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SUSTAINABILITY/LOGISTICS-BASING SCIENCE & TECHNOLOGY OBJECTIVE – DEMONSTRATION; DEMONSTRATION #2 – 300-PERSON CAMP DEMONSTRATION

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14. ABSTRACT

The U.S. Army Natick Soldier Research Development and Engineering Center (NSRDEC) collected data on technologies related to the objectives of Sustainability/Logistics-Basing Science & Technology Objective-Demonstration (SLB-STO-D) at the Base Camp Integration Laboratory (BCIL), Fort Devens, MA. The goal of the SLB-STO-D is to demonstrate emerging materiel solution technologies and associated non-materiel solutions that can reduce the need for fuel resupply by 25%, for water resupply by 75%, and for waste removal by 50%, while maintaining or improving the quality of life at expeditionary base camps. The SLB-STO-D is using modeling and simulation, closely integrated with field demonstrations, to show fuel, water, and waste savings attributed to these technologies. Technologies demonstrated at the BCIL include: Containerized Ice Making Technology (CIMT), Water Demand Reduction Technologies for Forward Operating Base Organizational Equipment (WDR), Self-Sustaining Living Module (SLiM), Minimized Logistics Habitat Unit (MILHUT), Nanoparticle-Polymer Composite for Soldier Power and Energy (NPC), Gray Water Reuse Forward Osmosis/Reverse Osmosis (GWR-FORO), Tactical Vehicle-to-Grid/Vehicle-to-Vehicle Power Demonstration System (V2G/V2V), Self-Powered Waste Water Treatment (WWT-D2), Water Quality Monitoring (Pathogen Monitor) (WQM-PM), HMMWV-Towable Load Following 100kW Power Unit (T100), Self-Powered Solar Water Heater (SPSWH), Energy Informed Operations-Central (EIO-C). This Technical Report documents the objectives, technologies, methods, and results of the Demonstration #2 at the BCIL.

15. SUBJECT TERMS
FUELS
WASTE
WATER
ENERGY
SAVINGS
FEEDBACK
LOGISTICS
REDUCTION
INSULATION
BASE CAMPS
SOLID WASTES
WASTE WATER
SELF-POWERED
ENVIRONMENTS
SOLAR HEATING
SUSTAINABILITY
WASTE DISPOSAL
WATER QUALITY
DATA COLLECTION
DEMONSTRATIONS
WASTE REDUCTION
RENEWABLE ENERGY
REDUCED FOOTPRINT
CONTINGENCY BASING
ENERGY CONSUMPTION
FUEL DEMAND REDUCTION
MODELING AND SIMULATION
WATER DEMAND REDUCTION
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PREFACE

During the period 17 May – 23 June 2016, the Experimentation, Demonstration, and Validation Team (EDVT), supported by the functional teams of the Sustainability/Logistics-Basing Science & Technology Objective – Demonstration (SLB-STO-D), conducted the second installment of Demonstration #2 at the Base Camp Integration Laboratory (BCIL), Fort Devens, MA to collect data on technologies that support the objectives of SLB-STO-D. This event was borne out of the execution of the approved Project Plan (version 3.0, dated 19 April 2013), the Integrated Master Schedule, and the Systems Engineering Plan (Lindo and Carpenter, 2013). This report fully supports the directives established therein to document the objectives, materials, technologies, methods and results of data collection events in support of the SLB-STO-D. Datasets associated with this demonstration were delivered to the SLB-STO-D's Lead Systems Engineer and are summarized in this report. Other functional teams, such as the Modeling, Simulations, and Analysis Team, will use the data collected during this demonstration to conduct analysis related to the SLB-STO-D objectives and publish those findings and results under separate covers.

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EXECUTIVE SUMMARY

In 2010, the Army recognized the need to reduce sustainment demands at contingency bases. Contingency bases are highly dependent on resupply, which can be unpredictable, put Soldiers at risk in convoys, and impact mission completion. It is too costly and labor intensive for a small unit (platoon, company, battalion) to transport and maintain all required consumables (fuel and water) to last for weeks or months at small base camps. In 2011, the US Army Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology charged the Research, Development and Engineering Command (RDECOM) with conducting a Technology Enabled Capability Demonstration (TECD) 4a - Sustainability/Logistics—Basing (SLB), now programmed as a Science & Technology Objective – Demonstration (STO-D) to develop, collaborate, and execute a program that would address these sustainment challenges.

> *The Army needs improved capability to enable sustainment independence by reducing resupply and backhaul demand at contingency basecamps. The FY12 through FY17 objective is to reduce the need for fuel resupply by 25%, reduce the need for water resupply by 75%, and decrease waste generation/backhaul by 50% while maintaining a Force Provider like Operational Quality of Life (QoL-(O)) at these basecamps.*

Current Army maneuver units have limited or no organic basing capability and rely on theater provided support. Except for Force Provider, the majority of theater provided equipment/support is not standardized, integrated, or optimized to be easily deployed, transported, or erected and is inherently inefficient. The problem mentioned above forms the basis for the program, lays the foundation for the formulation of the program execution plan, and is pervasively present in the program baseline.

The challenge is to formulate an integrated Model Based Systems Engineering approach for both technologies and non-materiel solutions to address current Army contingency basing barriers. The SLB-STO-D program uses modeling, simulation and analysis to show a reduction in fuel resupply by 25%, a reduction in water resupply by 75%, and a reduction of 50% in waste generated for backhaul at base camps compared to an established technical and operational baseline, while maintaining a Force Provider-like QoL (O). The focus of the SLB-STO-D program is on the 50, 300, and 1,000 personnel base camps on, which the Army's Science and Technology (S&T) efforts are most likely to have a greater impact in resource reduction.

The technology demonstrations were managed by the Natick Soldier Research, Development and Engineering Center (NSRDEC) and conducted in a series of operationally relevant trials of 50, 300, and 1000 personnel capacity venues. These venues are located at the Base Camp Integration Laboratory (BCIL) at Fort Devens, MA and the Contingency Basing Integration and Technology Evaluation Center (CBITEC), Fort Leonard Wood, MO. The venues were selected for their ability to replicate operational environments in field contingency bases (e.g., billets, dining facilities, latrines, showers, etc.) and their unique instrumentation capabilities which support data acquisition and authentication to enable subsequent analyses.

This technical report pertains to the events that transpired during Demonstration #2 at the BCIL, Fort Devens, MA venue during 17 May through 23 June 2016. It documents the objectives, technologies, methods, and results of this demonstration.

During this demonstration, 12 relevant technologies were showcased. These technologies are as follows:

- Containerized Ice Making Technology (CIMT)
- Water Demand Reduction Technologies for Forward Operating Base Organizational Equipment (WDR)
- Self-Sustaining Living Module (SLiM)
- Minimized Logistics Habitat Unit (MILHUT)
- Nanoparticle-Polymer Composite for Soldier Power and Energy (NPC)
- Gray Water Reuse Forward Osmosis/Reverse Osmosis (GWR-FORO)
- Tactical Vehicle-to-Grid/Vehicle-to-Vehicle Power Demonstration System (V2G/V2V)
- Self-Powered Wastewater Treatment (WWT-D2)
- Water Quality Monitoring - Pathogen Monitor (WQM-PM)
- High Mobility Multipurpose Wheeled Vehicle (HMMWV)-Towable Load Following 100 kW Power Unit (T100)
- Self-Powered Solar Water Heater (SPSWH)
- Energy Informed Operations-Central (EIO-C)

Data was collected on all systems using electronic instrumentation, automated data acquisition systems, and in some cases manual data collection methods (e.g., fuel consumption for the T100). The data was monitored, harvested, processed, and securely stored in a network storage device by a Data Librarian, who was responsible for the accuracy and integrity of the data. Periodic data reviews were conducted by a Data Authentication Group (DAG) to ensure the validity and fidelity of the data. The authenticated dataset was delivered to the Lead Systems Engineer.

The dataset is utilized by the SLB-STO-D’s Modeling, Simulation, and Analysis Team (MSAT) for the application of pertinent modeling and simulation methods/analysis to garner results and draw conclusions pertaining to the efficacy of the technologies to meet water, fuel, and waste reductions. The results of the MSAT’s analysis and conclusions are beyond the scope of this report and will be delivered under a separate report.

It is important to note that besides the instrumented and manual data collection measures, this demonstration featured the participation of Soldiers from two different Army units. One group was a squad of eight infantry Soldiers from the 82d Airborne Division at Fort Bragg, NC, which represented a typical user of the technologies when deployed in a base camp setting. These Soldiers were given overview briefings on each of the technologies and participated in focus group sessions to provide feedback. The Soldiers from the 82d Airborne Division did not live at the BCIL during the demonstration but were on-site during the week of 6 June 2016 to participate in the focus group sessions. The other group of Soldiers was a subset of the 542d Quartermaster Company (Force Provider). The 542d is a U.S. Army Reserve unit that is responsible for the set-up and maintenance of Force Provider assets within a base camp. The

Soldiers of the 542d Quartermaster Company lived at the BCIL as part of their two-week summer Annual Training. During the demonstration they received training on the new technologies according to their Military Occupational Specialty (MOS). Subsequently, these Soldiers participated in focus group sessions to provide feedback on their experience with the different technologies. The purpose of the group sessions and feedback was to provide insights to the Technology Providers on how to improve their technologies prior to potential fielding. Furthermore, the Soldiers' input assists the SLB-STO-D in assessing the impact of the demonstrated technologies on the QoL of the Soldiers while living in base camps.

In addition, during part of the demonstration, Soldiers from the Army's 804th Medical Brigade occupied the BCIL. These Soldiers used the facilities (i.e., billeting, laundries, latrines, showers, and kitchen) but were not trained on any of the technologies nor did they participate in focus groups. Their participation provided the means to demonstrate the technologies in a more realistic environment as the Soldiers used the facilities that the technologies were interfacing with in providing various levels of services (e.g., electrical power, gray and blackwater handling, heating water, conserving water, etc.).

During Demonstration #2 at the BCIL, the SLB-STO-D team was able to achieve the main objective of the field demonstrations, which was to collect empirical data on candidate and baseline base camp technologies to calibrate modeling and simulation models, and to conduct subsequent analysis. This objective was achieved and the datasets were delivered.

Other noteworthy accomplishments were the ability to offer the Technology Providers with the opportunity to:

- Integrate their technology with a working base camp, which allows the Technology Providers to assess the interoperability challenges of interfacing their technology with existing base camp equipment and other new technologies.
- Work alongside Soldiers to harvest their feedback, which ensures that Soldier input is used to improve technologies early in the developmental cycle.
- Garner visibility with Army leadership that could lead to future support and funding prioritization.

Technologies were demonstrated in an operationally relevant environment and significant lessons learned were captured as follows:

- CIMT: This system is the 1st-generation prototype. It successfully demonstrated the capability to produce and bag ice. While a final production unit should require only minimal human interaction, this unit required vigilant supervision to keep making ice continuously. The important feature was shipping this system out of the lab and getting it into the field and operational under realistic conditions. The vendor learned much about minor issues in the mechanical operation (bagger, conveyor, etc.) as well as improvements required in the software (harvesting, defrosting, etc.).
- WDR: The hypothesis driving the data collection for the WDR revolved around the question of whether the use of low-flow shower heads increases the shower duration times, thus reducing the water savings impact of the shower heads. This hypothesis was

not as straightforward as originally thought as there are numerous operational variables that could drive length of showers other than the rate or quality of the water flow. Schedule pressure, leadership, enemy situation, unit standard operational procedures, seasonal time of year, water resupply expectations, etc. could have various and perhaps significant impacts on shower water usage. Low-flow versus standard showerheads are just a piece of the bigger picture for water conservation.

- SLiM: The system was monitored to ascertain the performance of the electrical system (i.e., photovoltaic panel array, batteries, and generator backup). Charging rates, system overload capacity, and system startup lag times were determined and documented.
- MILHUT: The evaporative cooler is likely not a suitable solution under the conditions experienced at this demonstration. The air conditioner was effective for cooling, but unlike an Environmental Control Unit (ECU), there was no return duct to move and recirculate air through the shelter.
- NPC: During the demonstration, more than 37,000 current-voltage curves were obtained from the photovoltaics. In addition, there was an indication that the photovoltaic with nanoparticles showed an improvement over the control photovoltaic, at off-normal angles of incidence. Because of the large volume of data collected, and the potentially publishable results of improved low-angle power harvesting (which the researcher is seeking to reproduce in small-scale experiments at NSRDEC if funding can be secured), this data and analysis will be reported in a separate report.
- GWR-FORO: This system operated as intended. The only issues the Technology Provider had to deal with were a failure of the control module and some adjustments to the chlorine injector. A replacement control module was immediately shipped, received, and installed the next day.
- V2G/V2V: This system successfully powered the North Camp of the BCIL during the demonstration. As the project moves forward to further develop the V2G/V2V technology, Tank and Automotive Research, Development and Engineering Center (TARDEC) has identified several areas for improvement. First is weight and size. This is a prototype system. Making sure the system worked and figuring out management of time were most critical, so acceptance on size and weight was relaxed. With improved packaging, the Tactical Vehicle-to-Grid Module (TV2GM) and Energy Storage Unit (ESU) weight and size will come down by two-thirds and one-half, respectively. Eliminating ground fault detection issues as well as decreasing system boot-up time will increase system robustness.
- WWT-D2: The Cambrian wastewater treatment system incorporates a biological-based component in the treatment train that requires an active biomass to treat the wastewater. Typically biological-based systems can be difficult to start up rapidly and reliably. It can take a number of days to a number of weeks to get the biomass up and running at an optimal rate (i.e., it takes time for the bugs to grow). The introduction of wastewater with high organic carbon content will also increase the reaction rate. If the microorganisms reproduce too quickly the oxygen in the water can be depleted, causing the system biomass to become anaerobic/go septic, which could require the need to rebuild or reseed the system to keep the treatment at the desired rate. Some of these typical issues were encountered during the demonstration. TARDEC is exploring a variety of solutions to meet the wastewater treatment need for contingency base camp support and sustainment.
- WQM-PM: This system tested the recycled graywater for the target disease-causing

organism with limited success in its first field environment test (one failure in eight samples). The field event atmosphere had much pollen landing on the sample pad of the device, which blocked the sample flow and caused failure. Also, the STO-D testing discovered that this system can misidentify and count pollen particles as pathogens. The failures and the false counts can readily be addressed with engineering and software improvements. One positive is that the pathogen monitoring analyzed more difficult waters that were not intended in its mission, such as untreated graywater and treated blackwater with no significant increase in failure rate (4 failures in 19 samples).

- T100: The T100 successfully powered the Rigid Wall Shelter base camp on the east side of the BCIL during the demonstration. The differences between laboratory testing, i.e., using load banks, and an operational environment, i.e., actual resistive and reactive electrical loads, were evident and prompted firmware modifications to fix minor engine speed instability. An unexpected inverter leg failure occurred due to overloading and was fixed at the contractor's facility in order to continue participation in the demonstration. Consequently, the T100 will be upgraded to preclude the aforementioned incidents and be packaged in a modular format to ease maintenance and repairs in the field.
- SPSWH: The SPSWH system successfully heated water during the demonstration. However, during cloudy conditions the system could not automatically track the sun and the system would not track properly when the sun reappeared. This situation demanded constant manual adjustments and needs to be addressed in future design improvements. Heat losses in the hot water hose between the SPSWH and the Army Water Heater 400 (AWH-400) need to be addressed as it caused the AWH-400 to heat the water and had an impact on fuel savings. Other interoperability issues uncovered related to the system's ability to keep up with the demand for hot water and compatibility with the operating pressures of the BCIL's existing fresh water pump.
- EIO-C: Overall, the grid contributed to significant fuel savings. The inverter/battery system resulted in small reductions in generator runtime and increases in generator efficiency, but more importantly, showed that these parameters have the potential to be optimized with a more developed grid control algorithm and should result in greater improvements in the future.

After the data analysis is completed, specific results and conclusions will be provided under a separate report.

