their enhanced expertise and capability. It is driven by BCT-executed full spectrum operations to reduce the threat level above which other-than-combat forces are unable to effectively operate. Since threat level determines the duration of the S&R gap, US BCTs operating therein must be equipped, trained, and capable of conducting full spectrum operations to achieve the required progress and security without changing their essential nature.

Strategic Context: Reach, Endurance, Agility, and Effects

US national security is increasingly affected by globalization's embroilments, most of which do not follow our engagement strategy but occur unexpectedly. The diplomatic community does not typically plan for short-term contingencies on a regional scale, something in which the US military specializes.[11] Therefore, the US military has become the de facto executor of American foreign policy and the sole guarantor of selected world order.[4] Given the current and likely future security scenarios, US military forces will continue to deploy and operate in remote and unpredictable places on short notice with limited resources and high expectations.

As a result, US Army expeditionary forces, the BCTs, more often, more rapidly, and more remotely will be employed in increasingly complex strategic settings. National goal achievement will succeed or fail not just from employment of highly lethal actions but by how quickly BCTs can take all the necessary steps to reduce the threat.[3] Restoring essential services, initiating economic development, and enabling political progress must be integrated with security efforts, not diverging on separate tracks.[11] Rather than view these efforts sequentially and in accordance with notions of roles, policy makers need to acknowledge their interdependence and simultaneity and equip BCTs accordingly as they weigh decisions on how to best focus limited resources. Dual-purpose technologies that enhance reach and support the strategic effects of stability-focused operations must be sought. This contributes directly to the capabilities of all the elements of US power to coerce, influence, or attract the resulting desired *effects*.

Strategic reach is the nation's ability to rapidly project tailored force packages to conduct and sustain decisive operations of unknown duration in austere environments anywhere in the world. Endurance is the ability to conduct decisive operations over time. Agility is the ability to rapidly respond by employing and sustaining military capabilities in diverse regions and varying conditions. Balancing agility with endurance implies unfettering forces from lines of communications to increase options and enhance actions. Rapid introduction of full-spectrum-capable forces is an important strategic factor—more so if those forces' endurance is not dependent on existing infrastructure and long lines of communication.[6] Strategic reach is a function of strategic lift. There is a tradeoff within strategic lift between *tooth and tail*, the fighting versus the sustaining elements.

Given finite lift assets in a fixed period of time, reducing tail requirements can increase tooth capacity. More tooth—further, faster, or both—increases reach. An efficient way to increase strategic reach is to find ways to reduce tail requirements. If the Army can decrease tail and reduce its expeditionary forces' dependence on supply lines (see Figure 2), existing infrastructure, or host nation support without adverse impact on their endurance, lethality, or agility by introducing certain technologies, it can increase strategic reach. If those same technologies also better enable full spectrum capabilities—specifically in stability-focused operations—without reducing the units' lethality, then those technologies also enhance strategic effects. The Army's most deployable, mobile, and lethal expeditionary forces are its BCTs. Equipping them with such dual-purpose technologies that simultaneously increase reach, endurance, agility, *and* full spectrum capability has strategic impact.

Achieving this strategic impact is a matter of identifying those alternative sustainment assets that can replace or decrease select items in the deployment flow while enabling sustainment of the force package for a specific environment and expected mission set. Combat logistics are a necessary evil affecting combat forces' reach and agility.

Figure 2. Lines of communication supporting deployed forces.

Although sustainment has been performed admirably by our combat service support forces, supply lines are complex and vulnerable, both increasing commensurately as they extend. Space and weight constraints on strategic lift assets necessitate tradeoffs among what and what not to load and ship as well as when. Security requirements in theater for storage, transportation, and distribution create additional drains on combat power all the way to point of use. Local or host nation sources are inconsistent and of varying quality. Lastly, burdened costs of supplies—including transportation, security, and storage—can become key evaluative factors when looking for alternative means.[12]

Select equipment in BCTs, such as tactical water purification units (WPUs) and mobile waste-to-energy (WTE) generators, able to enhance strategic reach and endurance, can also enhance strategic effects during stability-focused operations during the S&R capability gap in Figure 1. Strategic effects do not spring solely from efforts at national levels but can be achieved and expanded at a multitude of local levels and then aggregated. Success is contagious, and progress in one area encourages progress in others. The Big 5 predicts what commanders will want and need to turn the interdependence between security and progress in their favor. BCTs equipped and trained to initiate projects addressing water, garbage, and power to achieve a running start in a high-threat environment can sooner establish conditions that will enable a more rapid

turnover to more S&R capable units and agencies. Dual-purpose technologies such as WPUs and WTE generators are the right choice to enhance strategic reach and effects.

Hammer and Nails

> When you have only hammers all your problems start looking like nails. —MAJ Curt Taylor, S3 2-8 IN, Diwaniyah, Iraq, August 2006.

To avoid the *hammer and nails* dynamic that may plague maneuver commanders during full spectrum operations, putting additional nonlethal tools in the toolbox is a necessary first step. Tools suitable for both major combat operations and stability-focused operations provide the highest payoff in reach and effects. Lethal capability provided by M1A2 SEP tanks and M2A3 Bradley fighting vehicles can only enable some of the actions required in balanced, full spectrum operations to address the population's needs. During Operations Iraqi Freedom and Enduring Freedom, leaders at all levels have energetically and creatively employed commander's emergency response program (CERP) funds, formed local councils, and worked with power brokers. However, generating tangible effects to address essential services such as improved drinking water, trash and debris removal, and distributed power generation has lagged, hampering the interdependent security and progress dynamic. Adding dual-purpose technology tools with essential services capability would enable maneuver commanders to achieve a running start on S&R operations while simultaneously conducting unit security operations and training indigenous security forces. WPUs and WTE generators can be the additional tools in the commander's toolbox.

Golden Hour and Platinum 10

The golden hour is a medical euphemism describing the time frame in a case of severe trauma during which a patient's chances of survival significantly increase if treated at a trauma center.[13] Ninety percent of combat deaths occur before a casualty makes it to a definitive care facility.[14] Recent experience in Iraq and Afghanistan shows that treatment at the point of injury, by anyone with minimal training and equipment, to stabilize a wounded Soldier in the first ten minutes, significantly increases his chances of making it to a trauma center. These minutes are known as the *platinum 10*.

The platinum 10 are among the reasons the Army continues to invest in additional equipping and training at the individual Soldier and unit level with the Combat Lifesavers (CLS) program. Soldiers routinely train self and buddy aid at the individual and small unit collective level. Tactical commanders invest valuable training time in this internal combat multiplier far beyond minimum requirements. The Army has also chosen to equip each CLS-trained Soldier with a CLS bag. CLS trained Soldiers don't replace but supplement medics, and few commanders turn down CLS training opportunities at home station or in combat because of their criticality during the platinum 10.

Stability golden hour and platinum 10 equivalents exist for indigenous populations stricken by the individual or combined effects of recent combat, years of strife from civil war, terrorist activity, or neglect. Their trauma is inadequate security exacerbated by lack of electrical power, unhealthy drinking water, insufficient waste management, food shortages, and unemployment. While the Army trains combat units for stability-focused full spectrum operations, it has not equipped them for any humanitarian assistance and restoration of essential services. *Platinum 10* actions at the point of injury during the S&R gap can prevent the population from further destabilizing the situation by reacting in desperation or frustration. If timely, platinum 10 actions can also initiate more favorable conditions sooner that will allow more comprehensive S&R to follow. Any actions addressing the Big 5 during the platinum 10 are critical and can favorably influence the fence sitting population before circumstances, emotion, and threat cause them to support those that oppose US objectives.

BCTs are sufficiently manned and equipped to win the fight and provide security as well as develop local indigenous security forces but beyond assessing and understanding a population's Big 5 needs, they are ill-equipped. Finding creative solutions can be hampered by inexperience, and CERP takes time. These delays and mounting population frustration prevent commanders from seizing the initiative in capitalizing on the interdependence dynamic during the platinum 10. Combat units must be equipped and trained to transition into stability-focused full spectrum operations addressing Big 5 needs. Lack of capability will be misunderstood as lack of willingness, and security efforts alone become counterproductive. Meanwhile, US adversaries are

hastening to take full advantage of their own lethal and information operations (IO) to influence fence-sitters' choices. If they are studying US challenges in Iraq and Afghanistan and current adaptations, they will act faster during the S&R gap and deny platinum 10 opportunities sooner in the next conflict.