SUSTAINABILITY/LOGISTICS-BASING SCIENCE & TECHNOLOGY OBJECTIVE-DEMONSTRATION

DEMONSTRATION #2 – 300-PERSON CAMP DEMONSTRATION

1. INTRODUCTION

This technical report documents the objectives, candidate technologies, methods, and results of the Demonstration #2 conducted by the Sustainability/Logistics-Basing Science & Technology Objective-Demonstration (SLB-STO-D) during the period 17 May–23 June 2016 at the Base Camp Integration Laboratory (BCIL), Fort Devens, MA. This report does not include analysis of the data collected. The analysis is a separate effort, following the demonstration, to be documented in a separate report.

1.1 SLB-STO-D Program

The SLB-STO-D was approved by the Department of the Army in February 2012. The program was approved to resolve the following Army-wide problem as stated below:

> “The Army needs improved capability to enable sustainment independence/self-sufficiency and to reduce sustainment demands at expeditionary basing levels contingency bases. It is too costly, too unpredictable, and too labor intensive for a Small Unit to carry all required consumables to last for weeks or months at a combat outpost or patrol base. Storage facilities and systems do not meet needs of these small bases, and resupply efforts are highly unpredictable.”

This problem statement forms the basis for the program and lays the foundation for the formulation of the program proposal and is pervasively present in the program baseline. To place the problem in perspective, in 2011 contingency bases of all services consumed approximately 254,000,000 gallons of fuel which is equal to that of ground and air platforms combined (according to Assistant Secretary of Defense, Operational Energy Plans and Programs). At even a conservative figure of $10 per gallon, the fully burdened cost of fuel, this represents a significant operations and support (O&S) cost. Equal to that is the risk that the significant tactical resupply burden required presents to the Soldier in the form of convoy incidents, etc.

The program plan (Rettie, 2012) uses modeling, simulation, and analysis to show a reduction in fuel consumption by 25%, a reduction in water consumption by 75%, and a reduction in waste generated by 50% at base camps compared to an established technical and operational baseline. Conducting live demonstration and collecting data in an operationally relevant environment will be key to developing and validating the models that will be used to address this challenge.
To achieve the programmatic goals and meet the 4Q2017 schedule, SLB-STO-D sought out fairly mature applicable technologies, i.e., Technology Readiness Level 5 (TRL 5) or above, and

conducted multiple operationally relevant integrated demonstrations in fiscal year (FY) 15 and FY16 to determine the capabilities that contribute to the overall goals of the program.

One of the goals for all the field demonstrations is to showcase technologies with the greatest impact to reduce fuel, water, and waste in base camps. Having a common venue for integration, empirical data collection, and Soldier interaction/feedback, encourages communication between transition partners and other technology leads. This communication and learning has the potential to improve prototypes and ultimately improve technology transition to Programs of Record (PoRs).

1.2 Overall Demonstration Concept and History

This section presents the general concept for the demonstrations that were conducted as part of the STO-D project. The "who, when, what, and where" are included. The "why" is discussed in the next section.

Who: The SLB-STO-D has six functional teams supporting the demonstration concept. The demonstration was led by the Experimentation, Demonstration, and Validation Team (EDVT), and supported by the other functional teams – Technology Maturation and Integration Team (TMIT), Systems Engineering and Integration Team (SEIT), Modeling, Simulation, and Analysis Team (MSAT), Requirements Integration Team (RIT), and the Core Leadership Team (CLT). Each functional team had a role to play. Also, each Technology Provider for the various candidate technologies, and their supporting contractor or vendor if applicable, participated in the demonstrations. For each of the demonstrations there was some level of participation by Soldiers from various units.

When: The demonstrations were managed by FY. Demonstration #1 was executed in FY15 and Demonstration #2 was executed in FY16. The full scope, including the planning window of each demonstration, included four phases – Planning Phase, Demonstration Preparation Phase, Integrated Demonstration Phase, and Analysis & Reporting Phase. The Planning phase began with development of the first Demonstration and Assessment Master Plan (DAMP) (Harris, 2016). The Demonstration Preparation Phases for Demonstration #1 and #2 began in April 2014 and April 2015, respectively, and featured testing of individual technologies by the sponsoring technology developers.

What and Where: The Integrated Demonstration Phase for Demonstration #1 began with the execution of the 50-person base camp demonstration during the period 29 September–17 October 2014 at the BCIL at Fort Devens, MA. Technologies demonstrated at the BCIL included:

- Expedient Shelters with Non-woven Composite Insulation Liner (LINER)
- 1 kWe jet propulsion fuel type 8 (JP-8) Fueled, Man-Portable GenSet (MANGEN)
- Renewable Energy for Distributed Under-supplied Command Environments (REDUCE)
- Bidirectional Onboard Vehicle Power/Tactical Vehicle-to-Grid Module (OBVP/TV2GM).

The second event in the Demonstration #1 Integrated Demonstration Phase was the 1000-person camp demo conducted during the period 7–24 April 2015 at the Contingency Basing Integration and Technology Evaluation Center (CBITEC), Fort Leonard Wood, MO[1].

This second event featured the following selected candidate SLB-STO-D technologies:

- Modular Appliances for Configurable Kitchens (MACK)
- Desert Environment Sustainable Efficient Refrigeration Technology (DESERT)
- Real Time Inline Diagnostic Technology for Water Monitoring (WATERMON)
- Wastewater Treatment – Biological (WWT-Bio)
- PowerShade Cost Reduction (PSHADE)
- Energy Informed Operations-Central (EIO-C)
- Deployable Metering and Monitoring System (DMMS)
- Hybrid Power Trailer (HPT)
- Structural Insulated Panel Hut (SIP-Hut)

The third and final event in the Integrated Demonstration Phase for Demonstration #1 was conducted at the BCIL during the period of 7–30 July 2015. This event, referred to as the 300-person base camp demonstration, included the following technologies:

- Onsite Automatic Chiller for Individual Sustainment (OACIS)
- LINERS
- Innovative Cooling Equipment (ICE)
- 1 kWe JP-8 Fueled MANGEN
- Real Time Inline Diagnostic Technology for WATERMON
- Graywater Reuse (GWR)
- Modular Force Water Generation Storage & Analysis (WFA)
- WWT-Bio
- Power Management and Control Technology (NANOGRID)
- Expeditionary Triple Container (TRICON) Kitchen System Appliance Integration, Fuel Fired (ETK-FF)
- Joint Inter-Service Field Feeding Burner (JIFF)
- Solar-Powered Shelter System (SPSS)

Demonstration #2 featured two field events in the Integrated Demonstration Phase. The first phase was executed at CBITEC during the period of 17 February–16 March 2016, featuring the following technologies:

- Minimized Logistics Habitat Unit (MILHUT)
- Rapidly Deployable Lightweight Austere Weather Shelter System (RDS)
- Shelter Radiant Heating System (SRHS)
- Structural Insulated Panel Huts – v3.0 (SIP-Hut 3.0)
- Structural Insulated Panel Huts – v4.0 (SIP-Hut 4.0)

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[1] The CBITEC is a joint venture between the Maneuver Support Center of Excellence (MSCoE), with the Training and Doctrine Command (TRADOC) Capability Manager Maneuver Support as the executive agent, and the Construction Engineering Research.

The second phase event of Demonstration #2 was conducted at the BCIL in May-June 2016 and is the subject of this report. This demonstration featured twelve candidate technologies.

- Containerized Ice Making Technology (CIMT)
- Water Demand Reduction Technologies for Forward Operating Base (FOB) Organizational Equipment (WDR)
- Self-Sustaining Living Module (SLiM)
- MILHUT
- Nanoparticle-Polymer Composite for Soldier Power and Energy (NPC)
- Graywater Reuse Forward Osmosis/Reverse Osmosis (GWR-FORO)
- Tactical Vehicle-to-Grid/Vehicle-to-Vehicle Power Demonstration System (V2G/V2V)
- Self-Powered Wastewater Treatment for FOB – Cambrian Innovation (WWT-D2)
- Water Quality Monitoring-Pathogen Monitor (WQM-PM)
- High Mobility Multipurpose Wheeled Vehicle (HMMWV)-Towable Load Following 100 kW Power Unit (T100)
- Self-Powered Solar Water Heater (SPSWH)
- EIO-C

Details of the demonstration planning and execution are documented in the Demonstration Plan (Harris, 2016). During each demonstration the different technologies were integrated with the venue and in some cases other technologies. Then the technologies were exercised either operationally by Soldiers during routine training or according to a script focused on collection of data elements.

1.3 Demonstration Purpose

Why: Because there is neither sufficient time nor resources for the SLB-STO-D to demonstrate all variations of technologies and current base camp systems in multiple environments and multiple configurations, a Model-Based System Engineering (MBSE) approach is key to meet the program goals. In support of the MBSE approach, the key purpose of this demonstration was to collect empirical data on selected candidate technologies and the BCIL's 300-person camp baseline systems in an operationally relevant environment. Data were used as indicated in the Analytical Framework **(Figure 1)** and described in the SLB-STO-D Systems Engineering Plan (Lindo, 2013). Many iterations of various base camps can be virtually simulated to assess accomplishment of the STO-D fuel, water, and waste challenge.

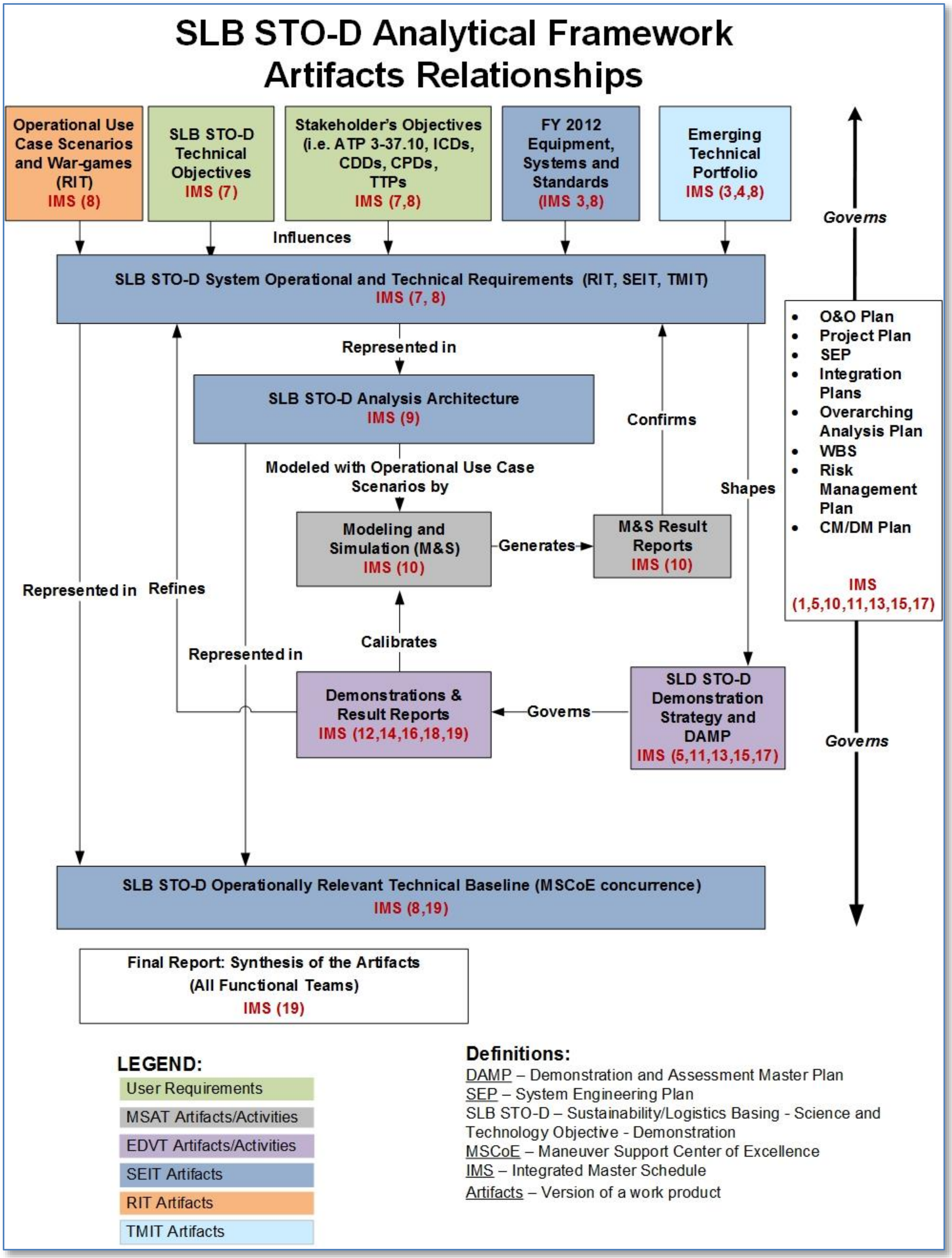


Figure 1: Analytical Framework

1.4 Specific Demonstration Objectives

The specific objectives for each of the Integrated Demonstration Phases are directed by the CLT in the Demonstration Strategy Document (CLT, 2014). These objectives are:

- **Objective 1**: Collect empirical data on candidate technologies and baseline systems that can be used to calibrate modeling, simulation, and analysis, and support trade-offs and engineering decisions (main effort).
- **Objective 2**: Collect data on non-materiel solutions (NMS) that can be used to influence the operational baseline, including doctrine, organization, training, leadership, personnel, and facilities. (NOTE: This objective for NMS was not included in this demonstration.)
- **Objective 3**: Collect data on Quality of Life (QoL) at the camp.
- **Objective 4**: Show how SLB-STO-D meets Contingency Basing and Operational Energy (OE) gaps.
- **Objective 5**: Showcase any “Wow Factors,” i.e., the materiel and non-materiel game changers.
- **Objective 6:** Present modeling and simulation methods and results as part of the demonstration through visual and physical displays, such as posters and computer representations of models.

1.5 Key Events Related to Demonstration #2 at the BCIL

Demonstration #2 officially began in April 2015 with the Demonstration Prep Phase, preceded by a few preliminary planning tasks. The demonstration is divided into three phases—the Demonstration Preparation Phase, the Integrated Demonstration Phase, and the Analysis and Reporting Phase. For Demonstration #2, the Integrated Demonstration Phase was further subdivided into two major field events. This section will focus on the key events related to planning and executing that portion of Demonstration #2 conducted at the BCIL.

- **October 2014** – Conducted the first workshop to identify candidate technologies to be demonstrated in FY16.
- **December 2014** – Conducted a Technology Readiness Review to assess the readiness and availability of the selected technologies.
- **March 2015** – The EDVT prepared and submitted the DAMP for Demonstration #2.
- **April 2015** – Demonstration Preparation Phase began.
- **May 2015** – Reviewed the DAMP for Demonstration #2 at the Demonstration Readiness Review (DRR) at Natick.
- **September 2015** – This was the suspense date for data elements to be submitted to the EDVT for inclusion in the Data Source Matrix (DSM).
- **October 2015** – The EDVT and SEIT met with the Lead Systems Engineer in Orlando to develop the draft plan for integrating the technologies to be demonstrated at the BCIL. Conducted a site reconnaissance at the BCIL. Presented the draft demonstration concept at the quarterly DRR (Michigan). Technology Providers briefed system status at the DRR.
- **November 2015** – Distributed the first version of the DSM for coordination.

- **January 2016** – Conducted the data conference with functional teams and Technology Providers to “finalize” the data elements to be collected. Conducted another quarterly DRR (Missouri).
- **February 2016** – Conducted coordination meeting with the Commander, 542d Quartermaster Company (QM Co.) (Force Provider). Presented the demonstration concept to the BCIL Configuration Control Board (CCB).
- **April 2016** – Conducted quarterly DRR at the BCIL and received updated status from Technology Providers. Included a site reconnaissance in the DRR agenda. Presented another update to the BCIL CCB. Conducted another coordination meeting with the 542d QM Co.
- **17 May 2016** – Conducted all-hands site briefing and initiated set up process for all technologies. Established the Demonstration Operations Center (DOC) and the Data Management Center.
- **17-26 May 2016** – Continued set up and instrumentation of all technologies.
- **1-3 June 2016** – Executed pilot runs of the data collection.
- **6-19 June 2016** – Executed record runs of the data collection.
- **8 June 2016** – Convened the first meeting of the Data Authentication Group (DAG).
- **15 June 2016** – Conducted Leadership Day and hosted the Honorable Katherine Hammack, Assistant Secretary of the Army for Installations, Energy and Environment (ASA IEE), among others.
- **16 June 2016** – Conducted the After Action Review (AAR).
- **17, 20-22 June 2016** – Convened the DAG and completed authentication of the Deliverable Datasets (DDS).
- **23 June 2016** – Delivered the authenticated and compiled DDS to the Lead Systems Engineer.