Transference

There is a difference between providing essential services to a population and transferring essential service capability. Transference is the decisive step beyond meeting a need in stability-focused operations. Conditions that dictate successful transference during the S&R gap include:

- The population has a need that cannot or will not be fulfilled in a timely or satisfactory manner.
- A leader has the vision and or experience to address the need.
- A leader has access to a source of supply from which he can meet the need.

Transference of capabilities can favorably tip a population's attitude to support US objectives. It does not entail leaders giving away unit equipment. They apply their vision and employ their unit's experience to meet needs. They acquire and transfer to populations *additional like items* to their own capabilities as part of a relationship with local power brokers. *How* they acquire these items—whether from theater stocks, purchase via CERP, or through contingency contract directly from a vendor—is immaterial. The issue is *that* they acquire and transfer essential service capabilities to meet local needs, and enable sustained operation and maintenance through training and encouraging economic plurality.

Army units will never be able to directly adequately satisfy the myriad needs of the populations they will inherit during full spectrum operations. They shouldn't have to. The Big 5 forewarns what populations will need most. By fielding WPUs and WTE generators, units would have the means to act during the stability platinum 10. These dual-purpose technologies do not replace but complement a commander's artful application of full spectrum solutions.

Transference meets two additional important human needs that cannot be overlooked: recognition and control. A commander's personal involvement recognizes and validates a power broker, meeting the powerful need for recognition and respect. This public affirmation not only sets conditions for a continued relationship but serves as an invitation to other power brokers. Transference also appeals to the human need for control.[15] It is an artful means of delegation that shifts the capability and responsibility to where it rightly belongs and supports the cooperation required for security and progress interdependence. Transference has extrinsic appeal, the quid pro quo of the transaction. It also and more powerfully has intrinsic appeal—equal elements of exchanged trust, control, and a stake in the future.[15] Addressing Big 5 needs through transference from commander to power broker does not undermine follow-on units' or agencies' efforts for more comprehensive S&R projects. It provides them the necessary running start.

The focus of the rest of this paper is on tactical WPUs and mobile WTE generators. These two items suit four of the five Big 5 needs. Food shortages, while critical, can only be addressed during the platinum 10 by lift and effort, short-term solutions. Service men and women can and do provide direct assistance to populations suffering from food shortages. In many situations they are the first, if not the only, assistance providers. In the long term, commanders can take steps to enhance agricultural production through cooperative unions, fertilizer, water pumps, canal improvement, and veterinary services. Meeting populations' immediate food needs, while important, does not meet this paper's dual-purpose (useful for both combat- and stability-focused full spectrum operations) screening criteria and will not be further addressed.

There are a multitude of alternative and renewable resource technologies available that can meet a BCT's dual-purpose requirement. This paper focuses on two, which may or may not be the absolute best. Perfect can be the enemy of good enough, and that search is not within the scope of this paper either. Conversely, an exhaustive laundry list of technology additions would get unwieldy. Too many "great ideas" risk altering the nature and lethality of the BCT. The intent is to avoid turning a BCT into a civil affairs brigade and vice versa.

Two items of equipment fielded at the tactical level—WPUs and WTE generators—can enhance both strategic reach and effects in support of full spectrum operations. Each has a role in reducing tail to extend reach by replacing transportation and storage capability with point-of-use production capability. Together they address four of the five Big 5 needs and will be further explained. This equipment, like combat lifesaver bags, requires no additional personnel, just training and experience. These technologies will add value to units at home station training, combat training centers, and while deployed. The technologies are available now or in advanced stages of prototyping, and both are commercial off-the-shelf (COTS) resources.

Enhancing full spectrum capability for US BCTs and adding value to their essential mission to fight and win is the art of transformation. Opportunistic action with specifically chosen dual-purpose technologies will support addressing elements of the Big 5 during the stability platinum 10 and provide the missing running start for more comprehensive efforts by follow-on units and agencies. Constraining these ideas are three themes: full spectrum capability—suited to offensive-focused as well as stability-focused operations; train as you fight; and point-of-use production.

Water

"Soldiers run on water….everything else on fuel."[16]

Access to clean water is one of the world's most urgent problems. Globally, over one billion people lack access to safe drinking water. Between two and five million people, many of them children, die every year from water-borne diseases. Tens of millions are made significantly ill,[17] and twenty percent of the world's population is chronically infected by ingesting water-borne parasites.[18] Eighty percent of all known diseases come from contaminated water.[19] Water shortages will affect two-thirds of the world's population by 2025, according to United Nations estimates. In sub-Saharan Africa alone, billions of hours a year are dedicated to collecting water. This labor generally falls to women and children competing with other developmental pursuits, such as education or agriculture. Even regions with sufficient water supplies have contamination problems exacerbated by inadequate and aging treatment facilities.[20]

Failure to provide basic necessities, like water, is a contributing factor to instability in already struggling nations. Water inequities are a source of tension and competition within regions.

It does not require hardships from years of neglect, international sanctions, or an invading US Army to create the need for clean, healthy water anywhere on the planet. Wherever the US military deploys, as part of shaping or full spectrum operations, water is both a problem and opportunity ripe for efforts to win hearts and minds. Combat units properly equipped and experienced with WPUs could reap strategic benefits during combat operations and during opportunities arising during the S&R gap. This is a potential worthy of consideration.

Drinking water is among the most critical resources in combat. Water is also needed for hygiene, preparation of meals, general purpose cleaning, and latrines.[16] In an arid environment like Iraq or Afghanistan, Soldiers need 2–3 gallons of drinking water per day,[18] and an estimated 9–11 gallons per day for total use (drinking and contact activities such as hygiene). Estimates for total water use by a 3400-Soldier heavy BCT in an arid environment are between 27,000 and 40,000 gallons per day.[21] During the 4th Infantry Division's Operation Iraqi Freedom Rotation 05–07, water transport accounted for 53% of the division's supply transport effort.[12]

Military drinking water must be potable and palatable. Potable water by military standards has been treated to remove contaminants and microorganisms, disinfected to destroy residual microbes and prevent their growth during storage, and tested by preventive medicine experts to ensure it meets set US Environmental Protection Agency (EPA) standards. Any untested water is assumed nonpotable. Nonpotable water may be used with restrictions for human contact activities given the proper risk management. Palatable water is pleasing to the senses, taste, smell, and sight, and is inviting to drink.[22]

Very few places on earth offer water that meets US or international EPA standards, including that from the majority of municipal water systems.[18] In order to provide the best potable water for the US military, meeting or exceeding the most stringent recognized standards and properly equipping our units is a must.

Water 101

There are three broad categories of water sources: fresh, salt, and contaminated. Fresh water has less than 500 particles per million (ppm) of total dissolved solids (TDS). Fresh water is available through local sources such as a municipal water system (in and around the population), or from surface and ground water. Salt water includes brackish and sea water categorized by the presence of TDS at greater than 500 ppm. Brackish water averages 10,000 ppm TDS, and sea water averages 36,000 ppm TDS.[18] Contaminated water is any water that has come in contact with fecal or hazardous waste. Even contaminated water can be purified, although it is not a preferred choice in source selection.

Ground water is generally cleaner, as it undergoes a form of natural filtration. Surface waters, generally more readily available, can be contaminated by various means. Surface water and sea water are susceptible to infectious microbes from organic decomposition[19] and to chemically or radioactively contaminated substances. Other sources of contamination include industrial waste, landfill leachates, sewage outfalls, or human dumping.[22] These contaminants, as well as bacteria and viruses, can enter water sources through various means, via urban or agricultural run off (petrochemical or pesticides, respectively), direct input via industrial waste, or contact with contaminated water through natural occurrence. Hurricanes or floods can flood local sewer systems, causing waste to enter sea swell or runoff and contaminate water sources.[23] In Iraq, any available water seemed to be simultaneously a source of water for cooking or bathing and a latrine to any passer-by. Microbes can also grow and spread during storage in containers not sterilized or disinfected.[18]

Water Treatment

A preliminary step to treating water is choosing the best available water source, looking for water that has minimum contact with hazardous materials or human or animal fecal matter.[24] Although systems differ in sequence and method, water treatment (or purification) entails three basic steps before distribution and storage. If followed, the process results in cleaner water than any bottled water commercially available:

Step 1. Remove the parasites.