2. DEMONSTRATED TECHNOLOGIES

The systems employed during the demo can be categorized in two ways. The first category is the most obvious, that being the SLB-STO-D candidate technologies selected by the TMIT for inclusion in the demo. But the team also considered and collected data on some key baseline systems that the MSAT was used for comparison to determine savings in fuel, water, and waste.

2.1 Containerized Ice Making Technologies (CIMT)

The goal of the CIMT **(Figure 2)** project is to develop advanced technologies for containerized ice machines that will have greater capability and use less fuel compared to the current deployed systems and near-term solutions.

Figure 2: CIMT

The CIMT used in this demonstration consisted of the following components and modules (**Figure 3**):

- TRICON
- Compressor and evaporator
- Condenser
- Ice maker
- Ice bagger
- Ice screw conveyor
- Refrigerated ice storage compartment

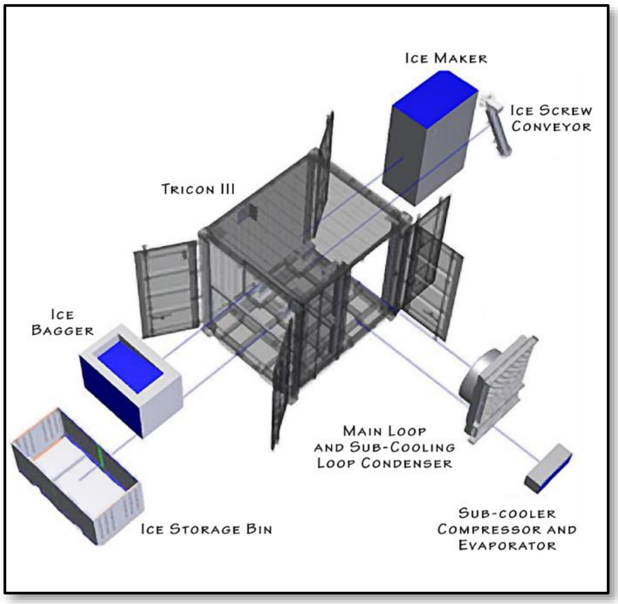


Figure 3: CIMT Components/Modules

The CIMT's new capabilities as compared to existing ice making systems are:

- Suitability to hot/dusty/outdoor environments
- Greater ice production rate
- Mobility/transportability
- Modularity
- Compatibility with alternative sources of energy and smart grids

The following products and capabilities were demonstrated:

- 1st-generation CIMT prototype
- TRICON-containerized
- System weight of 6,900 lb
- Estimated production cost of $100K

- 3600 lb/day production rate
- Automatic bagging
- 1200 lb of onboard storage

Technical Point of Contact (POC): Alexander J. Schmidt, NSRDEC, alexander.j.schmidt4.civ@mail, 508-233-4244.

2.2 Exploration of Water Demand Reduction Technologies for FOB Organizational Equipment (WDR)

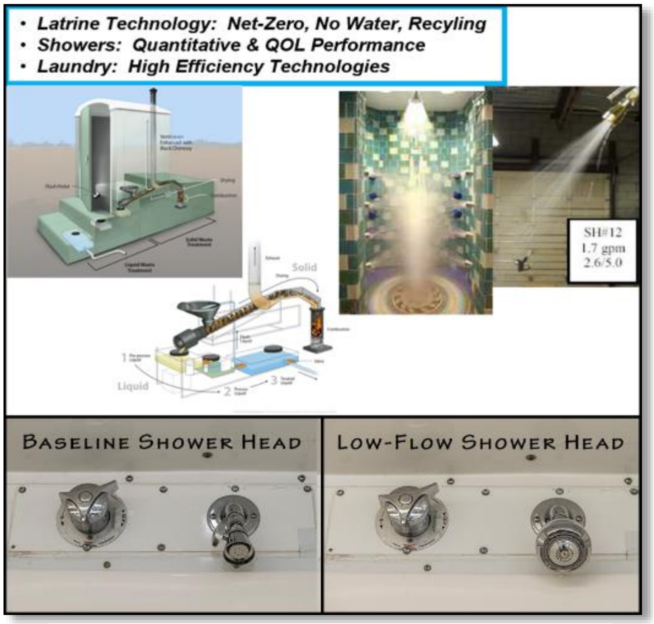


Figure 4: WDR Concept

The WDR (**Figure 4**) technology project investigated non-traditional technologies (novel materials, chemistries, and processes) capable of reducing or eliminating the use of water within base camp organizational equipment, such as laundries, showers, and latrines. During this technology exploration, the definition of water demand reduction requirements and program metrics will be completed. The highest payoff and manageable risk technologies will be down-selected and prototyped for demonstration.

The WDR technology project will demonstrate the following capabilities and/or products:

- Formalized water demand reduction requirements and program metrics
- Test data and validation of water demand reduction technology through small-scale laboratory experimentation
- Insertion of technology metrics into the SLB-STO-D modeling and simulation environment to determine net impact to base camp water consumption
- Explored solutions included the Xeros laundry unit, a low flow showerhead, and RTI liquid disinfection system (or complete latrine system)

Demonstration of these capabilities and products would provide:

- Overall reduction in base camp water demand
- Significant reduction in the cost and logistical burden associated with base camp resupply
- Fewer personnel and vehicles required to perform hazardous resupply of base camps

Participation in SLB-STO-D BCIL demonstration was limited to the low-flow showerhead seen in the bottom right of **Figure 4**.

Technical POC: Chris Aall, christian.d.aall.civ@mail.mil, NSRDEC, 508-233-5188.

2.3 Self-Sustaining Living Module (SLiM)

The SLiM **(Figure 5)** technology project will study the complex Contingency Basing interrelationships of habitation, life support, and organizational equipment. The SLiM provides life support functions for approximately 20 personnel within a global architecture with scalable infrastructure capabilities.

Figure 5: SLIM

The SLiM demonstrated during this venue consisted of:

- Billeting module with man-portable components (**Figure 6**)
- Photovoltaic (PV) array and microgrid **(Figure 7**)
- Rain water collectors (**Figure 8**)
- 10 kW Tactical Quiet Generator (TQG) (**Figure 9**)
- Air conditioner (**Figure 10**)

Figure 6: SLiM During Assembly

As part of this project, a hygiene (shower/latrine), waste management or repurposing, and laundering module was also planned, but was not delivered for this demonstration.

Figure 7: Microgrid and Photovoltaic Panels Array

Figure 8: Rainwater Collectors

Figure 9: 10 kW TQG

Figure 10: Air Conditioner for SLiM

The SLiM demonstrated the following capabilities and products:

- Provided shelter/billeting and mission planning space for around 20 personnel
- Maintained habitable internal temperatures and living conditions
- An expeditionary nature (regardless of environmental conditions/water exposure) - compactable for shipment/transport, air-droppable, or vehicle-carried/towed
- Minimal manpower required for set-up, no Material Handling Equipment required
- Interoperated with standard base camp utility structures

Demonstration of the above capabilities and/or products would provide:

- Increased efficiencies in power and water consumption, and also waste management
- Decrease of operations and maintenance costs
- Increased Warfighter focus on mission operations vs. base camp establishment

Technical POC: Elizabeth Swisher, elizabeth.d.swisher.civ@mail.mil, NSRDEC, 508-233-5457.

2.4 Minimized Logistics Habitat Unit (MILHUT)

Figure 11: MILHUT

The MILHUT **(Figure 11)** project aims to develop a military habitation system that is easily transported, rapidly set up, primarily self-sufficient in operation, and provides enhanced mission capability to deployed Warfighters. Through implementation of renewable energy technologies, the MILHUT system plans to reduce the reliance on resupply operations, and therefore lengthen the time Warfighters can be deployed in remote locations without resupply. Furthermore, the system aims to increase comfort and mission readiness by providing essential capabilities in the areas of hygiene, habitation, and food preparation, normally not available during deployments of this nature.

The MILHUT system that was used at this demonstration consisted of the following:

- Hygiene TRICON (**Figure 12**)
  - 70-gal water tank
  - 30-gal fuel tank
  - ECOJOHN toilet
  - Sink
  - Shower
  - Clothing washer
  - Kitchen appliances (i.e., electric stove, refrigerator, ice maker, etc.)
  - Reverse osmosis system

- Power TRICON (**Figure 13**)
  - 77-gal fuel tank
  - 95 kBTU Heater
  - Generator
  - Environmental control unit (ECU)
  - Battery pack
- Air-supported tent (**Figure 14**)
- 10 kw solar panels (**Figure 15**)

Figure 12: Hygiene TRICON

Figure 13: Power TRICON

Figure 14: Air-Supported TEMPER

Figure 15: Solar Panels

The MILHUT demonstrated the following capabilities and products:

- A fully integrated TRICON MILHUT system for remote deployments, integrated with a 32-ft air-supported TEMPER (tent, extendable, modular, personnel) shelter system
- Insertion of technology metrics into the SLB-STO-D modeling and simulation environment to determine net impact to base camp water consumption

Demonstration of the above capabilities and products would provide:

- Overall reduction in base camp water demand and waste backhaul logistics
- Significant reduction in the cost and logistical burden associated with base camp resource resupply
- Fewer personnel and vehicles required to perform hazardous resupply of base camps; greater number of Soldiers available for mission essential operations

The MILHUT previously demonstrated the following capabilities at CBITEC: blackwater waste incineration, heat energy recovery systems, solar power to reduce reliance on waste disposal efforts, reduction of net fuel reliance, and reduction in potable water resupply.
The MILHUT is currently at TRL 6 and scheduled to transition to PdM – FSS at TRL 7 in FY17.

Technical POC: Chris Aall, christian.d.aall.civ@mail.mil, NSRDEC, 508-233-5188.

2.5 Nanoparticle-Polymer Composite for Soldier Power and Energy (NPC)

The NPC **(Figure 16)** for Soldier Power and Energy technology project will provide more power and energy than traditional PV and thermoelectrics (TE); charge batteries even at dusk, dawn, and in the case of overcast skies; be lightweight; and result in net weight reduction by assuring confidence that fewer batteries can be carried by Soldiers on operational missions.

The NPC that was used in this demonstration consisted of:

Figure 16: NPC

- NPC panels of various materials and sizes (**Figure 17**)
- Instrumentation and computer assets to collect data (**Figure 18**)
- Batteries (**Figure 19**)

Figure 17: NPC Panels

Figure 18: Instrumentation and Data Collection

Figure 19: Batteries

The NPC project demonstrated the following capabilities and products:

- Reports, publications, and samples of technology and materials to significantly improve PV and possibly TE conversion efficiencies
- Soldier-portable NPC material that can be scaled up to a rollaway for power/energy harvesting or possibly a melt-extruded fiber

Demonstration of the above capabilities and products would:

- Provide significant improvement in efficiency of radiative energy harvesting from the environment
- Enable more time for power harvesting under overcast skies, dusk/dawn, etc., to charge batteries faster (i.e., more harvested energy)
- Provide concealment by the potential use of a matte finish

The NPC technology project (also known as “Nano-enhanced photovoltaics”) is currently at TRL 4 and planned, contingent on obtaining funding, to transition to Program Manager-Soldier Warrior or to an EBCP Directorate or Warfighter Directorate 6.3 program (for example, 16-272 is a candidate for a transition in EBCPD) in FY17 or FY18.

Technical POCs: Dr. Richard Osgood, richard.m.osgood.civ@mail.mil, NSRDEC, 508-233-5494 and Nicholas LeGrand, nicholas.j.legrand.civ@mail.mil, NSRDEC, 508-233-5246.

2.6 Graywater Reuse – Forward Osmosis/Reverse Osmosis (GWR-FORO)

The GWR-FORO **(Figure 20)** technology project will provide graywater recycle/reuse at contingency bases to reduce non-potable water resupply needs. It will also provide an improved capability that can adapt to widely varying load conditions to treat more influent streams with less fouling and increased recovery of treated water.

Figure 20: GWR-FORO

The GWR-FORO that was used in this demonstration was comprised of the following components:

- TRICON containing GWR-FORO system (**Figure 21**)
- Gray water blivet (3000 gal) to store gray water output of laundry, showers, and sinks **(Figure 22)**
- Waste water blivet (3000 gal) to store wastewater processed by the GWR-FORO (**Figure 23**)

Figure 21: GWR-FORO within a TRICON

Figure 22: 3000-gal Graywater Blivet

The GWR-FORO technology project demonstrated the following capabilities and products:

- A graywater reuse technology that can be integrated into current support equipment to include:
  - Water purification systems
  - Shower and laundry systems
  - Field feeding and medical systems

Figure 23: 3000-gal Non-potable Water Blivet

- Characteristics:
  - Weight – ≤7,110 lb
  - Size – pack out volume of ≤ 416 ft^3
  - Cost target – <$250K per unit for production >100
  - Manpower – minimal, automatic control and operation

Demonstration of the above capabilities and products would provide:

- Reduction in transportation assets required to haul wastewater and provide potable water currently used for non-potable uses
- Expected reduction in the water logistical footprint of 75%
- Improved safety and force protection at base camps
- Reduction in water, fuel, and waste
- Reduction in health risks from wastewater-associated vectors

The GWR-FORO technology project is currently at TRL 5 and scheduled to transition to PdM Petroleum and Water Systems (PdM PAWS) at TRL 6 in FY18.

Technical POC: Lateefah Brooks, lateefah.c.brooks.civ@mail.mil, Tank and Automotive Research, Development, and Engineering Center (TARDEC), 586-282-6587.

2.7 Tactical Vehicle-to-Grid/Vehicle-to-Vehicle (V2G/V2V) Demo System

Figure 24: Tactical V2G/V2V

The V2G/V2V (**Figure 24**) project will develop a roll-up/roll-away vehicle-based alternating current (AC) power system with cyber-secure bidirectional power and communications management, and grid services. The development includes four On-Board Vehicle Power (OBVP)-capable tactical host vehicles and supporting ancillary equipment for microgrid connectivity. Grid services include peak shaving, power regulation, and current source mode.

The V2G/V2V system that was used in this demonstration was comprised of the following equipment and components:

- Two Mine-Resistant Ambush Protected (MRAP) vehicles capable of generating up to 120 kW of electric power (**Figure 25**)
- Two HMMWV capable of generating up to 30 kW (**Figure 26**)
- Four Tactical Vehicle-to-Grid Module-Electronic Support Unit of 60 kW each. (**Figure 27**)
- Eight Power Distribution and Illumination System, Electrical (PDISE) systems (**Figure 28**)

Figure 25: MRAPs

Figure 26: HMMWVs

Figure 27: TVGM-ESU

Figure 28: PDISE M100s

The V2G/V2V technology project demonstrated the following capabilities and products:

- Tactical roll-up/roll-away 240 kW vehicle-centric AC power supply
- Two MaxxPro MRAPs (120 kW) and two M1152 HMMWVs (30 kW) with OBVP; 260 kW export direct current (DC) power to supply four Tactical Vehicle-to-Grid Modules (TVGMs) producing 208V/120VAC 3Ø AC
- Variable-speed operation and energy storage (~90 kWh) enabling anti-idle, grid services, and optimized generator operation (fewer but at/closer to rated power)
- Communications standards between vehicles and the four 60 kW inverters for grid management, vehicle-faults, and maintaining vehicle mission readiness
- Modeling and simulation of vehicle fleet in microgrid environment
- Performance and fuel data of vehicles and impact on microgrid

Demonstration of the above capabilities and products would provide:

- Validation of very fast-forming, integrated, robust, ad-hoc, reconfigurable, vehicle-based power supply for austere contingency bases – 240 kW AC power supply < 20 min
- Better utilization of vehicle systems capable of electrical power production; currently vehicles utilized ~5% of time on the base camp
- Utilization in microgrids will save fuel/lives

- Base power fuel reduction: 20% fuel usage reduction utilizing energy storage – Hybrid Power System (MIT-LL/NAVSEA study)
- Validated tactical vehicle V2G and V2V power and communications sharing

Technical POC: Steve Kolhoff, steven.w.kolhoff.civ@mail.mil, TARDEC, 586-282-3588.