Step 2. Remove the hazardous chemicals and metals.

Step 3. Kill the bacteria and viruses.[18]

Disinfection of the water follows the treatment. This is the addition of a chemical to prevent water contamination from contact with unsanitary containers during storage or distribution. Water treatment and storage equipment must be maintained so that they remain in working and sanitary order. Lastly, water quality must be monitored. For more detailed information about the three-step water treatment process, see Appendix A.

Tactical Water Purification System (TWPS) and the BCT

> "The basic concept of tactical bulk water support is to purify water as close to the user as possible. This requires proper planning for water point selection for bulk water, if required, and purification, storage, and distribution of bulk water."[24]

Heavy BCTs have six subordinate battalions (Bn) and one brigade-level headquarters company. The brigade support battalion (BSB) has the sole organic water treatment capability for the BCT's 3400 Soldiers.

Water treatment to potable standards exists in the Distribution Company's fuel and water platoon. This platoon has Soldiers specifically trained as water purification specialists. These Soldiers operate and maintain the equipment and adhere to the standards for water treatment and handling.[21]

The platoon currently has a single TWPS and multiple trucks and droppable trailer systems, HIPPO water tankrack systems[25] and forklifts. The TWPS is transported on its own trailer and is complete with pumps, a 60 kW tactical quiet generator, and a 15,000 gallon storage bladder. This bladder supports centralized storage at the main supply location or at a forward transload site. Battalions and companies receive and transport water with 400 gallon water trailers pulled by unit trucks. Smaller 3,000 gallon bladders also support scaled storage at point of use.

The platoon's TWPS, using RO technology, can produce 1,500 gallons per hour (gph) of potable water from a fresh water source and up to 1,200 gph from sources with up to 60,000 ppm TDS. RO is a filtration process where pressure forces source water through a semi-permeable membrane (filter) which blocks the passage of larger TDS

molecules.[26] RO is analogous to distillation using pressure rather than heat to isolate and remove impurities.[22] For more information about RO and distillation of water, see Appendix B.

The heavy BCT's daily production capacity is about 30,000 gallons of potable water from a nonsaltwater source and by Army doctrine is inadequate to meet all total use needs.[27] This centralized production, storage, and distribution system is also resource intensive, can be tactically limiting, and is vulnerable to threat, especially during dispersed and nonlinear operations.

With only one means to produce potable water, the heavy BCT does not have excess capacity to address the likely water problems of the local population it will interact with in its area of operations (AO). To even begin to address this foreseeable requirement, estimates are as high as five additional water platoons, at a cost of 150 additional Soldiers and associated equipment.[21] Such additions might serve to fulfill immediate needs in the S&R gap. However, they would take an exorbitant toll in reach as well as forego the more permanent effect of transference. Rather than add to a crucial but centralized water distribution system, there is another way to fulfill a units' water requirements and better enable full spectrum operations. Currently available technology enables, and the nonlinear battlefield requires, that subordinate combat units, as able, meet their own needs on demand, and equipped with water purification technology and experience, create options during stability-focused operations.

Equipping Units

Increasing reach by cutting tail without adversely affecting unit endurance, especially during dispersed operations, requires demoting the current centralized water distribution system from primary to backup. Equipping select BCT subordinate units, to the company or even platoon level, with the ability to produce their own water on demand from local sources, can reduce the trucks and trailers required to support the current centralized system.

Army units, especially BCTs, need to be able to deploy anywhere at any time. To best equip our deploying units with multifunctional water purifiers to suit all future environments, they need to have the capability to perform all treatment steps:

desalination via RO (optional), parasite filtration to one micron, absorption and adsorption of hazardous chemicals and metals, and microbe destruction.[48] A basic country study can allow planners to estimate the availability of source water at a unit's destination and better optimize available lift space by cutting redundant systems and reallocating the cube and weight to other enablers. Also, Soldiers with first-hand WPU experience and units better poised to conduct full spectrum operations, especially during the S&R gap, have incalculable value.

Changing how combat units get their water is a matter of leveraging current and available technology and making informed equipping decisions. Cost-benefit analysis will show that equipping expenses are rapidly recouped in water production alone when compared to the burdened cost of water (production, storage, shipment, and security costs included) in a combat theater, currently estimated at $15 per gallon. However, increasing strategic reach and enabling positive strategic effects is not a matter to be decided merely by cost amortization.

WPUs in select combat units would improve endurance and agility during MCO. These units conducting dispersed operations could break free of inflexible production and distribution schedules and untether from immobile storage locations. With fewer trucks conducting water resupply in either case, units could commit less combat power to securing them. Appropriately equipped, combat units could move more freely as the mission dictates and produce the water they need, when needed, *as close as possible to the user level*.[28] Just as importantly, they would gain valuable experience with the WPUs for stability-focused operations.

Smaller units producing, storing and distributing their own water as the *primary* supply means, and holding centralized production and distribution as a backup, reduces tail. Recognizing this, the Army is already conducting a limited fielding of RO based lightweight water purifier (LWP) systems, primarily to BSBs. These LWPs have the capability to produce 125 gph from freshwater sources, supplementing the BSB's 1500 gph unit. The LWP has its own 3 kW power source and fits in the standard cargo high mobility multi-purpose wheeled vehicle (HMMWV)[25] and is therefore preconfigured to support dispersed operations.

The armored reconnaissance squadron (ARS), the two combined arms battalions (CAB), and the field artillery (FA) battalion in a heavy BCT are the best candidates for fielding organic water purification capability. These units generally operate furthest from the BSB or support those that do. Each battalion should have one 300 gph unit, shown in Figure 3, organic to its forward support company.

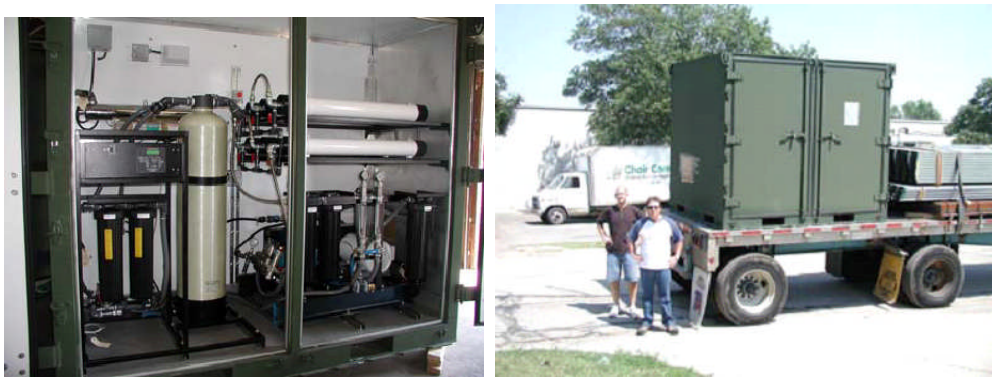

Figure 3. 300 gph water purification unit—battalion size.

Each line company, troop, or firing battery in those battalions should have a 75 gph unit (Figure 4).

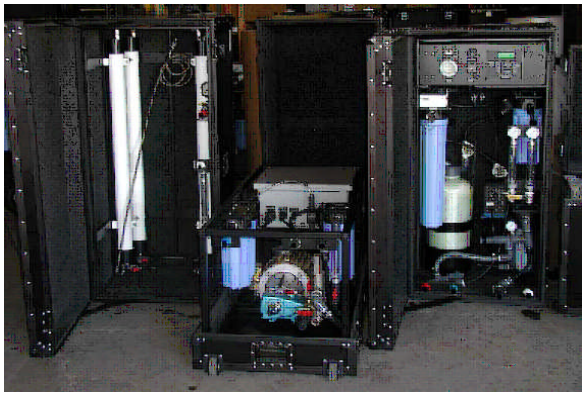

Figure 4. 75 gph water purification unit—company size.

One platoon in each line company, troop, or firing battery in those battalions should be equipped with a 60 gph backpack unit (Figure 5).

Figure 5. 60 gph water purification unit—platoon size.

The BSB's 1500 gph capability suffices for providing water to the special troops battalion (STB) and the BCT's operations centers. The distribution is summarized in Table I.

Table I. WPU Distribution within a BCT's Subordinate Units

	2 × CABs	ARS	FA Bn	STB	BSB
COTS WPU (gph)	1 × 300 ea	1 × 300	1 × 300		*1 × 1500*
	4 × 75 ea	3 × 75	2 × 75		
	4 × 60 ea	3 × 60	2 × 60		

This distribution scheme could eliminate any and all water delivery requirements to the equipped units, battalion level and below. The STB is left out only because I do not envision them performing full spectrum operations, specifically stability-focused, and that was my own arbitrary screening criterion. Unit nuclear, biological, and chemical (NBC) specialists at the battalion and company levels should be the primary experts and maintain the organic equipment. Training for COTS WPUs, such as provided by Global Water Group, Inc., is minimal, less than 2 hours to operate, troubleshoot, replace components, and perform preventive maintenance.[48]

Water production, storage, and transportation are expensive. Securing water during transportation is even more expensive. A single Army TWPS costs just over $600,000 with the RO feature, generator, trailer, and a nuclear, biological, and chemical (NBC) environment capability. The Army TWPS requirement is 261 units. The smaller

LWP costs $167,000, and the Army looks to field 556 units. HIPPOs cost $168,000, with 2,436 units projected; 3,000 gallon bladders cost $73,000 each, with almost 1,000 projected to be fielded.[25]

The burdened cost of water in theater is upward of $15 per gallon. Much of that cost is the security for water's transportation and delivery from centralized production facilities or from bottled water depots.[16] Determining at what gallon production point the equipment pays for itself is a matter of dividing the equipment's total cost by the burdened cost factor. While this may seem simplistic, it gives an indication of the economy of WPUs. At the estimated burdened cost rate in theater, the Army's TWPS, at $602,000, pays for itself in 40,133 gallons, or in 1.33 days of full capacity operation. However, these centralized assets still require numerous resources to get the water to the subordinate units. It is very difficult to assign a cost estimate to Soldiers' risk transporting water from centralized treatment locations to the point of use. Cost estimates also cannot factor in combat power diverted away from other missions escorting water truck convoys. Fuel cost differences for running the WPU generators at a central location versus those at dispersed locations are assumed insignificant. Table II examines costs for smaller, proven, on-demand WPUs from Global Water Group, Inc., that meet the three-step requirement and offer an optional pretreatment step with reverse osmosis.

Table II. Cost basis for COTS WPUs (Compilation from selected documents[29],[30],[48])

Feature/ GPH/GPD	300/7200 (Battalion)	75/1800 (Company)	60/1440 (Platoon)
Base Price	123,000	49,900	5,475
Trailer	11,250	7,000	
Generator	18,750	9,800	
All-Weather Housing	22,000	9,000	
Year of Spare Parts	6,675	4,520	
NBC Capability	24,375	16.500	
Year of Chemicals	11,943	4,496	
3 year Warranty	11,250	3,600	
Optional 60K ppm desal feature (RO)	3,125	1,500	
Solar Array		8,040	2,010
Total	$232,368	$114,356	$7,485
Pays for Self in gallons/days @ $15/gal	15,491 gallons / 2.15 days	7,623 gallons / 4.2 days	499 gallons < 1 day

***Since this equipment is intended to produce water at point of use, there are no additional burdened costs.**

Again, the value of on-site water purification capability and experience cannot be expressed solely in dollar values. The envisioned equipping scheme would support dispersed operations as well as current operations in theater with combat outposts more prevalent. With a solar array power option, as shown above, savings in burdened costs of fuel would also offset additional costs rapidly. A solar-powered water unit would also transfer well to a local population, relieving it of fuel costs as well as introducing alternative and renewable resources for further consideration. This ability within a BCT—at the battalion, company and platoon level—would be, from my experience, an outstanding option for stability-focused operations enabling the BCT to generate a running start toward meeting this foreseeable need. After assessing his area of operations (AO), a commander may decide that providing WPUs to the local population supports his efforts in addressing essential services. He should not give away his own organic capability or create dependency by merely providing available excess water to the population. He should be able to acquire and transfer *additional like items* funded by CERP. By ordering like items from pre-positioned theater stocks or directly from a vendor via contingency contracting, a commander can address assessed needs with rapidly available water treatment equipment. Having the vision to employ such assets requires experience, which in turn requires their availability for training.

The Army espouses *train as you fight*; train just as you will perform in combat. This axiom makes good sense and provides focus in a time-constrained environment. Commanders at all levels have too many tasks and too little training time to allocate. However, producing a critical resource such as water at the user level would be a good investment, especially if the training time was in hours, not days or weeks. Ideally, equipment is available at home station, and as a backup, at combat training centers. While preparing for deployment to Iraq, my battalions had little knowledge of water purification technology. Global Water Group, Inc., traveled from Dallas at the request of the brigade commander to provide his battalion commanders a demonstration. I personally did not appreciate the full value of the demonstration at the time, but once I arrived in Iraq in November 2005, memory of that experience came back to serve us and our Iraqis well and led us to the following example.

Personal Experience with Water

In 2006, AO Normandy, in the Babil Province of Iraq (2-8 IN's portion of AO Warhorse [2/4 ID]) was still a contested area. In a theater matured after over 30 months of military operations, clean water for the local tribes and urban areas had yet to be adequately addressed. As part of balanced approach to increase security, our goals were to support local governance, enhance economic progress (including Big 5 essentials) and forge relationships with the population via consistent engagement.

In AO Normandy, one larger, centralized water project had been started and another was planned. It would be 8–10 months before these centralized projects came to fruition, and we projected complaints about inequitable distribution as the projects would only benefit some of the population. As a result, we arrived at a distributed method of clean water production, which served to shorten delivery time and allow us to more precisely solidify relationships with specific tribes based on the cooperativeness of their sheiks and other power brokers.

Transferring WPUs served our battalion in three ways. Promise of clean water through a select local power broker (sheik or city councilman, mayor or imam) was an extension of good will to people who had not whole-heartedly accepted our published intentions. Our saying was "work with the sheik, serve the people, and win cooperation from both." Distribution of smaller WPUs gave people clean water sooner. Tribal sheiks realized the benefits and became more willing to exert greater efforts to cooperate with us. Previously standoffish or unfriendly sheiks became more interested as well.

Our initial overtures involved more than just promises. At first, our best means of getting water to the local population was via the Iraqi Army (IA) battalion, 2/4/8 IA, which had a 1,500 gallon tanker. Nongovernmental organizations (NGOs) that might normally support the population were not operating in our AO, as the press deemed the area too dangerous. Our US water trucks were contract and could not nor would not go outside the wire, as the AO was still contested. US water trailers would not carry the same publicity value as the Iraqi water tanker with the big IA patch painted on the sides. The IA battalion commander was not overly excited to expose his one and only water truck to improvised explosive devices (IEDs) or ambush by driving it into tribal areas to

deliver water. With the promise of escort by US Soldiers, he agreed. This ongoing operation had IA Soldiers bearing clean water and humanitarian assistance (HA) bags (bags filled with dry foodstuffs and spices) to distribute inside the tribal areas. We coupled this operation to collective training we had scripted for 2/4/8 IA, the focus being on nonlethal operations and IO.

Our initial aims for this ongoing operation were more about getting the IA to interact with the population than delivering clean water. The IA looked like the heroes we were advertising them to be, and they got out to meet people who had been labeled terrorists. Our battalion's payoff was a foothold to relationships that would persuade the people and their sheiks to stop trying to kill our Soldiers, or stop supporting those who did. If we could entice the population with clean water and deliver a long-term solution working through sheiks, we thought security through cooperation, rather than lethal operations, would improve. We were right.

The next phase of the operation was well-intended, but not nearly as smooth. We individually engaged the tribal sheiks and introduced the concept of distributed WPUs serving a tribal or geographic area. The sheiks were generally amenable, and word spread about our intentions. Sheiks began coming to us. To quote the Kafagi tribesmen from Jiff Jaffa that came to see CPT Colin Brooks, my B Team commander, "Whatever you are doing with the Gurtani tribe, we want it too."

The promise of WPUs was very successful in initiating relationships and, I believe, a major factor in the positive turn our AO took. However, the WPUs purchased through the US Army Corps of Engineers at $40K per unit were painfully slow to arrive, were delivered incomplete, and were missing their chemical components. In hindsight, we think we now know a better way.