2.8 Self-Powered Wastewater Treatment for Forward Operating Bases - Cambrian Innovation (WWT-D2)

The WWT-D2 **(Figure 29)** technology project will provide wastewater treatment at contingency bases to reduce non-potable water resupply needs and wastewater backhauling. It will also provide an improved capability that can adapt to widely varying load conditions with rapid startup and waste-to-energy conversion for net-zero system operation.

Figure 29: WWT-D2

The Cambrian wastewater treatment system incorporates a biological-based component in the treatment train that requires an active biomass to treat the wastewater. Typically biological-based systems can be difficult to start up rapidly and reliably. It can take a number of days to a number of weeks to get the biomass up and running at an optimal rate (i.e., it takes time for the bugs to grow). Seeding or inoculating the system, the process of adding additional microbes or organic matter (i.e, food for microbes), can be used to hasten the startup process. The introduction of wastewater with high organic carbon content will also increase the reaction rate. If the microorganisms reproduce too quickly the oxygen in the water can be depleted causing the system biomass to become anaerobic and go septic which could require the need to rebuild or reseed the system to keep the treatment at the desired rate. Otherwise, the treatment rate would be reduced, taking longer to treat the wastewater to the desired level or resulting in less complete treatment.

The WWT-D2 system that was demonstrated consisted of the following components:

- Wastewater treatment system housed in a TRICON (**Figure 30**)
- 3000-gal wastewater storage tank (**Figure 31**)

Figure 30: WWT-D2 Housed in a TRICON

Figure 31: Wastewater Storage Tank (background-right)

The WWT-D2 technology project demonstrated the following capabilities and products:

- A wastewater treatment technology with potential stand-alone capability
- Characteristics:
    - Size – Pack out volume of ≤ 416 ft^3
    - Weight – ≤7,110 lb
    - Cost target – <$250K per unit for production greater than 100 units
    - Manpower – minimal, with automatic control and operation

Demonstration of the above capabilities and products would provide:

- Reduction in transportation assets required to haul wastewater and provide potable water currently used for non-potable uses
- Onsite treatment to dischargeable standards for 90% of input stream providing order of magnitude reduction in wastewater
- Improved safety/force protection at base camps
- Reduction in water, fuel, and waste
- Reduction in health risks from wastewater associated vectors

The WWT-D2 technology project is currently at TRL 5 and scheduled to transition to PdM PAWS at TRL 6 in FY18.

Technical POC: Lateefah Brooks, lateefah.c.brooks.civ@mail.mil, TARDEC, 586-282-6587.

2.9 Water Quality Monitoring - Pathogen Monitor (WQM-PM)

The WQM-PM (**Figure 32**) will provide the capability to solve technical challenges in the areas of contaminant detection and gray water recycling process verification. **Figure 32** shows the current field 24-h incubation (left) vs. cell phone-based pathogen detection kit <1 h (right). The WQM-PM demonstrated was comprised of a pathogen detector, a cell phone, and various sampling titrators and containers. The WQM-PM technology demonstrated the following capabilities and products:

- Prototype handheld pathogen detection devices
- Integration into small base support mission
- Informed graywater recycling concept of operations


Figure 32: WQM-PM. Left: the current field 24-h incubation; right: cell phone-based pathogen detection kit

Demonstration of the above capabilities and products would provide:

- Onsite monitoring of water recycling technologies to reduce skilled manpower support to small bases
- Protection of Soldier health through improved process monitoring

The WQM-PM is currently at TRL 5 and will be submitted for transition to PdM PAWS at the end of FY16 at TRL 6.

Technical POC: Lisa Neuendorff, lisa.k.neuendorff.civ@mail.mil, TARDEC, 586-282-4161.

2.10 HMMWV-Towable Load-Following 100 kW Power Unit (T100)

Power and energy requirements in a rapidly modernized, modular, highly digital and network centric Army are growing exponentially. This growth imposes a significant logistics burden on fuel consumption, power density, reliability, and environmental issues. Transportation of generator sets to the battlefield is a logistical burden due to the weight of the large generator sets 30 kW and up. The Communications-Electronics Research, Development, and Engineering Center (CERDEC) Command, Power, and Integration Directorate is working in conjunction with Program Manager Expeditionary Energy and Sustainment Systems (PM E2S2) to leverage a previous Science and Technology (S&T) investment and further mature the T100 **(Figure 33)**. Investments supported development of critical enablers such as innovative combustion enhancements, JP-8s fuel conditioners, advanced power electronic controls, and thermal management solutions. The T100 integrates a commercial-off-the-shelf (COTS) engine and energy storage technology, resulting in a highly power dense, fuel efficient 100 kW system that reduces the logistics and transportation burdens of the battlefield. The T100 reduces the


Figure 33: T100

weight of the skid-mounted 100 kW TQG from 5880 lb to 2500 lb, enabling it to be trailer-mounted (4000 lb with trailer) and towed behind a HMMWV or Joint Light Tactical Vehicle (JLTV).

The T100 that was used in this demonstration consisted of the following equipment and components:

- T100 mounted on a HMMWV-towable trailer
- 55 gal fuel drum (**Figure 34**)
- Two LEX 200A power distribution boxes
- 30 kW load bank (**Figure 35**)

Figure 34: 55-gal Fuel Drum

The T100 demonstrated the following capabilities and products:

- Reduced fuel consumption by 20%
- Continuous power output of 80 kW (0.8 power factor) {NOTE: The objective is 100 kW of continuous power output, hence the name.}
- 120/208 V_{AC} (four wire), 3Ø, 60 Hz
- Use of an integrated fuel tank sized to allow 8 h of continuous operation at 100% load
- Use of load-following system to reduce fuel consumption at low loads, reduce component wear, and reduce noise signature

Demonstration of the above capabilities and products would provide:

- Improved fuel efficiency which reduces O&S cost and logistics burden of fuel resupply (~20% less fuel than current 100 kW TQG).
- Reduced noise signature to enhance Soldier survivability and reduce Soldier fatigue
- Enhanced reliability by 15%

Figure 35: Load Bank (55 kW shown for illustration)

Point of Contact: US Army CERDEC, usarmy.apg.cerdec.mail.cerdec@mail.mil.

2.11 Self-Powered Solar Water Heater (SPSWH)

The SPSWH **(Figure 36)** technology project will develop the capability to reduce fuel required for heating and pumping water by concentrating solar energy to heat water and generate electrical power for a pump.

Figure 36: SPSWH

The SPSWH that was used in the demonstration was comprised of the following components and equipment:

- SPSWH system, including water pump and battery pack (**Figure 37**)
- Pressure regulator (**Figure 38**)
- Army Water Heater 400 (AWH-400) fuel-powered water heater (**Figure 39)**
- Two three-way valves (**Figure 40**)

Figure 37: SPSWH Including Water Pump and Battery Pack (bottom right)

Figure 38: Pressure Regulator

Figure 39: AWH-400

Figure 40: Two Three-way Valves

The SPSWH technology demonstrated the following capabilities and products:

- Four modular, man-portable components (147 lb) with thermal/electricity collectors
- Generated 200 W of power for a 5-gpm (gal per min) pump

- Provided an instant hot water source for up to 240 gal per day
- Was able to be transported and stored in a TRICON shipping container
- High reliability (mostly solid state)
- Supplemented/offset M80/AWH-400 water heater assets

Demonstration of the above capabilities and products would provide:

- Hot water to support field kitchen and sanitation center operations; may also support showers and latrines with the ability to couple SPSWH units for additional hot water capacity
- Conservative estimates are 75kBTU per hour of hot water per TRICON, which saves about 0.75 gal of JP8 per h
- Low maintenance, high reliability; requires manpower (four personnel) for initial setup in no more than 4 h

Technical POC: Peter Lavigne, peter.g.lavigne.civ@mail.mil, NSRDEC, 508-233-4939.

2.12 Energy Informed Operations-Central (EIO-C)

The EIO-C **(Figure 41)** will develop, implement, and support an intelligent power system interface standard and associated applications which allow optimization of power and energy resources based on mission objectives.

The EIO-C demonstrated was composed of the following components, equipment, and systems:

- Laptop to monitor power and status of the grid (lower left **Figure 41**)
- Four 60 kW TQGs (**Figure 42**)
- One 60 kW/106 kilowatt-hour (kWh) Inverter/Battery system (**Figure 43**)
- Four Intelligent Power Distribution–200 (IPD200) boxes (**Figure 44**)
- Six PDISE M100 boxes (**Figure 45**)

Figure 41: EIO-C

Figure 42: TQGs

Figure 43: Inverter/Battery System

Figure 44: IPD200

Figure 45: PDISE M100

The EIO-C demonstrated the following capabilities and products:

- Open standards for centrally controlled intelligent power system interfaces
- Applications for awareness and control of power resources

Demonstration of the above capabilities and products would provide:

- Improved efficiency in operational energy to reduce cost and logistics burden of fuel resupply
- Ability to prioritize and utilize power resources according to mission needs, thus enabling commanders with information and flexibility to complete the mission in a resource constrained environment
- A more reliable and resilient energy network to ensure the availability of power across the battlespace

Technical POC: Michael Gonzalez, michael.l.gonzalez.civ@mail.mil, CERDEC, 443-395-4381.

3. BASELINE SYSTEMS, ARCHITECTURE, AND INSTRUMENTATION

To address the STO-D challenge of saving fuel, water, and waste, the candidate systems described in Chapter 2 must be integrated with the base camp infrastructure and then instrumented to collect data. Section 3.1 identifies the base camp infrastructure at the BCIL, Section 3.2 documents the architecture showing how the candidate technologies are integrated with that infrastructure, and Section 3.3 identifies the instrumentation that will be installed to collect the data.

3.1 Baseline and Other Demo Support Systems

As noted, this demonstration took place in and around the BCIL. The BCIL is mostly composed of two 150-person Force Provider Expeditionary (FPE) camp sets. For the STO-D's purposes, the FPE systems are considered "baseline systems" and comprise the bulk of the systems in the SLB-STO-D's approved Operationally Relevant Technical Baseline. The other major support system for this exercise was the Energy-Efficient Rigid Wall Shelter (E2RWS) camp that was set up on the east side of the BCIL. **Figure 46** is an aerial view of the BCIL taken in 2014. The tan-colored systems in the photo are the FPE camp sets. The green-colored systems, while no longer in place, are a fair representation of the E2RWS modules that were in place and employed during this demo.

Figure 46: BCIL Aerial Photo - 2014

The Army maintains FPE capabilities in order to provide critical base camp life support, even as it transforms from a legacy to a modular to a future Force. The FPE system is essentially a "tent city" that is (1) containerized and highly deployable via all means of transport (air, land, sea); (2)

employable upon arrival in as little as 24 h without significant dependencies on local infrastructure; (3) capable of reliable and efficient systems operations and management; and (4) outfitted with the intent to provide improved life support sustainment, combat readiness, and QoL for deployed Soldiers, regardless of location. An FPE module is designed to support 150 personnel. Each FPE module provides climate-controlled billeting, quality food preparation and dining facilities, and hygiene services (latrine, shower, laundry) through a blend of commercial and military equipment. Waste management (solid waste, and gray- and blackwater/sewerage), fuel and water storage and distribution, and power generation (generators, and prime power connection kits) are also included in FPE modules.

3.1.1 Force Provider Systems

This was the third major demonstration the SLB-STO-D conducted in the BCIL, and the participants were very well acquainted with the capabilities and features of the FPE systems. In **Figure 46**, all the tan-colored structures are FPE components – billets, showers, changing tents, latrines, kitchens, dining facilities, laundry, and refrigeration. The larger tan shelter on the right side of the figure is a maintenance shelter and is not part of the 150-person camp, but is an add-on feature. The FPE systems are installed as two 150-person camps – the North Camp and the South Camp, evenly divided by an imaginary line running east-west through the center of the camp. Each FPE camp also has a set of six 60 kW TQGs. However these gensets were not employed in this demonstration.

In the North Camp, the FPE systems (billets, dining facility, showers, ECUs, latrines, and laundry) served as power loads for the V2G/V2V. However, there was no requirement to collect data on these FPE systems. In the South Camp the FPE systems (billets, dining facility, showers, ECUs, latrines, and laundry) served as power loads for the EIO-C and supported integration of the WWT-D2, GWR-FORO, WQM-PM, SPSWH, and WDR. Power, water, and wastewater data were collected on these FPE systems to support analysis of the candidate technologies. In addition, the AWH-400 fuel-fired water heater (**Figure 39**) was employed during the SPSWH demonstration in the South Camp.

3.1.2 Energy-Efficient Rigid Wall Shelters (E2RWS) Camp

The green shelters on the right side of **Figure 46** are representative of the location of the E2RWS. The PdM FSS uses this section of the camp to conduct testing and experiments with new developmental systems and prototypes. For this demo, a number of the E2RWS modules (billets, kitchen, and laundry – left to right in **Figure 47**) were employed as power loads for the T100.

Figure 47: E2RWS Modules

The E2RWS offered the following capabilities:

- Billets: Each shelter supports 10 personnel with each person having 2 electrical outlets, a bunk, and a personal storage locker
- Kitchen: The kitchen center includes a sanitation system, hand wash station, and hot water heater. Appliances include a Turbo Air Refrigerator Model M3R72, Groen 6, 10-qt table top, tilting Steam Jacketed Kettle, Wells Griddle, Blodgett convection oven, Accutemp Steam Hold, Alto Sham Cook/Hold and a Hoshizaki Ice Maker. These are the same kitchen appliances used in the FPE Kitchen Electric Facility and Expeditionary TRICON Kitchen System. The shelter has onboard water supply with pumps and includes the fabric tanks and hoses.
- Laundry: The laundry is intended for self-serve operation. The shelter consists of six Unimac Model LTUA7 stacked washer/dryers, an ECU and electrical supplemental heaters. The shelter has onboard water supply and graywater pumps and comes with 3000-gal fabric tanks and hoses. Tables are provided for folding and sorting. A utility sink is also included.

In addition, it is worth noting that two E2RWS configured as Command Post/Admin Shelter were used to house the DOC and “Bull Pen”. The DOC served as the nerve center of the demonstration where the Demonstration Director and key personnel conducted day-to-day demonstration management activities. The Bull Pen was reserved for use by Technology Providers to perform their daily actions. The E2RWS Command Post/Admin Shelter is capable of providing the following facilities:

- Work stations with power and Cat 5 connection capability
- Displays – flat screen light emitting diode (LED), projector screens, map boards
- Space/power for equipment – servers, projectors, safe, shredder, printer/scanner
- LED lighting
- Heating, ventilation, and air conditioning (HVAC) system – common on every shelter/low power (125 °F to -25 °F)
- Power panel interface – Military Class L
- Signal entry panel consisting of Registered Jack Function 11 (RJ-11), RJ-45, binding posts and cable pass-throughs
- Weapons lockers

There was no requirement to collect data on these E2RWS modules.

3.2 Architecture

Top-level view of the venue is shown in **Figure 48**. It displays the relative location of each technology.

Figure 48: BCIL Layout Architecture

Starting on the eastern side of the camp (the right side of **Figure 48**) and working counterclockwise, the technologies were located as follows:

The **T100** generator was located very near the Hercules Engineering Solutions Consortium (HESCO) wall. It was positioned near the Lex boxes to connect its output to the camp's power distribution system to power certain E2RWS modules. A fuel drum was positioned adjacent to the T100.