Hindsight—Water

With our operational experience I offer changes to our methodology. Equipped with and trained on WPUs, my Soldiers and our partner IA Soldiers would likely have been more familiar with all facets of their operation. Our initial IO plan would have the IA toting a backpack version like the one offered by Global Water Group, Inc.'s WPU in the tribal regions to offer clean water and demonstrate the technology onsite. The IA

could run a unit all day filling water containers and interacting with the people for the best publicity available. This would attract more fence-sitting sheiks faster.

For all sheiks agreeing to our plan for cooperation, their selected young men would be offered a preparatory training program at the IA compound to learn how to set up, operate, and maintain the equipment. When the equipment arrived, we would turn it over to a local expert whose job it would be to run. We would empower the Iskandariyah City Council or the local agricultural unions to support our engagements by advertising what we intended and inviting new prospects. We would work with and through these councils to create additional water-related opportunities for the population. Treating source water for ice, a popular retail commodity, for example, has marketable potential. Upon delivering purified water capability to a region, we could follow up with projects to distribute the water. Beyond economic pluralism, this would also incentivize keeping roads free of at least victim-operated IEDs. As the project matured, we would introduce alternative and renewable power sources, such as wind, solar, or WTE generators, to reduce WPU fuel costs. Long-term projects would include piping and pumping the water into individual homes and apartments. Any project would be possible once we overcame the initial obstacles of security and cooperation.

Had we more experience and expertise with small WPUs such as those sold by Global Water Group, Inc., we could have greatly improved the order-to-ship time—weeks instead of months—with preordering. Dealing directly with a single vendor of known quality would have prevented receiving incomplete units and reduced time for corrections by avoiding the middleman. While we achieved the intended effect, people did not have access to clean drinking water as fast as we had hoped. If we had WPUs at home station during training, at NTC, and inside forward operating base (FOB) Kalsu, our Soldiers would have been more prepared to act on the above hindsight. I believe we would have thought of the project earlier and realized greater success sooner. With a shorter time to deliver and stronger and more numerous relationships formed, we might have achieved further downstream effects before we rotated out of Iraq.

Commanders, if equipped with WPUs, should not give their organic equipment away. Any transferred WPUs should come from theater stocks or be purchased via CERP

or contingency contracting. Involving the IA and or a local governing or administrative council further legitimizes those organizations as well as the projects.

We ended up transferring 27 WPUs to our local Iraqis. Our battalion achieved the desired effect and capitalized on the water units approach. I would like to think the WPUs are running at full capacity, making for a happier, healthier AO full of Iraqis with fond memories of the good Americans. Hopefully, follow-on units continued this engagement method and improved upon it.

No solutions are straightforward or silver bullets. They must be stubbornly executed but malleable enough to adjust to changing conditions and unexpected opportunities. The water is important, but more important are the relationships that offering and transferring WPUs enable commanders to form and build upon. These relationships can be converted into cooperation, increased security, and possibly mitigating the risk to Soldiers' lives. We achieved our desired effect—strong relationships with the sheiks, a reputation for caring about the people, fewer folks attempting to kill our Soldiers or supporting those who do, and an ever widening ring of cooperation within and around AO Normandy. In hindsight, there was so much more we could have done in our year. We ran out of time and missed some great opportunities because we were inexperienced. "Train as you fight" applies in counterinsurgency operations.

While we had positive experiences and results applying WPUs to our challenges in Iraq, more opportunities to apply appropriately fielded nonlethal technology to recurrent and future military and humanitarian problems exist. As promising as WPUs seem to be, WTE generators may have even more potential to achieve strategic reach and effects.

Waste to Energy

It is almost impossible to think of a human process that does not produce waste in one of its many forms—including agricultural, solid municipal, food, human, chemical or packaging.[31] US forces deployed abroad, regardless of the mission, also produce waste. Waste cannot be avoided, but waste to energy (WTE) technology can convert it to an opportunity and a resource to reduce the logistics burden and support economic

development while encouraging sanitary conditions improvement.[32] The Army, through the Environmental Staff Office, Assistant Secretary of the Army for Acquisition, Logistics, and Technology [ASA (ALT)], is pursuing and evaluating multiple technologies to apply against waste and energy issues for deployed forces. However, ASA (ALT) may be limiting their search to *inside the wire* applications only. WTE technologies can support US forces during combat operations, reducing the logistics tail by turning trash into electrical power. WTE applications can also support mitigating three of the Big 5 needs that plague populations following combat operations—electrical power, waste disposal, and jobs.

Inadequate waste removal hardly seems on par with the immediate health hazards of a population's contaminated drinking water, frustration caused by lack of electricity, or rampant unemployment. Viewed as an opportunity and resource, WTE generation is a topic worth exploring while thinking about future US military full spectrum operations. Inadequate trash removal and nonfunctioning sewers in Sadr City, Iraq, remain second only to lack of electricity as a constant source of complaint and frustration. Addressing trash and energy concurrently would have tremendous and positive impact on that or any distressed population.[33]

The dominant philosophy for waste disposal in developed nations has been *out of sight, out of mind*. Waste is separated, collected and incinerated, recycled, or (most often) taken to landfills.[34] This philosophy ignores the energy potential of waste as well as the environmental impacts of burning or land filling.[35] Burning trash without energy gain is a wasteful polluting effort. Landfills generate methane, a byproduct and pollutant that, if not captured, is over twenty times as environmentally hazardous as the same amount of carbon dioxide.[36] Better ways to deal with trash exist.

In less developed nations where US forces are more likely to operate, waste disposal, or lack thereof, and its multi-faceted problems are even more pronounced. Open sewers and makeshift dumps prevalent in these nations have direct health impacts on populations and US service members operating among them. Chemicals, microbes, and other byproducts from sanitation breaches cause death, disease, and further stress inadequate health care systems. Landfills compete for space with housing, industry, and

farming, and even modern landfills can render land unusable. US forces as waste producers must remain cognizant of their impact on local populations' attitudes. They must seek ways to set an environmentally conscious example while encouraging more productive practices rather than exacerbate existing problems with their own dumping.

During offensive operations, dealing with trash is not a high priority. The field sanitation and environmental standards met in training are not so rigidly observed during combat. However, leaving trash lay may be a decreasingly desirable option for forces that have to remain to stabilize that same AO. Waste that affects people's health or merely creates a negative image can become a useful tool in US adversaries' propaganda. As US forces' operations become more geographically stationary and their efforts transition from offensive to stability-focused operations, they must better focus on dealing with their waste. This may also lead to efforts to work with local populations in dealing with theirs, to include: collection, processing, transportation, reduction or disposal.

The "broken windows" theory postulates that crime is contagious. I submit that this theory applies to instability as well. Populations exposed to *broken windows*, a metaphor for unpleasant conditions including intimidation and violence, lack of essential services, and even the unappealing sight of garbage, soon believe that no one cares and no one is capable of fixing their problems. Unfixed broken windows signal that lawlessness and poverty will persist and aesthetically reinforce a downward spiraling self-fulfilling prophecy.[37] This hopelessness is exactly the prevailing condition and attitude our current adversaries want. It is tangible proof of disorder and disrepair, exploitable in the case for their ends against US forces.

In less developed regions with rampant problems, from corrupt officials to criminal gangs and lack of other essential services, organized trash pickup is difficult to visualize as a priority or an operation. If commanders aim to favorably shape the attitudes of the local population, waste removal and neighborhood cleanup can serve as opportune tools. An important factor is figuring a way to make trash pay.