The **V2G/V2V** was located outside the HESCO wall north of the camp. The two MRAPs and two HMMWVs were positioned side-by-side facing north with their respective TVGMs and ESUs behind each. Eight each 100-Amp power cables were run across the road, through the north pedestrian gate, and connected to the North Camp power grid through M100 PDISE boxes.

The TARDEC water treatment technologies – **GWR-FORO, WWT-D2, WQM-PM** – were located behind (west of) the South Camp showers. The GWR-FORO connected to a graywater bladder already in place at the BCIL. The WWT-D2 was installed with a special blackwater bag.

The **WDR** low-flow showerheads, a total of eight, were installed in the South Camp showers.

The **SPSWH** was located just to the southwest of the South Camp showers and was connected to the AWH-400 water heater via hoses.

The **EIO-C**, including the inverter/battery, set up adjacent to the South Camp gensets. From here, the microgrid was connected to the camp's power distribution system for the South Camp facilities.

The **NPC** was set up daily next to billeting shelter #2.

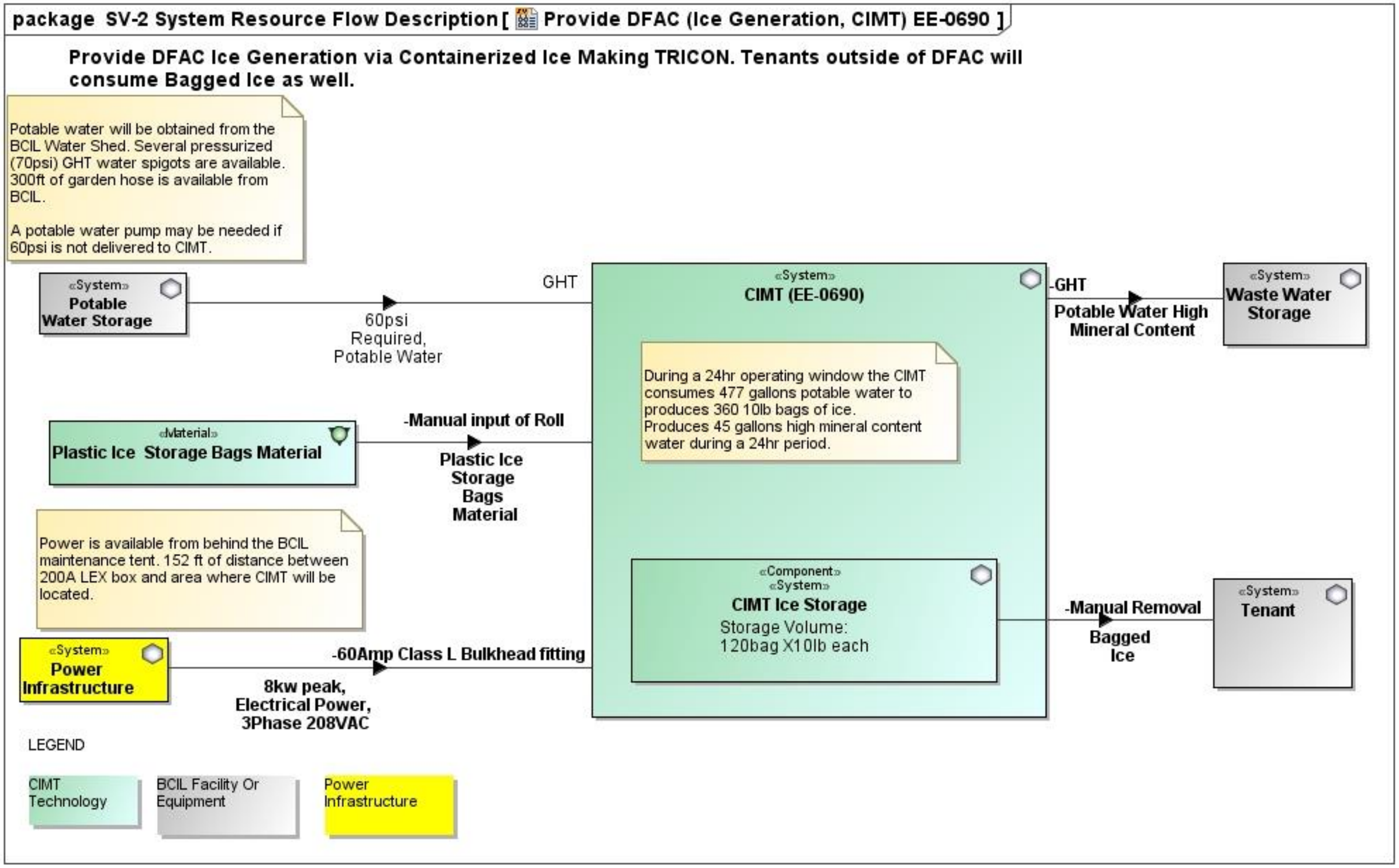
Due to space constraint, three technologies were positioned outside the HESCOs southwest of the camp. These were:

- The **SLiM** and its accompanying solar panels were positioned in a small clearing to get the best solar exposure possible in the lightly wooded area.
- The **MILHUT** and its accompanying TRICONs and solar panels were set up across the trail where the ground was most level.
- The **CIMT** was set up where it could draw water from the camp's water storage and power from the camp's maintenance facility.

For each of the candidate technologies, System Views (SV-2s) were developed and documented by SEIT in a Robust Integration Plan (Lindo, 2016). The SV-2s depict the capabilities of the technology and the interrelationships of inputs (e.g. fuel, water, etc.) and outputs (e.g. gray- and/or blackwater, solid waste, etc.), including interface with other technologies. The SV-2s are included in Sections 3.2.1 to 3.2.12.

3.2.1 CIMT SV-2

Figure 49 shows the CIMT SV-2. The CIMT was set up in the southwest satellite camp and was powered by shore power. It drew water from the camp supply via a standard water hose.



Provide DFAC Ice Generation via Containerized Ice Making TRICON. Tenants outside of DFAC will consume Bagged Ice as well.

Potable water will be obtained from the BCIL Water Shed. Several pressurized (70psi) GHT water spigots are available. 300ft of garden hose is available from BCIL.

A potable water pump may be needed if 60psi is not delivered to CIMT.

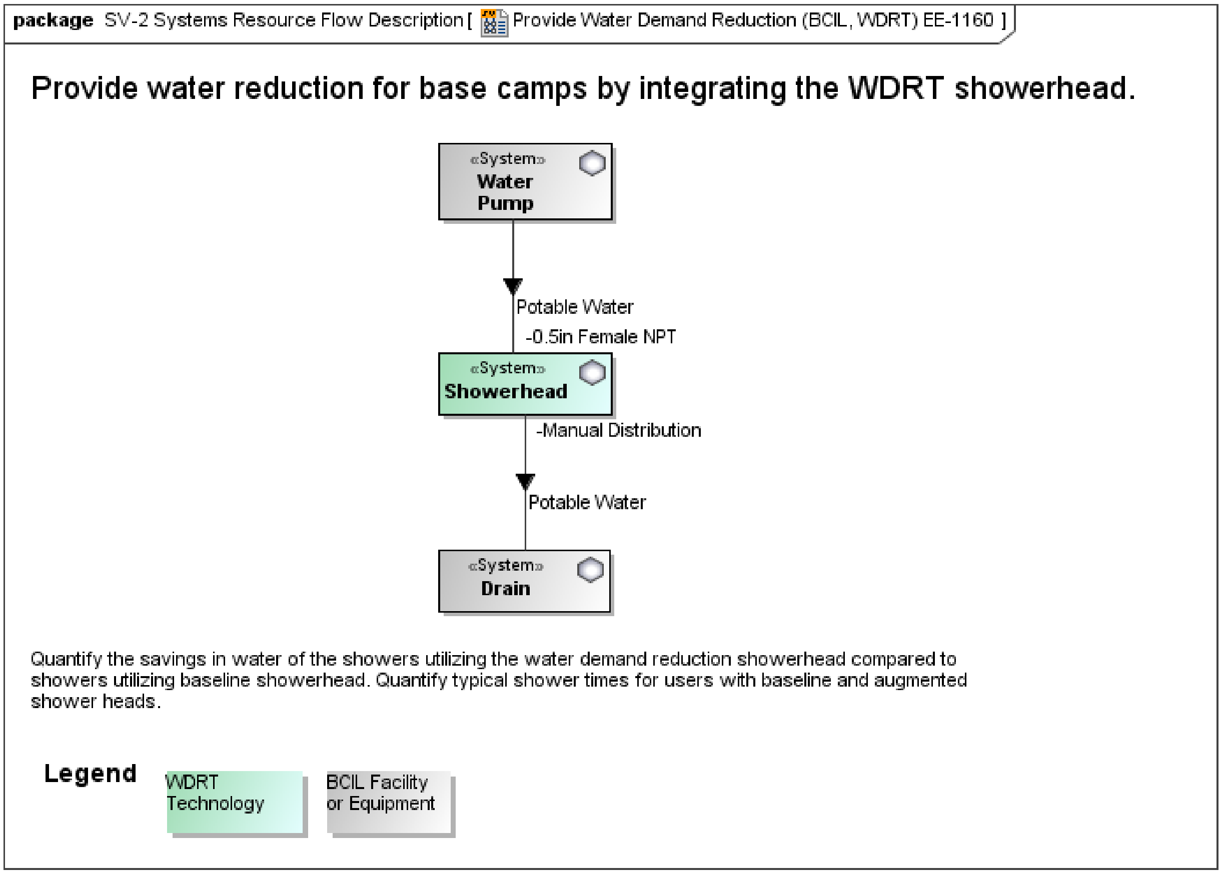
During a 24hr operating window the CIMT consumes 477 gallons potable water to produces 360 10lb bags of ice. Produces 45 gallons high mineral content water during a 24hr period.

Power is available from behind the BCIL maintenance tent. 152 ft of distance between 200A LEX box and area where CIMT will be located.

Figure 49: CIMT SV-23.2.2 WDR SV-2

3.2.2 WDR SV-2

Figure 50 shows the SV-2 for the WDR. Essentially, low-flow showerheads were installed in the South Camp showers. The showerheads were rotated on a schedule with the baseline showerheads to make a comparison. Showers were timed via instrumentation to see if there was any difference in shower time for the Soldiers, based on the type of showerhead installed.



Provide water reduction for base camps by integrating the WDRT showerhead.

Quantify the savings in water of the showers utilizing the water demand reduction showerhead compared to showers utilizing baseline showerhead. Quantify typical shower times for users with baseline and augmented shower heads.

Figure 50: WDR SV-2

3.2.3 SLiM SV-2

Figure 51 shows the SV-2 for the SLiM. The SLiM is designed to be a self-sustaining unit and was not connected to other infrastructure in the camp. It was set up in the area southwest of the camp. A group of subject matter experts (SMEs) from NSRDEC disassembled the SLiM at Natick, transported it to the BCIL, and reassembled it. This is a unit-level task and the SMEs provided feedback on the tear-down and set-up operation. EDVT did not collect technical data on this system during the demo. Instead, personnel from the Expeditionary Basing & Collective Protection team at NSRDEC ran some of their own experiments during this timeframe.

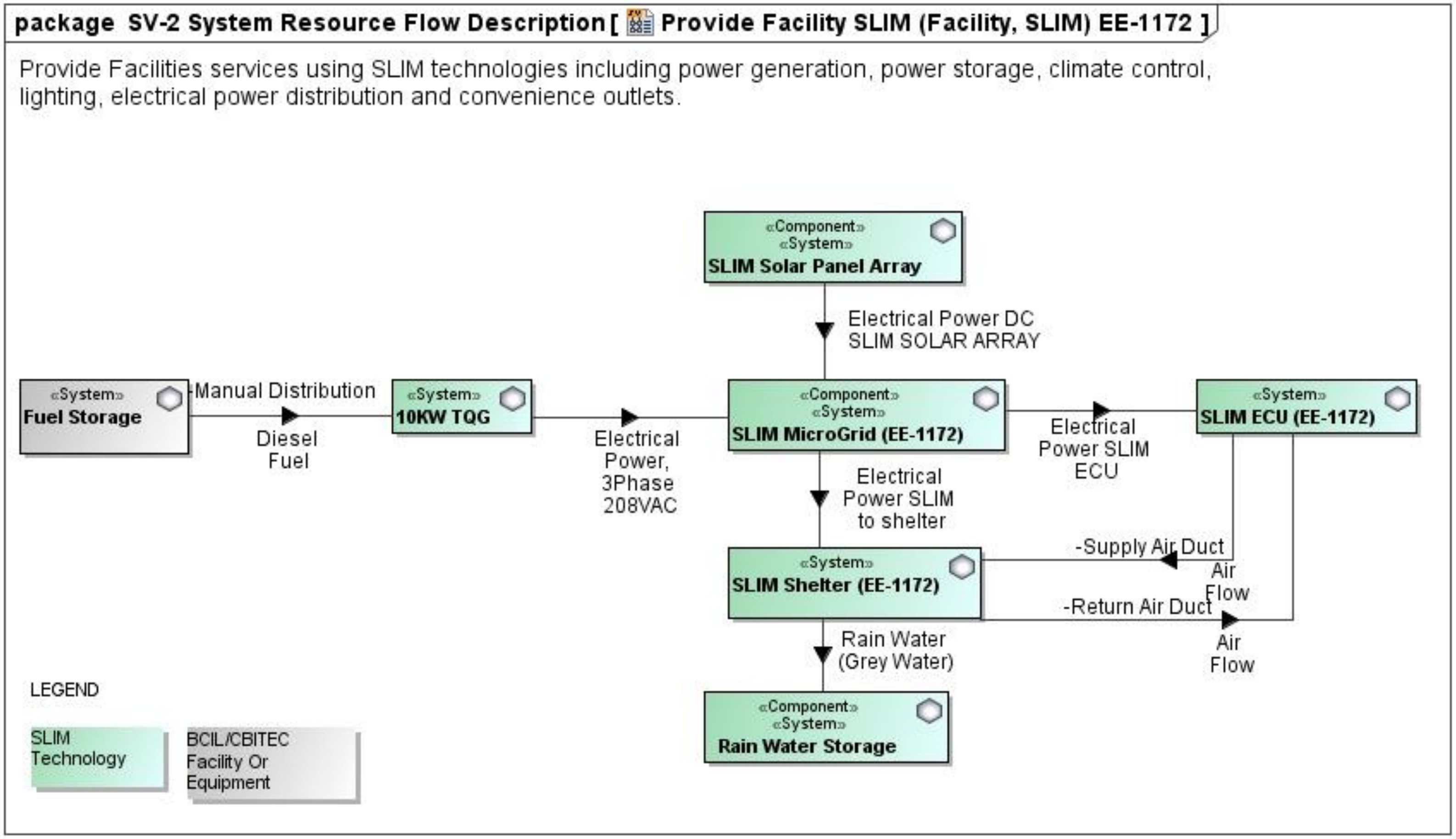


Figure 51: SLiM SV-2

3.2.4 MILHUT SV-2

Figure 52 shows the MILHUT SV-2. The MILHUT was also set up in the southwest area. Like the SLiM, the MILHUT is designed to be self-sufficient, so it was not connected to any grid other than its own solar panels and on-board generator. The Hotel TRICON was set up for demonstration, but it was not used since there is an overflow hazard associated with the wastewater features. The Power TRICON was set up and used to power and provide environmental control for the 32 ft TEMPER air-supported shelter. A portion of the solar array was set up and provided power to the system.

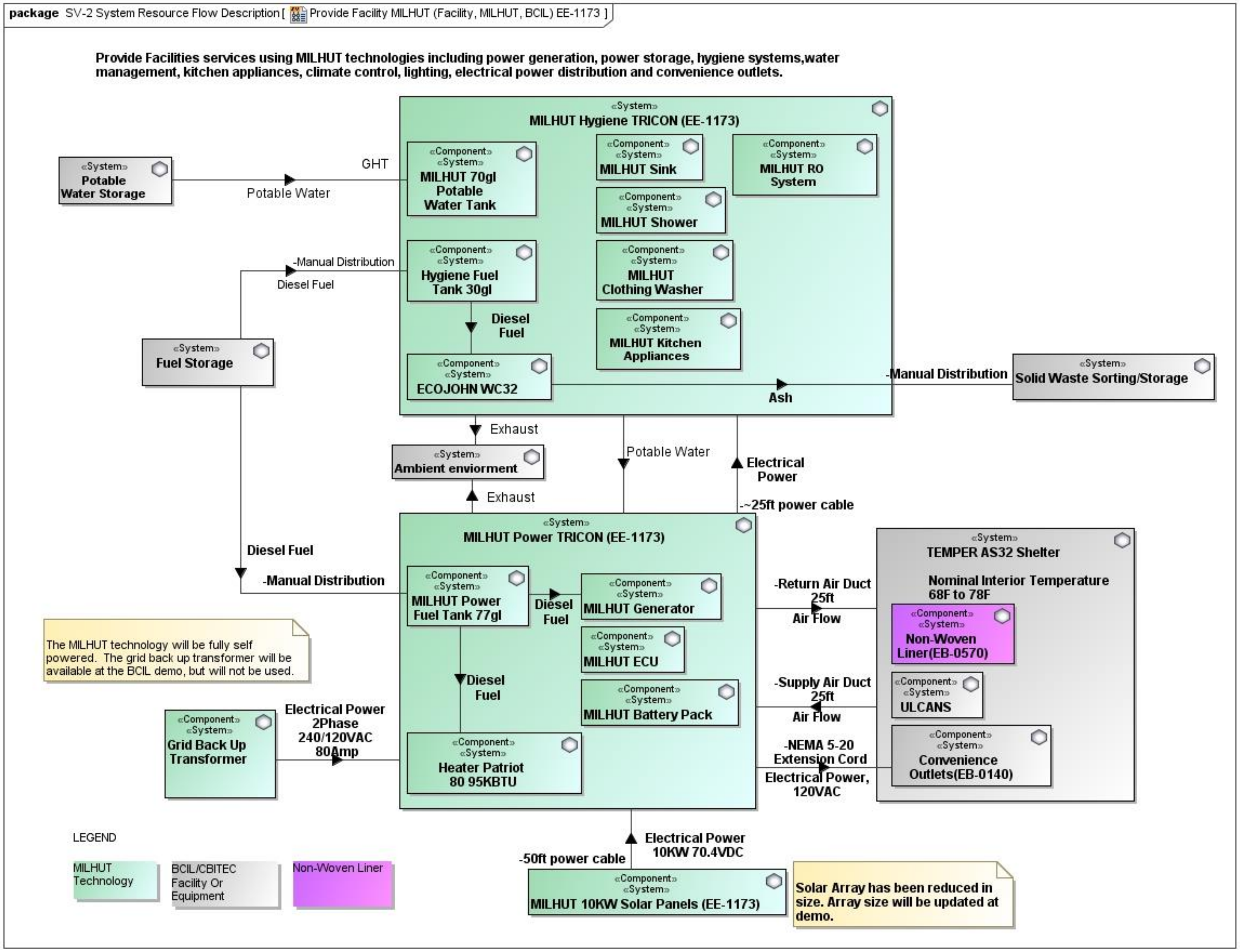


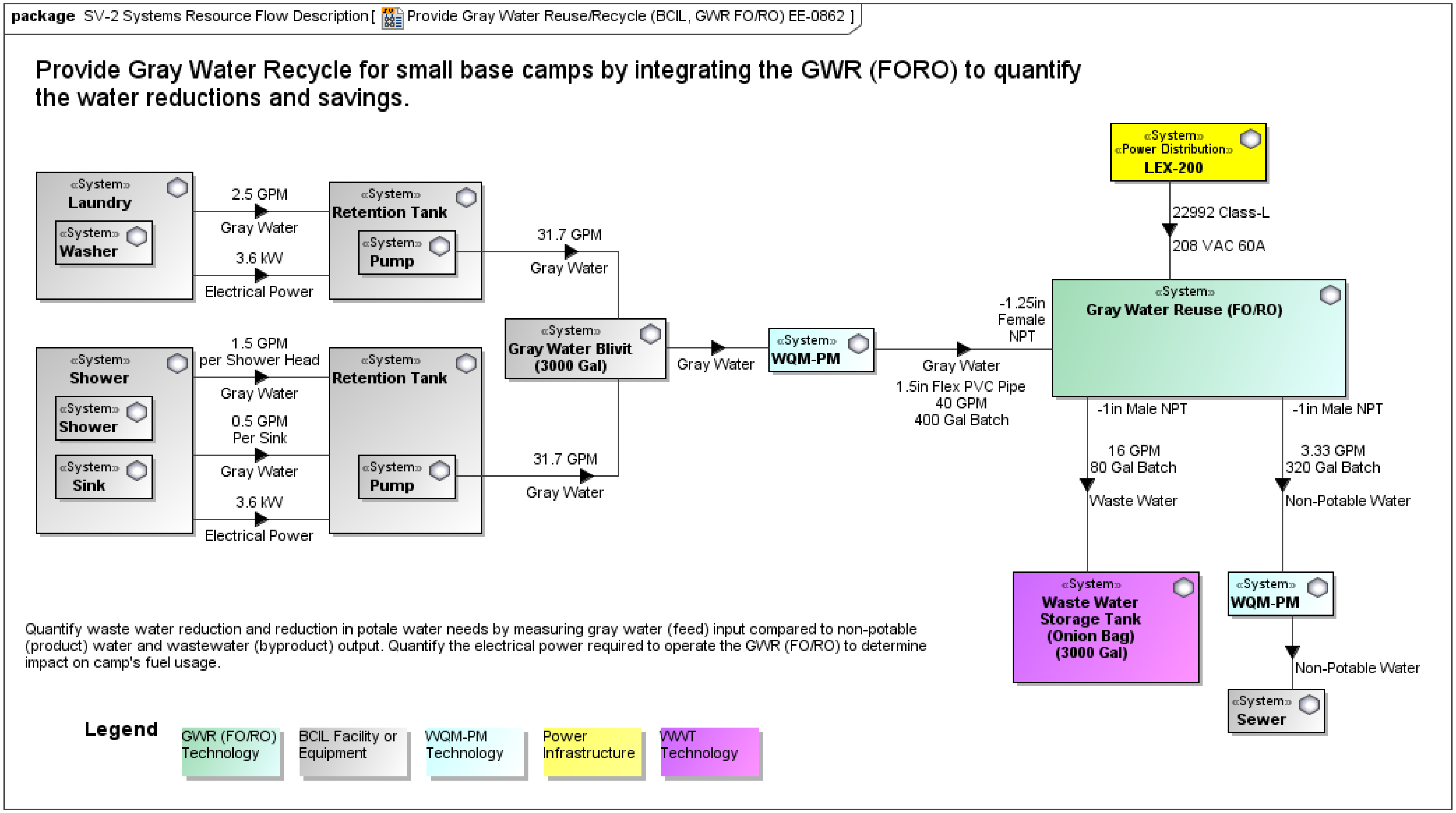
Figure 52: MILHUT SV-2

3.2.5 NPC SV-2

The NPC was set up and controlled by a team from NSRDEC. The system was not integrated with camp infrastructure, and as a result there is no SV-2. All data was collected and processed by the Technology Provider.

3.2.6 GWR-FORO SV-2

Figure 53 shows the SV-2 for the GWR-FORO. This unit was set up behind the South Camp showers and connected to the camp’s graywater bladder. Wastewater from the South Camp showers and laundry was directed to the bladder for processing in the GWR-FORO.



Quantify waste water reduction and reduction in potale water needs by measuring gray water (feed) input compared to non-potable (product) water and wastewater (byproduct) output. Quantify the electrical power required to operate the GWR (FO/RO) to determine impact on camp's fuel usage.

Figure 53: GWR-FORO SV-2

3.2.7 V2G/V2V SV-2

The Tactical V2G/V2V Demonstration system consisted of four tactical vehicles plus four TVGMs, two of which were on trailers and two of which were skid-mounted. The vehicles were staged in the woodline outside the HESCO barriers. The power cables were laid across the paved road and entered the pedestrian gate in the North Camp. These cables connected the TVGM bus to PDISE boxes. The North Camp loads – billets, showers, etc. – were connected to the PDISE output. **Figure 54** shows the SV-2 for the V2G/V2V system.

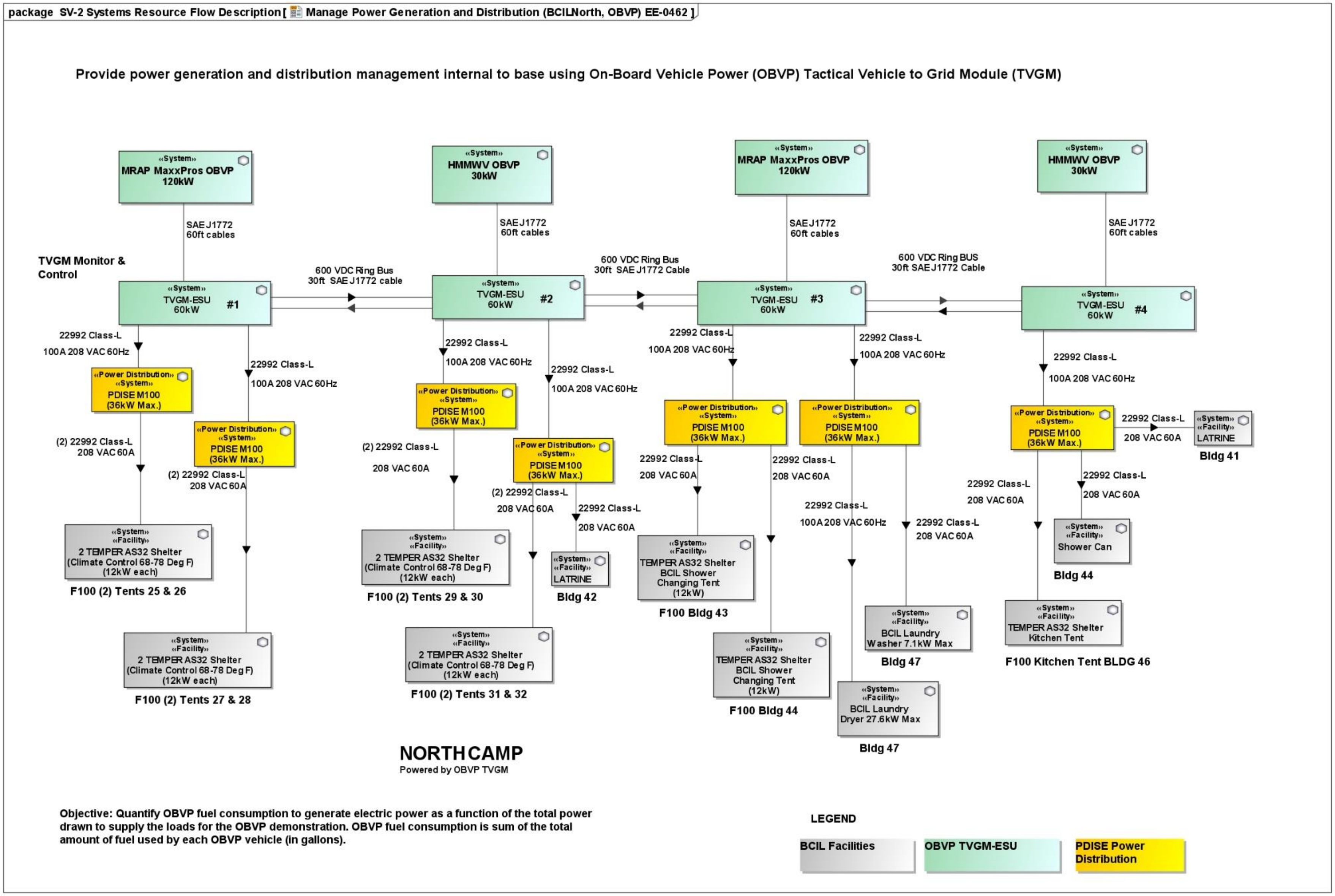


Figure 54: V2G/V2V SV-2

3.2.8 WWT-D2 SV-2

The WWT-D2 was set up behind the South Camp showers. While the objective is for this system to be self-powered, it did not have that capability at this demonstration. The system required a 28Vdc power source. The blackwater sources were plumbed to a modified wastewater blivet that comes as part of the system. **Figure 55** shows the SV-2 for the WWT-D2.

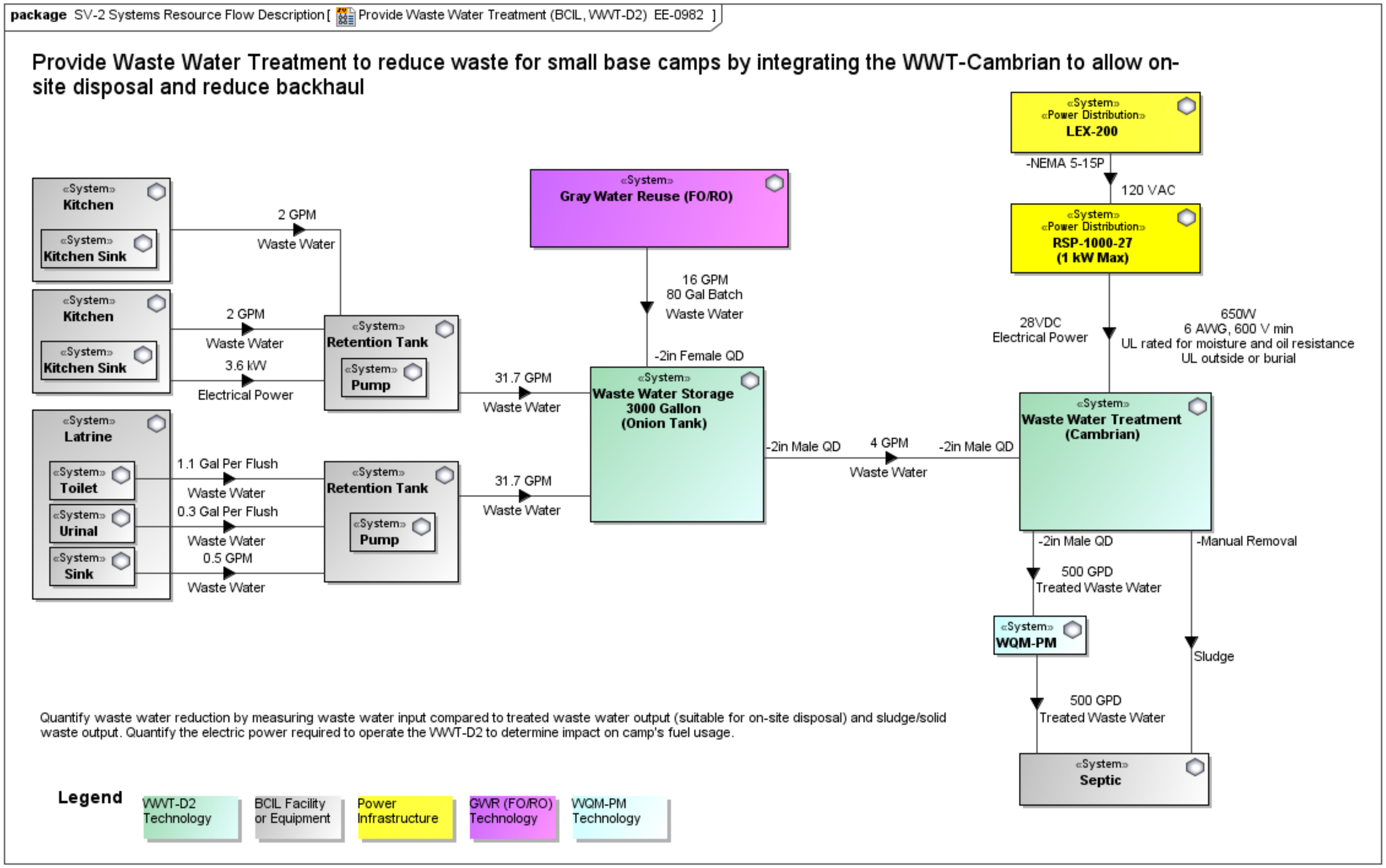


Figure 55: WWT-D2 SV-2

3.2.9 WQM-PM SV-2

The WQM-PM requires no special setup. This system was operated by TARDEC. **Figure 56** shows the SV-2 for the WQM.