Discussion of the Technologies

Viewing waste as a resource instead of a problem is a matter of applying technology to convert it into useful energy. There are numerous approaches for capturing

energy from trash produced in the field for conversion to usable energy.[38] Many WTE technologies, however, are geared to specific waste streams and feed stocks and are not universally cross-applicable without some modification. Waste can be converted and used onsite via combustion, or it can be stored as a solid, liquid, or gas fuel. Three primary methods for WTE conversion are: physical, thermal-chemical, and biological.[36]

Physical methods mechanically transform the raw waste into a more useful form known as refuse-derived fuel (RDF). After removing noncombustible matter such as glass and metal during preprocessing, waste is treated by shredding to reduce its bulk. Steam treatment can also reduce bulk for mechanical compression, and destroys microbes and pathogens as well. The RDF's final forms can be pellets or bricks, which burn cleaner and more efficiently than the raw waste.[39]

Thermal-chemical WTE technologies include mass burn, pyrolysis, thermal gasification, and plasma-arc gasification. Incineration, or mass burn, combusts waste as a fuel to create steam, which can generate electricity in a steam turbine generator. Ash and other pollutants, unless captured, are a negative byproduct of mass burn. Pyrolysis, the application of heat to break down organic materials anaerobically, produces a fuel gas composed of methane, hydrocarbons, hydrogen, and carbon dioxide. Low-temperature pyrolysis produces a form of synthetic diesel. Both produce liquid and solid byproducts such as bio-char, a beneficial solid residue that can be used as fertilizer or as a waste gas absorbent. Thermal gasification is similar to pyrolysis but is aerobic, including limited amounts of oxygen, and results in a synthetic fuel gas (syngas) and residue. Plasma-arc gasification uses extremely high temperatures, up to 13,000 degrees Fahrenheit, to break down wastes at the molecular level to form syngas and solid refuse. While very energy intensive, this process can break down a wide variety of feed stocks, to include hazardous chemicals, cement, and metal.[39]

Biological WTE technologies use living organisms such as microbes or algae to produce usable fuel.[39] Landfill gas is captured from the byproducts of naturally decomposing waste, which produces large amounts of carbon dioxide, methane, and natural gas. Capturing this gas is preferable to allowing it to escape as pollutants into the atmosphere. Biogas plants are controlled forms of producing landfill gas using various

bacteria in airtight containers called digesters. Fermentation is a form of biological WTE generation using yeast to generate ethanol from organic waste.[39]

The WTE generation system I focus on is the tactical garbage to energy refinery (TGER), which combines two complementary technologies—biological and thermal-chemical decomposition—to produce combustible fuel for power generation. TGER is a relatively mature technology, having been successfully tested in Iraq during the summer of 2008. For more information about TGER's operation, see Appendix C. The Army continues to pursue research and development on a variety of technologies. I chose TGER, shown in Figure 6, simply it because has the ability to convert a broad range of waste and is designed to convert the most common military trash items to useful electricity.

Figure 6. TGER in operation in Baghdad, Iraq.

Military Trash and Unit Equipping

Deployed US forces generate trash. Food waste, packaging, and waste wood are the major components for forces in the field, differing from those generated on military installations. Trash estimates for deployed units range from 5 to 16 pounds per Soldier

per day, 96% of which is usable for conversion to electric energy.[40] Since operations tend to be somewhat dispersed, subordinate battalions in a BCT—the two CABs, the ARS, and the FA Bn—should be equipped with one TGER apiece (as shown in Table III) to convert their trash to needed electric power. Sufficient argument can be made for equipping the STB and the BSB as well; however, my screening criterion for equipping was for use during combat-focused *and* stability-focused operations. Collocated elements of the STB and HHC Brigade elements could conceivably combine their trash to fuel an STB TGER during major combat operations, but neither unit is generally assigned a separate AO during full spectrum operations.

Table III. BCT WTE Generator Allocation

BCTs Units	2 × CABs	ARS	FA Bn	STB	BSB
TGER WTE Generator	1 each	1	1		

Unit cooks designated as the WTE experts supported by generator mechanics could enable each battalion to capitalize on this technology and energy potential. WTE generators are not nearly as simple as the WPUs discussed earlier. Cooks and mechanics would need to attend a 40-hour training course to learn TGER's operation, preventive and minor maintenance, and feedstock requirements.

Table IV shows the make up of that feedstock, typical military trash and the British thermal unit (BTU) content.

Table IV. Energy Value of Normal Military Trash (Chart Data)[40]

Type	Percentage of Total Trash	BTU/lb
Paper & Cardboard	36%	7900
Food	23%	2370
Slop Food	16%	1000
Plastic	11%	17400
Cooking Oil	5%	16800
MRE	5%	8750
Metal, Glass, Misc.	4%	-
Average BTU/lb Value		6742

[Note] With 1 kWh = 3412 BTUs, the energy potential for a 3400 Soldier BCT producing 10 pounds of trash per Soldier per day with 96% useful as energy is 229,228,000 BTUs. Conversion of thermal energy to electric energy is typically 25% efficient, and the BCT's trash has an electric energy potential of 16,795.5 kWh or just under 17 megaWatt hours per day. Power generation projections for each TGER equipped battalion/squadron would be dependant on the trash generated by Soldiers. However, TGER is designed to consume 2500 pounds of trash per day to generate 1440 kWh per day under ideal conditions. Each battalion level unit can generate enough trash at conservative estimates per Soldier.[36]

Also of note, 7 lbs plastic produces has the same energy potential as 1 gallon of jet fuel propellant JP8.[41] The BTU value of Wood is 8600 BTU/lb.[34] The BTU value of 85% solution of Ethanol is 11,800 BTU/lb.[42]

Waste's Strategic Effects

In order to enhance strategic reach and endurance, the planning process should consider options for utilizing waste as a potential source of energy. Extracting power from field waste can reduce the number of fuel trucks tethering combat forces to vulnerable supply lines. To realize this potential, units must be equipped with the WTE generation means. Productively disposing of the trash rather than leaving it behind may also support US forces' future relationships and the negotiation process during conflict resolution. Reasonable objectives for WTE programs include: waste elimination, usable energy production, reduced fossil fuel consumption, and technology transference to the population.[43] During the S&R gap, transferring WTE capabilities can meet three of the population's Big 5 needs—waste reduction, power, and jobs—with multiple downstream opportunities as conditions mature.

A Good Investment

Granted, new equipment has associated costs. While commanders think in terms of effects and time, taxpayers and Congress think in terms of dollars. WTE equipment additions to a BCT's modified table of organization and equipment (MTOE) can support cost reduction, support reach, endurance, and agility, without a significant increase in training and maintenance requirements. The question becomes, "How long does it take for a WTE generator to pay for itself?"

In 2006, 4th Infantry Division used 50,000 gallons of (JP8) per month. Fifteen to twenty percent of this fuel was for static power generation at forward operating bases and smaller combat outposts.[12] Fuel costs differ by location, and estimates run between $10 and $400 per gallon depending on the remoteness of the site. Sixty-kilowatt generators in Iraq use about 95 gallons of JP8 per day running 24/7.

Were a forward-deployed, standard Army 60 KW tactical quiet generator's fuel replaced by power extracted from waste at a median estimate of $200/gallon rate, a prototype TGER costing $3.2 million would pay for itself at a $19,000 (95 × $200) per day in 168 days, about 5 and 1/2 months.[38] Prototype costs are typically very high, as many of the subcomponents are custom built.[36] These costs generally decline with commercial production and economies of scale. Estimates for a manufactured TGER are about $750,000,[31] which means it would pay for itself in about 40 days. In a July 2008 prototype trial, TGER ran for 4 weeks in Baghdad, Iraq. It produced 37,000 kW of electricity and saved 2,500 gallons of fuel while consuming 50,000 lbs of military waste.[43] Analysis of emerging technologies should include the burdened costs of fuel to forward-deployed units. Using the calculations above coupled with the equipping scheme recommended, a single BCT's units would save enough fuel converting trash to electricity to take a 5,000 gallon tanker truck off the road every 13 days, or almost 30 trucks a year. Reducing US Soldiers' exposure to hazardous roads is another benefit of applying this technology.

Other costs associated with trash and therefore other economies exist with WTE generators. Dollar-wise they are not significant, but with respect to risk they are. Haul-away costs are about $200 per ton of garbage. This dollar amount cannot quantify the risk

to the individuals hauling the garbage outside the wire or the risk of a local national entering an FOB to pick it up. Burdened costs also fail to account for the effect on the local population's attitude about military trash and landfill. Estimated savings do include fuel saved by fewer trucks transporting fuel but do not quantify the risk reduction to Soldiers escorting fuel resupply convoys. Also missing are estimates of the economic and operational value of transferring WTE generators to the local populace via CERP. Opportunities for strategic effects may be the most valuable but unquantified component in the cost-benefit analysis.

Eventually, WTE generators pay for themselves, combining the unavoidable trash with the need for electrical power. During more stationary operations, as in Iraq and Afghanistan, US forces can employ suites of WTE generators that take advantage of multiple feed stocks to the point where trash becomes the primary option for static power generation. As more WTE generators are employed, fewer fuel trucks are required. Ideally, trash becomes a scarce feedstock, and US forces run out of trash as they satisfy their power needs.