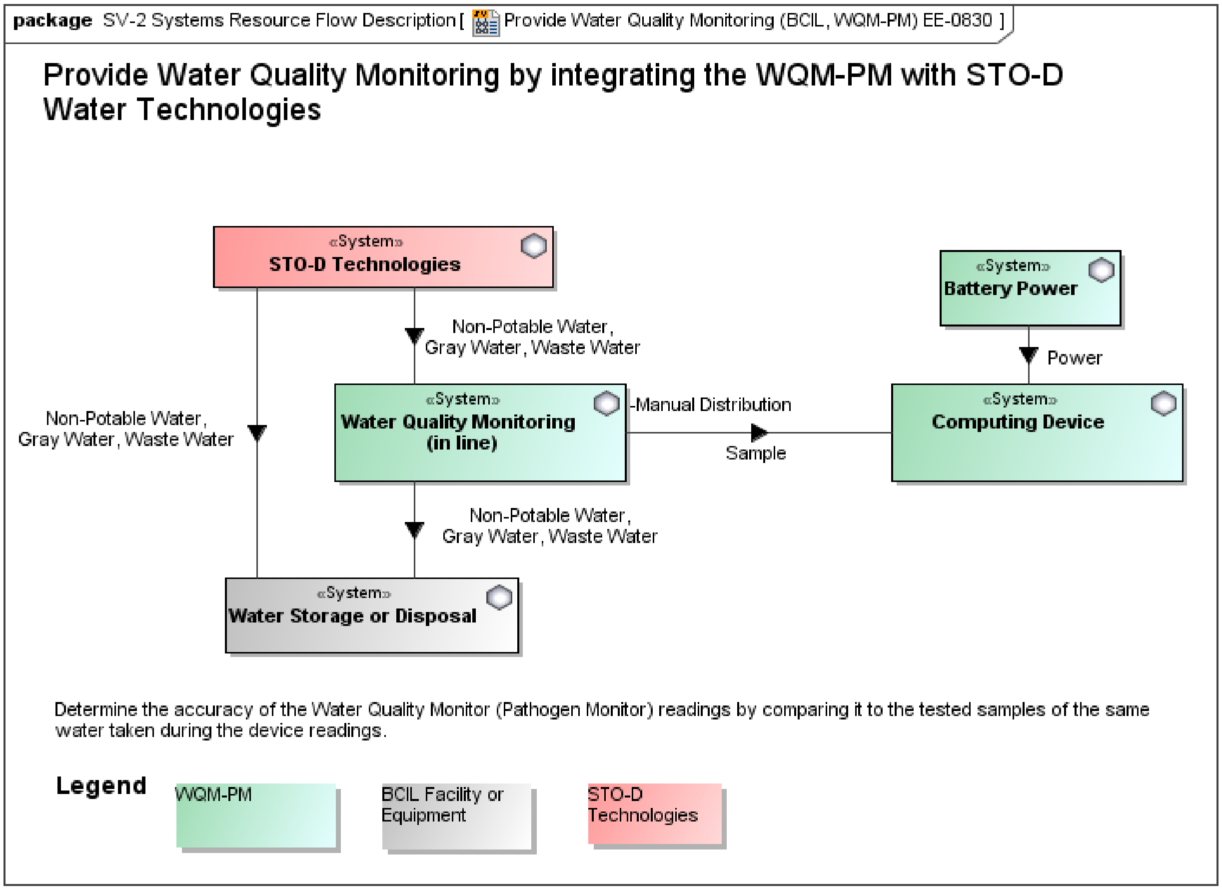


Figure 56: WQM-PM SV-2

3.2.10 T100 SV-2

The T100 was employed to power the E2RWS modules in the east portion of the camp. The T100 drew fuel from a drum positioned on a scale next to the genset. “Pigtail” cables connected the T100 to the Lex box distribution system. **Figure 57** shows the SV-2 for the T100.

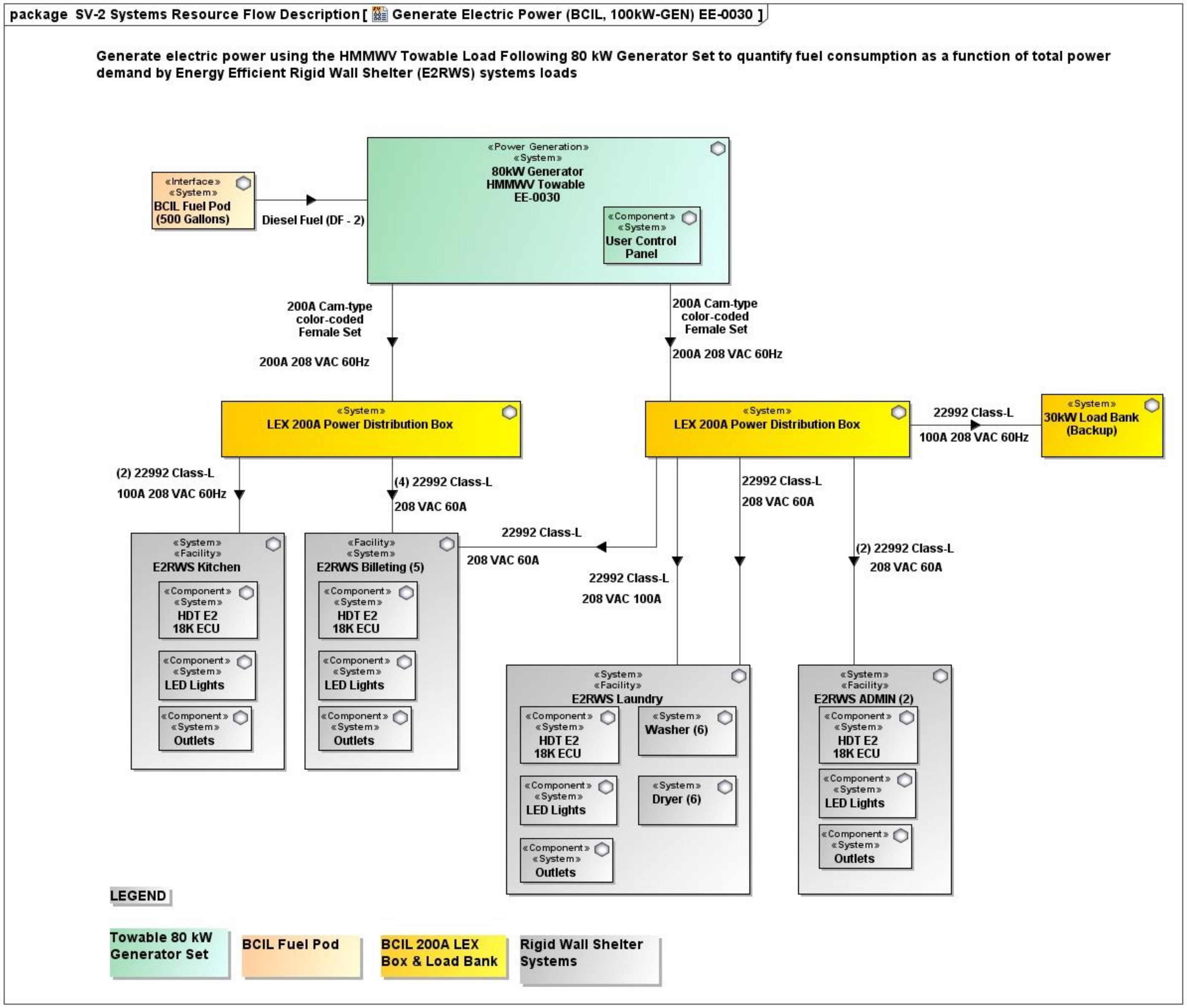
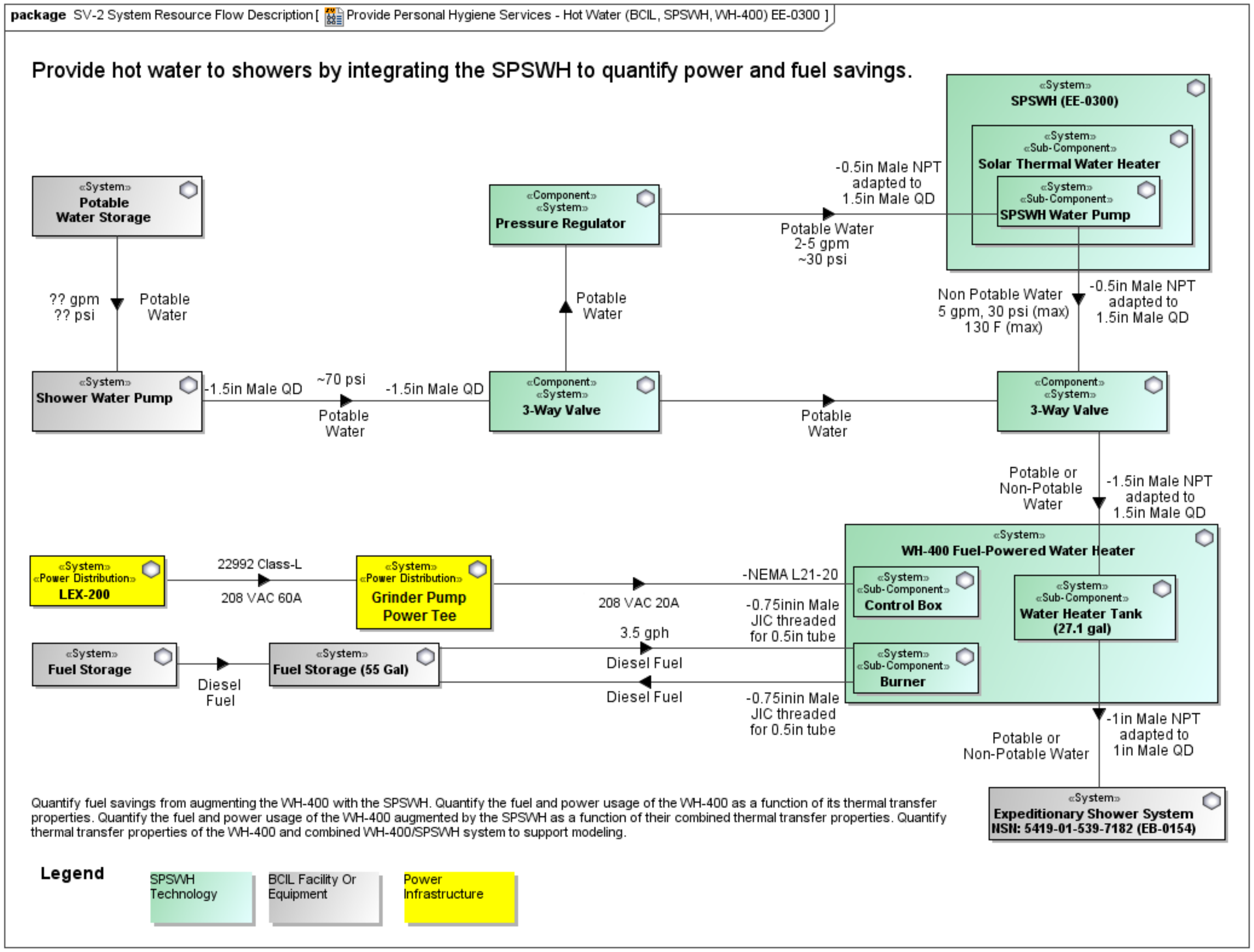


Figure 57: T100 SV-2

3.2.11 SPSWH SV-2

The SPSWH was set up near the West Gate. It was connected to the water source and the AWH-400 by water hoses. There was no power requirement. This system is self-powered. **Figure 58** shows the SV-2 for the SPSWH.

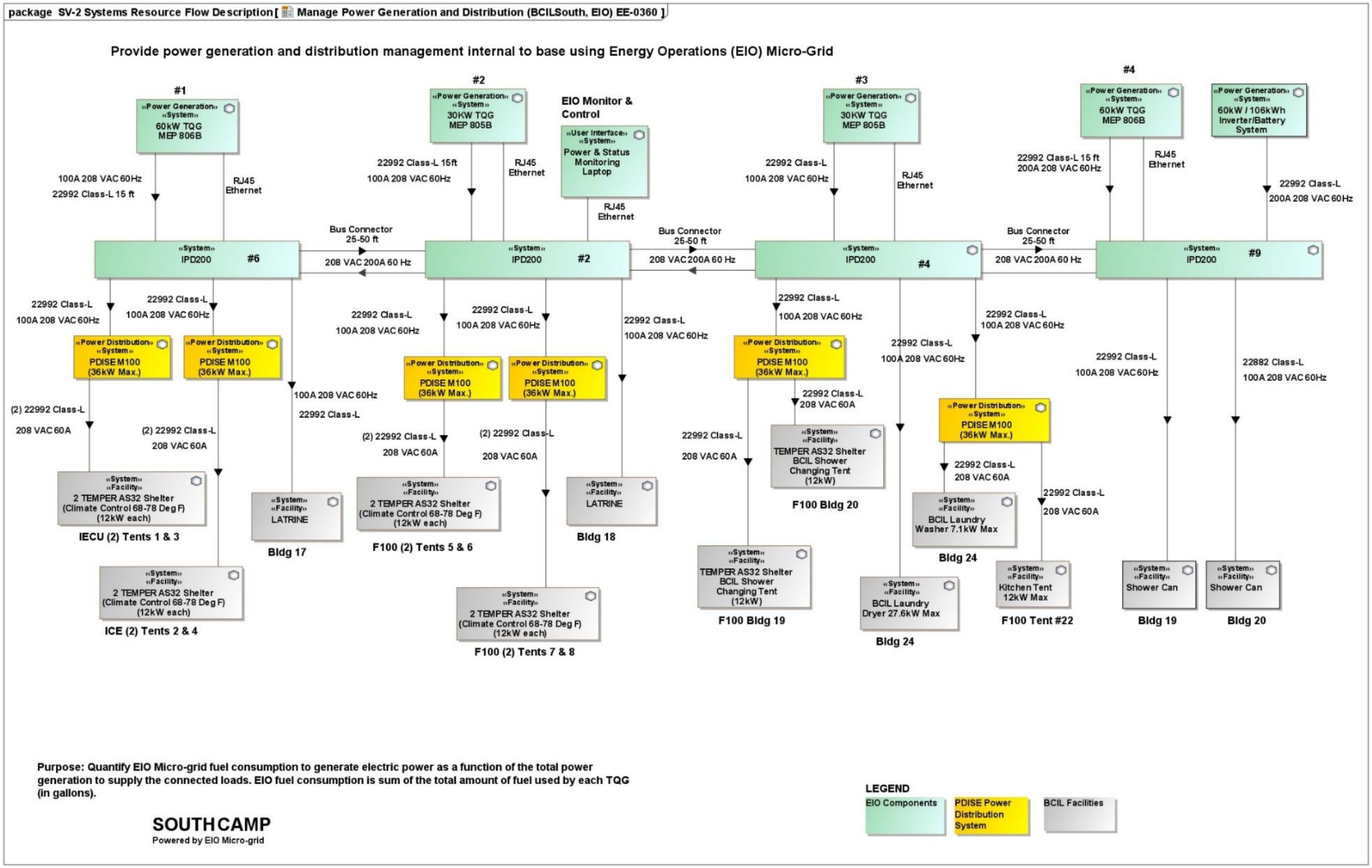


Quantify fuel savings from augmenting the WH-400 with the SPSWH. Quantify the fuel and power usage of the WH-400 as a function of its thermal transfer properties. Quantify the fuel and power usage of the WH-400 augmented by the SPSWH as a function of their combined thermal transfer properties. Quantify thermal transfer properties of the WH-400 and combined WH-400/SPSWH system to support modeling.