Currently or imminently available technologies vary in price, waste streams, and kilowatts produced. The ASA (ALT) continues to evaluate promising technologies besides TGER. These include the Bal-Pac System, a pyrolysis gasification unit from Balboa; the HAWK, a microwave treatment system from Global Resources Corporation; the Dry Pyrolysis and Gasification System from Princeton Environmental Group; the AgriPower system, based on the "open" Brayton Cycle technology; and Thermogenics Gasification System.[31] Mobile assets have upper limits to their trash consumption and power output before they become too large to move. Other technologies are intended solely for static use and have greater power generation capacities. This paper focuses on the smaller, mobile assets with dual-use capabilities employed by a BCT, such as TGER. My unit had no exposure to WTE technology during our train up for the OIF deployment. As a result, we were unable to envision solutions to problems we encountered.

Waste to Energy Personal Experience

In Iraq, trash and debris were prevalent throughout AO Normandy, and we knew we were looking at a potential tipping point. If the battalion could facilitate neighborhood

cleanup while progressing with security efforts and other projects (water), we believed we could improve the local population's attitude and outlook toward us and their own future. We managed to achieve some effects beyond good will and publicity from providing jobs, and working through local power brokers was difficult. We counted on the broken windows theory having merit, and that steps taken to improve the appearance of the neighborhoods would have effects far past the immediate.

Lack of electricity was our population's most prevalent complaint. However, trash, we believed, diluted the image of hope we thought we were offering the Iraqis. Trash was everywhere. Cleaning it up, we realized, would require a sustained effort by us and the Iraqis. We found out that to achieve this degree of effort commitment, we had to find a way to make trash pay.

The unit preceding ours had purchased six garbage trucks and hired trash crews. While the local Iraqis grasped the trash pickup concept, the system was plagued with problems. Someone stole one of the six trash trucks. The other five ran only intermittently and without a schedule. Dumpster use was an optional endeavor for the population, and the trash truck drivers dumped their load of trash just about anywhere but the designated dump site. While the drivers claimed they feared IEDs on the route to the dump, we surmised that dumping just off a paved road was an expedient way to cut short a work day.

My battalion used trash and debris cleanup as make-work opportunities. We first contracted sheiks to hire men to clean up canals and roadsides. North Babil is a fertile agricultural region, and elephant tail grass grows rampant in the extensive canal systems, providing concealment for IEDs, caches, or the emplacing teams. We later contracted for workers in the urban areas to pick up garbage and debris on city streets and in abandoned, vandalized, and looted buildings. Unfortunately, these projects were only temporary with no self-sustaining effects. Ultimately we turned over the periodic cleanup process to the Iskandariyah City Council, but with CERP procedural red tape, it was not a smooth process. Cleanup projects for pay were popular, much more so than the failed trash truck effort. They grew to include future projects such as Iskandariyah's Vocational Technical College buildings and student housing area, both vacant as of the invasion.

In addition to cleaner areas, dividends from these projects included empowering the sheiks and the city council, solidifying relationships, putting money in honest men's hands to spend in local markets, and removing concealment for IEDs. Our short-term solutions met only two of the population's Big 5 needs—jobs and trash removal. We lacked experience, and therefore imagination, to achieve a self-sustaining effort or create opportunities for additional downstream effects, all of which would somehow benefit the Iraqis beyond aesthetics. Experience with WTE generators would have provided us with a better way.

Hindsight—Waste

Working with the city council, I would find a high-visibility concern, such as a mosque, public service (WPU), or hospital, to apply WTE generators as a starter project. With WTE generator equipment and experience during our predeployment training, we would be able to forecast everything needed to start a comprehensive project and achieve and sustain downstream effects. Supporting efforts would include site preparation, trash pickup and receiving, separation of metals for recycling, incineration and energy recovery, residue disposal, personnel training, and personal protective equipment supply.

Previous WTE experience would allow us to better analyze the local waste stream—generally food waste, paper and plastic, and agricultural waste—to choose the most suitable technology for each project. Soldiers with a 40-hour course and hands-on experience could, directly or through the IA, train the locals to set up, operate, and maintain a WTE generator. By linking these systems to our wayward garbage truck drivers, we could make the trash pickup in the AO pay, at least in electricity if not cash. Sheiks, imams, businessmen, and the local population would get power for as long as the generator ran and the supporting waste stream continued to flow. Positive IO supported by electric power and jobs would incentivize the security of the project. If the broken window theory has merit and trash is a potential tipping point, the local population would expect improvement rather than continued lawlessness. They might opt to exert more control over their security situation, discouraging IED emplacement—at least on trash truck routes—through overt or tacit forms of cooperation.

A $750,000 price tag to transfer a WTE generator to the local population may seem expensive. Upon first look this may be true, but more detailed inspection is required to find the full value of the project. A WTE generator is more than a vehicle that can make trash a paying commodity. The effects are at least threefold: electricity, trash removal, and jobs. WTE generators have good prospects for self-sustainment and can encourage economic pluralism. Opportunities include jobs handling the waste streams. Recycling and nonfuel byproducts disposal have potential for additional downstream benefits. Studies show that communities employing WTE programs recycle more responsibly and at a higher rate, contributing to waste reduction.[44] The ash produced from the incineration process has construction uses, including roadbed materials and cement blocks.[45] Another byproduct from some WTE processes is high-quality fertilizer, important in a developing country.[31]

From a military commander's standpoint, winning support from the population is the most valuable outcome. An effort that may bind a community with common interests may also steer those interests to coincide with those of US forces. As with other important services, the community may choose to stand up to protect their generator as well as the infrastructure and functions that sustain it. If the project discourages one IED team from pursuing harm to US Soldiers or entices a community to cooperate more fully to protect the roads that service the WTE generator, it is worth the investment. Again, opportunities to achieve strategic effects may be the most valuable elements in the cost benefit analysis.

Using an unavoidable *resource* such as trash also relieves the community from the cost burden of paying for fuel to run electric generators. Transference of the entire system of possibilities truly gives a community a multi-faceted stake in their own future. For the local commander, this enables greater cooperation, security, and publicity for further opportunity, with the added benefit of improved security and reduced risk—not a bad investment for $750,000.

WTE generators can turn the unavoidable byproduct of human activity—military or civilian trash—into a valuable resource. Electricity from these items has useful applications during MCO as well as stability-focused operations. They can support

reducing the military's logistics tail, and they ultimately pay for themselves in cost avoidance and reduced risk to support forces. WTE generators support efforts in a BCT's stability platinum 10 as well as in a more mature AO. They can directly address three of the Big 5 needs. Ordering and transferring these items also demonstrates US commitment to the people and to the environment. Cost no longer appears as exorbitant as on first inspection. Training unit personnel to capitalize on the energy potential of trash requires a 40-hour investment, the same as commanders routinely invest in each additional combat lifesaver. Tangible enhancement to strategic reach and effects are clearly possible. WTE generators must be considered for the Army's full spectrum forces.

Conclusion and Recommendations

For the foreseeable future in the most unstable regions of the world, US military forces will continue to serve as the de facto executors of American foreign policy. BCTs will often be the first to arrive and will be the only elements of hope and control able to operate in a high-threat, nonpermissive environment. Unfortunately, military operations—especially those offensively focused—exacerbate conditions of instability, and suffering populations are easily influenced to oppose US efforts. BCTs will therefore require additional equipment and training to realize *more* full spectrum capability to enable a running start for long-term stability and reconstruction efforts.

Opportunistic action with appropriate equipment and experience during the S&R gap, much like a combat lifesaver, stabilizes a population by addressing its most immediate needs during its most critical time. BCTs able to better address Big 5 needs in conjunction with a comprehensive security effort can enable a population to endure the immediate trauma of combat and conflict better postured to progress to the next phase of stabilization. These full-spectrum efforts also support achieving positive conditions, including reduced threat, and many of the right relationships for transition to whole of government primacy.

The anecdotes for WPUs and WTE generators demonstrate the need and opportunities for equipping innovation without personnel additions using commercial off-the-shelf technology for training and executing full spectrum operations.[46] WPUs and WTE generators support the stability platinum 10 concept without altering the nature of

the BCTs. Tactical units equipped and experienced as recommended would have the means to address select essential services and form or solidify positive relationships with local populations. Table V recapitulates recommendations for equipping additions. Unit NBC specialists could operate the WPUs while each battalion's cooks can operate the WTE generators.

Table V. Equipment Addition Recap

	2 × CABs	ARS	FA Bn	STB	BSB
COTS WPU (gph)	1 × 300	1 × 300	1 × 300		
	4 × 75	3 × 75	2 × 75		
	4 × 60	3 × 60	2 × 60		
TGER WTE Generator	1 ea	1	1		

Such equipping offers alternative and complementary approaches to lethal operations capitalizing on, rather than ignoring, their interdependence. These capabilities can enable BCTs to simultaneously address the circumstances that provoke populations and elevate threat levels. As threat levels decline, whole-of-government participation can increase. These technologies also support the Army's expeditionary purpose, enhancing strategic reach and endurance. For those reasons, equipping all the subordinate units in a BCT makes a reasonable case.

If the Army is unwilling to individually equip BCTs for full spectrum operations as suggested, alternatives exist. Placing this equipment at combat training centers or at units' home stations for centralized use is not optimal but is a good first step. This will not enhance strategic reach or contribute to endurance during major combat operations (MCO) but may trigger the right lessons and ideas for stability-focused operations when the BCTs, for a time, are on their own.

BCTs, specifically their subordinate units, must be equipped with WPUS and WTE generators and trained on their operation and employment. These equipment additions, much like combat lifesaver bags, require no additional personnel, just additional training for existing personnel. These additions will provide units the experience to conduct better full spectrum operations. During the S&R gap, dual-purpose technologies such as WPUs and WTE generators can, while threat remains high, provide

a much needed running start to more comprehensive efforts required for conflict resolution.

APPENDIX A. THE 3 STEP WATER TREATMENT PROCESS

Step 1—Remove the parasites. Parasites found in water include Giardia, cyst or trophozite; cryptosporidium, an oocyst, and various amoebae. Removing parasites is a matter of filtration to one micron (1 millionth of a meter).[18] Filtration membranes provide a physical barrier to the passage of particles and micro-organisms.[22]

Step 2—Remove the hazardous chemicals and metals. Adsorption (surface attraction of unlike substances) and absorption reduces and eliminates hazardous materials. This often skipped step requires an adequate holding time for the hazardous materials to be removed and is but one problem with high volume systems.[18] Activated carbon filters and porous exchange resins remove dissolved organic and inorganic matter from the source water.[22]

Step 3 - Kill the bacteria and viruses. Ways to destroy bacteria and viruses include: electro dialysis (electric current and ion exchange), oxidation (treatment with ozone), and photo-oxidation (exposing them to ultra-violet light). In systems using ultra-violet (UV) light, this step occurs last in the process as the previous two steps reduce the water's turbidity and enable the UV light to fully penetrate. A more common method to kill the microbes is by chemical disinfection using a poisonous additive such as chlorine. Chlorine disinfection is commonly used because other methods are deemed energy intensive and their effectiveness inconvenient to measure.[22]

If the source is brackish or sea water, the *three steps* require a preliminary step. The water must undergo desalination through reverse osmosis (RO) reducing the TDS to below 500 ppm.[47] Processing fresh water through RO is unnecessary as it reduces throughput and can unnecessarily strip the water of good minerals and electrolytes. Any multi-functional system should have the option to turn off the RO filtration when the source is fresh water.[48]

APPENDIX B. ILLS OF COMMON TREATMENT METHODS

For almost all modern municipal water systems the chosen method to clean water is via chlorine poisoning. US Army treatment systems combine RO with chlorine regardless of the water source. Military RO membranes have not been specifically tested for effectiveness against parasites called for in Step 1, but filtering to one micron and below presupposes this capability. Chlorine additive (calcium hypochlorite) can kill most microbes and leaves a measurable residual known as free available chlorine (FAC). When FAC levels are above a certain level, disinfection is assumed with a residual preventive effect killing microorganisms picked up via handling and storage. Measuring FACs is the Army's preferred method for water treatment testing.

Chlorine treatment alone has drawbacks. It works well in destroying vegetative bacteria and viruses; however protozoa entamoeba histolytica, Giardia lamblia, and cryptosporidium parvum are resistant to it. If they are not first filtered out, via Step 1 above, chlorine disinfection alone is ineffective in killing or disabling them. Also, Army water purification units are RO based using special semi-permeable membranes which are sensitive to chlorine. Host nation water sources, if treated with chlorine, must first be de-chlorinated using a carbon pre-filter to avoid contaminating the RO membranes.[22]

Alternative water treatment methods requiring less chlorine for disinfection may be preferable to those requiring more chlorine as a primary treatment means. While not in the scope of this paper, too much chlorine has other adverse effects than taste. Chlorine in drinking or total use water reacts with natural substances and pollutants forming chloroform, a carcinogen.[49] Human absorption of chloroform increases when it is ingested as a vapor as during a hot shower. There is a high association between cancer and chlorinated water use.[50] Chlorine is not the best disinfectant, only the cheapest and most convenient. Military total use water should be disinfected by chlorine only to minimum levels for storage, not as a primary part of the treatment process.

Reverse osmosis is a form of distillation removing minerals from water. It is also the Army's mandated method. Bad minerals including mercury, lead, and cadmium need

to be filtered or absorbed. Calcium, magnesium, and potassium are examples of good minerals that if possible should not be stripped away for their electrolyte as well as taste characteristics. Water without minerals will absorb minerals from the body upon ingestion. These minerals end up in the urine.[51] While percentages of minerals absorbed may not be medically significant under normal conditions, water without minerals can exacerbate the conditions in which deployed Soldiers currently operate, especially if they do not have access to electrolyte additives. Also, distilled water in contact with the air will absorb carbon dioxide, making it more acidic. "The more distilled water a person drinks the higher his body's acidity becomes."[52]

Palatability is a consideration for military water. Military mobile water treatment equipment does not produce inviting water and is not as convenient or as aesthetically pleasing as bottled water. RO water's flat taste is notably less palatable than non-RO water.[16] The taste of highly chlorinated water is also less palatable. If the water is offensive or even uninviting, Soldiers may not drink enough to remain hydrated. This palatability factor is exacerbated by extreme temperatures in current operations areas. While chlorine remains a cheap and convenient disinfectant for treated water, Soldiers deserve a better, more thorough, albeit less conveniently measured method, such as using UV, ozone, or electrolysis. Also, if RO is unnecessary for desalination, other technologies offer deployed Soldiers better solutions for water treatment.

Counter-intuitively, larger, more centralized municipal systems are less equipped to perform all three purifying steps and rely heavily on chlorination alone. Filtering reduces flow rate, often to unacceptable levels for volume required. The necessary throughput of these systems also prevents the necessary holding time for adsorption and absorption.[48] Resultant turbidity can prevent effectively treating unfiltered water with UV light. These steps are easier with smaller, distributed water purifiers, which if arranged in parallel could achieve the necessary volume and better purify the water.[18] These larger, municipal systems may be the water sources for our Soldiers in future conflicts.

APPENDIX C. HOW TGER WORKS

According to Concurrent Technologies Corporation's Final Feasibility Study, Phase II, TGER is one of the most promising technologies available. The portable system has it own diesel generator to run the unit until it can power itself with RDF. It converts the most common military field wastes to fuels to provide off-grid tactical units electricity and thermal energy for forward field use.[31]

TGER combines two complimentary technologies, biological and thermal decomposition to produce combustible fuel for power generation. Many WTE systems are designed for specific waste streams. TGER has the ability to convert a broad range of waste. Bulk trash is fed into a shredder to reduce volume. Water is added to dissolve sugars and starches from food waste. This liquid solution is then separated using a sieve for bio-catalytic conversion using a package of advanced enzymes, yeast, and commercial grade anti-biotics. This package ferments the sugar and starch liquid solution for 12 hours into a 6-8% ethanol solution. This solution is then filtered, distilled, and cooled to an 85% ethanol liquid fuel.[36]

The solids are compacted into pellets and fed into a gasifier. Under high temperatures and a little oxygen they are thermally decomposed into syngas. This syngas is cooled and filtered. The resultant fuel gas and ethanol solution are fumigated into a modified diesel engine for a 60kW generator.[43] The net power efficiency is about 90%. Byproducts from the process are water, carbon dioxide, and an environmentally benign ash.[31]

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