Figure 58: SPSWH SV-2

3.2.12 EIO-C SV-2

EIO-C was set up to power the South Camp with two 60 kW TQGs, two 30 kW TQGs, and an inverter, all connected via a microgrid of IPDs and PDISE boxes. In addition, EIO-C substituted in four of the shelters two each modified Improved Environmental Control Units (IECU) and two each modified ICE units that communicated over the microgrid. **Figure 59** shows the SV-2 for the EIO-C system. (NOTE: The ICE units were disconnected prior to Soldier occupation due to lack of safety release.)



Purpose: Quantify EIO Micro-grid fuel consumption to generate electric power as a function of the total power generation to supply the connected loads. EIO fuel consumption is sum of the total amount of fuel used by each TQG (in gallons).

Figure 59: EIO-C SV-2

3.3 Instrumentation

This section describes all instrumentation components and systems used in this demonstration in a high level of detail.

To meet **Objective 1** (Collect empirical data on candidate technologies and baseline systems that can be used to calibrate modeling, simulation, and analysis, and support trade-offs and engineering decisions) the following instrumentation was employed. This instrumentation was provided and installed by the EDVT team or provided by the venue, and the data were harvested by the EDVT.

3.3.1 Shark® Power Meters

This demonstration used 100-Amp, 60-Amp and 20-Amp Shark meters in plastic enclosures **(Figure 60)**.

From their website at https://electroind.com/product-info/shark-200-data-logging-power-metertransducer/, the Shark® 200 Data Logging Power Meter/Transducer features include:

- 0.2% Class Revenue Certifiable Energy and Demand Metering
- Expandable I/O with 100BaseT Ethernet
- V-Switch™ key technology upgrade
- Extensive data logging
- Power quality recording
- Embedded web server - with smartphone and tablet support
- Distributed Network Protocol (DNP) 3.0 over Ethernet
- Integrated Electronic Control (IEC) 61850 protocol

Figure 60: Shark® 200

3.3.2 DC Power Meters

To measure DC, the EDVT employed two AccuEnergy Meters – the AcuDC 243 and AcuLink 710 **(Figure 61).**

Features of the AcuDC 243 include:

- Multifunction DC power and energy meter
- 3-line liquid crystal display (LCD)
- Nominal input voltage of 600 VDC

- Current input via shunt (50~100 mV)
- Power supply 100-240 VAC 50/60 Hz, 100-300 VDC
- Modbus remote terminal unit

This setup also included the Shunt-100 Amp/75mV.

These three items – the shunt, the DC meter, and the AcuLink **(Figure 62)** – were used to monitor DC voltages on site. Below is a diagram that covers the setup.

Figure 61: DC Power Meter Configuration

Figure 62: Accuenergy DC Meter High Level Setup

3.3.3 Humidity Sensors

To measure humidity in the shelters where required, the EDVT employed the Vaisala HMP60-L **(Figure 63).**

Features of the HPM60-L include:

- Accuracy: ± 3% (0–90% relative humidity and 0–40 °C)
- Input Power: 5 – 28 VDC
- Output: 0–1 V or 0–5 V options

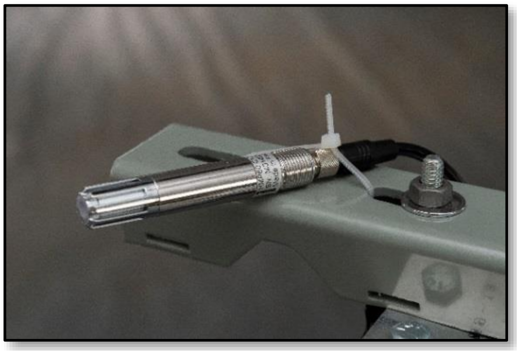


Figure 63: Vaisala HMP60-L Humidity

3.3.4 Thermocouples

The EDVT used thermocouples **(Figure 64)** to make temperature measurements. There are many different types of thermocouples and each has its own unique characteristics in terms of durability, temperature range, capability, and resistance. For this exercise, the EDVT employed Type J and Type T thermocouples. Characteristics of each are outlined in **Table 1**.

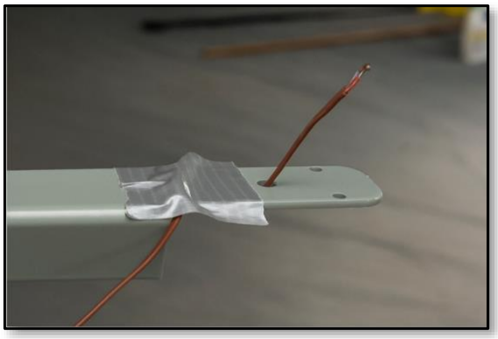


Figure 64: Thermocouple

Table 1: Thermocouple Types

Thermocouples	Temperature Range	Accuracy (Standard)	Accuracy (Special) Error
Type J	-346 °F to 1,400 °F	1 °C	0.4%
Type T	-454 °F to 700 °F	1 °C	0.4%

3.3.5 Door Sensor

The EDVT employed a door sensor to monitor entry and exit to the MILHUT shelter. The SECO-LARM SM-205Q miniature surface-mount magnetic contact **(Figure 65)** senses the opening and closing of doors. This item came with pre-wired 15 in leads and was mounted to the vestibule door frame.

The SM-205Q door sensor specification includes:

- Magnet type – Alnico 5
- Temperature range -15 °F to +160 °F
- Switch cycles 50 million (0.1mA@5 VDC)
- Operation gap 3/4 in (19 mm)

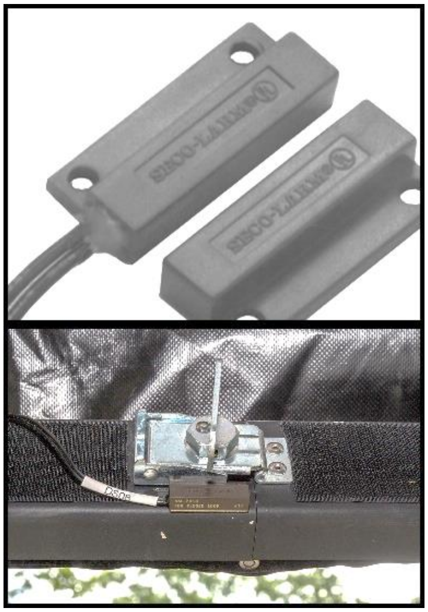


Figure 65: SM-205Q Door Sensor

3.3.6 IFM SM8001 Water Flow Meter

The SM8001 Water Flow Meter **(Figure 66)** was used to measure water flow for the CIMT and the SPSWH. Its features include:

- Magnetic-inductive flow meter
- Quick disconnect
- Process connection: G1 flat seal connection to pipe by means of an adapter
- Programmable function
- Totalizer function

- Two outputs
  - OUT1 = flow monitoring (binary), flow rate meter (pulse), preset meter (binary)
  - OUT2 = flow monitoring or temperature monitoring (analog or binary)
- Input for counter reset
- Measuring range: 0.10 to 26.40 gpm
- Application: conductive liquids (conductivity: ≥ 20 µS/cm; viscosity: < 70 cSt at 104 °F)
- Pressure rating: 232 psi
- Medium temperature: 14 °F to 158 °F
- Electrical data
  - Electrical design: DC Positive-Negative-Positive (PNP)/Negative-Positive-Negative (NPN) transistors
  - Operating voltage: 19 to 30 VDC
  - Current consumption: 120 mA
  - Insulation resistance: > 100 MΩ (500 VDC)
  - Protection class III
  - Reverse polarity protection
  - Output function
    - OUT1: normally open/closed programmable or pulse
    - OUT2: normally open/closed programmable or analog (4 to 20 mA/0 to 10 V, scalable)
  - Current rating: 2 x 200 mA
  - Voltage drop: < 2 V
  - Short-circuit protection: non-latching; overload protection
  - Analog output: 4 to 20 mA; 0 to 10 V
  - Maximum load: 500 Ω (4 to 20 mA); minimum load: 2000 Ω (0 to 10 V)
- Pulse output flow rate meter; accuracy ± (2% measured + 0.5% final value of measured range); repeatability ± 0.2% final value of measured range
- Temperature monitoring; accuracy ± 4.5 K (quantity > 0.26 gpm)

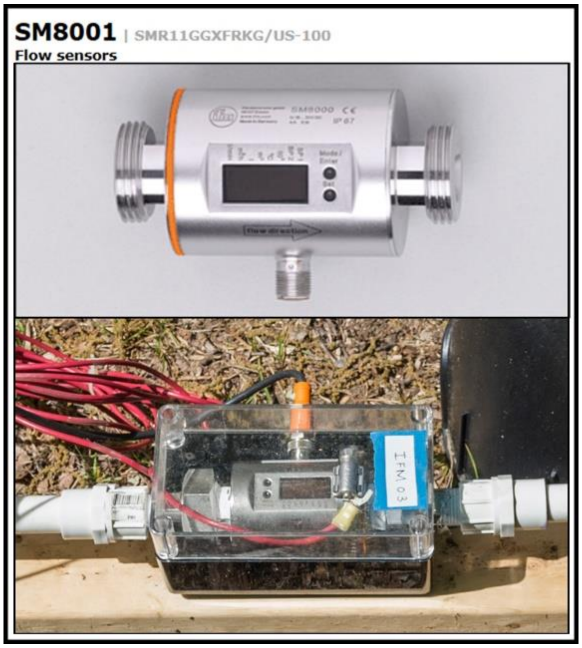


Figure 66: IFM SM8001 Water Flow Meter

3.3.7 GF Signet Water Flow Meters

The Signet 2551 Magmeter **(Figure 67)** is an insertion-style magnetic flow sensor that features no moving parts. The patented sensor design is available in corrosion-resistant materials to provide long-term reliability with minimal maintenance costs. Material options include polypropylene (PP) with stainless steel (SS), polyvinylidene fluoride (PVDF) with Hastelloy-C, or PVDF with titanium. The model employed in this demo was the PVDF version. Utilizing the comprehensive line of Signet installation fittings, sensor alignment, and insertion depth is automatic. These versatile, simple-to-install sensors deliver accurate flow measurement over a wide dynamic range in pipe sizes ranging nominal diameter (DN) DN15 to DN900 (½ to 36 in), satisfying the requirements of many diverse applications.

Signet 2551 Magmeters offer many output options of frequency/digital Scalable Scientific Subroutine Library (S3L) or 4 to 20 mA which are available on both the blind and display versions. The frequency of digital (S3L) sensor output can be used with Signet's extensive line of flow instruments while the 4 to 20 mA output can be used for a direct input to Programmable Logic Controllers, chart recorders, etc. Both the 4 to 20 mA output and digital (S3L) sensor interfaces are available for long distance signal transmission. An additional benefit is the empty pipe detection, which features a zero-flow output when the sensors are not completely wetted. Also, the frequency output is bidirectional while the 4 to 20 mA output can be set for uni- or bidirectional flow using the display or the 3-0250 USB to Digital (S3L) Configuration/Diagnostic set-up tool which connects to PCs for programming capabilities.

Figure 67: GF Signet Meters

Features include:

- Test certificate included for -X0, -X1
- Patented Magmeter technology
- No moving parts
- Bidirectional flow
- Empty pipe detection
- Installs into pipe sizes DN15 to DN900 (0.5 to 36 in)
- Operating range 0.05 to 10 m/s (0.15 to 33 ft/s)
- Accurate measurement even in dirty liquids
- Blind 4 to 20 mA, digital (S3L), frequency, relay output
- No pressure drop
- Corrosion resistant materials; PP or PVDF with SS, Hastelloy-C, or titanium
- Multi-language display menu available

3.3.8 Gems FS-150 Series Flow Switch

The Gems FS-150 flow switches **(Figure 68)** were used to monitor the “on” time of the showers in the South Camp. These items were left installed in the showers as the BCIL staff thought they might be useful in the future.

Features include:

- Flow rate settings: 0.5 to 5 gpm
- Setting Type: fixed

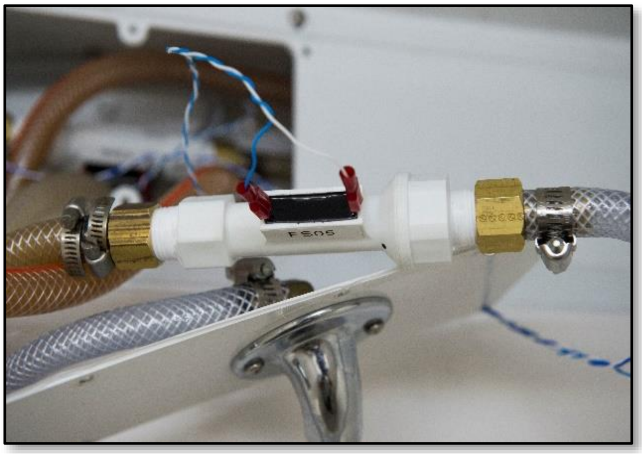


Figure 68: Flow Switch

- PP housing, hydrolytically stable, glass reinforced
- Maximum operating pressure: 200 pounds per square inch gauge (PSIG) @ 70 °F
- Operating temperature: 0 to 212 °F
- Set point accuracy: ±15%
- Set point differential: 20% maximum
- Switch: single pole, single throw (SPST), 20 Volt-Amp (VA)
- Inlet/outlet ports: 1/2″ National Pipe Taper (NPT) Male
- Electrical termination: 1/4″ male quick connect terminals (two)

3.3.9 Arlyn Scale

The demonstration used an Arlyn scale **(Figure 69)** with digital readout (Model 325D) that achieves accurate weight readings, using modern digital techniques to provide best results. The scale uses four load sensors embedded in the corners of the scales to convert weight into an electrical signal.

The Arlyn Scale with readout (Model 325D) specifications include:

- Capacity: 500 lb
- Accuracy: 0.1% of full scale
- Power requirements: 117 VAC, 50/60 Hz, 24VDC optional
- Display: digital indicator 1 in LCD, updates at 0.4 s, adjustable
- Operating temperature: 14 °F to 104 °F
- Dimensions: overall 36 in x 36 in

The Arlyn scale was used to measure fuel for the T100 genset, fuel for the AWH-400 hot water heater, and wastewater for the CIMT processes.

Figure 69: Arlyn Scale

3.3.10 BCIL Weather Station

The BCIL has a Davis Vantage Pro 2 weather station with several expansions. The EDVT used the weather station to collect solar radiation, temperature, humidity, wind speed, and rainfall.

3.3.11 Instrumentation Network

The National Instrument (NI) network consists of three primary hardware pieces. The Wireless Sensor Network (WSN) 9791 gateway, the WSN-3202 node, and the WSN-3212. The 9791 is a gateway that connects the WSN-3202s and 3212s to a computer. The gateway routes the traffic and controls the 2.4 GHz Zigbee network. **Figure 70** shows gateway on the left and a typical node, either 3202 or 3212 on the right. The 3202 and 3212 are similar in appearance.

Figure 70: NI Gateway and Node

The WSN-3202 is a 4-channel, 16-bit analog input node. The measurement node is a wireless device that provides four +/- 10V analog input channels and four bidirectional digital channels.

The WSN-3212 is a wireless device that provides four 24-bit thermocouple input channels that can support J, K, R, S, T, N, B, and E type thermocouples. It is also capable of supporting four bidirectional digital channels that can be configurable for input, synching, or sourcing output, and value change detection. **Figure 71** shows a 3212 in a protective case.

Figure 71: NI WSN-3212 in Enclosure

The EDVT Data Collections team used a combination of the above NI network and a wifi network to provide the backbone for the data collections during the event. The first network is the one that is installed on site at the BCIL, the second is an EDVT network set up on site specifically for this demonstration.

The BCIL network is a 2.4 GHz wifi network that has been set up to conduct the data collections on site for the BCIL. The BCIL allows customers to log onto the network to harvest real-time data as well as to access the database where all data are stored.

The EDVT network is a separate network of the same type as the BCIL network. The hardware pieces are all the same, but the channels and end-to-end collections were controlled by the EDVT team. **Figure 72** shows the BCIL diagram with an overview of the EDVT instrumentation team’s data collection network layered on top.

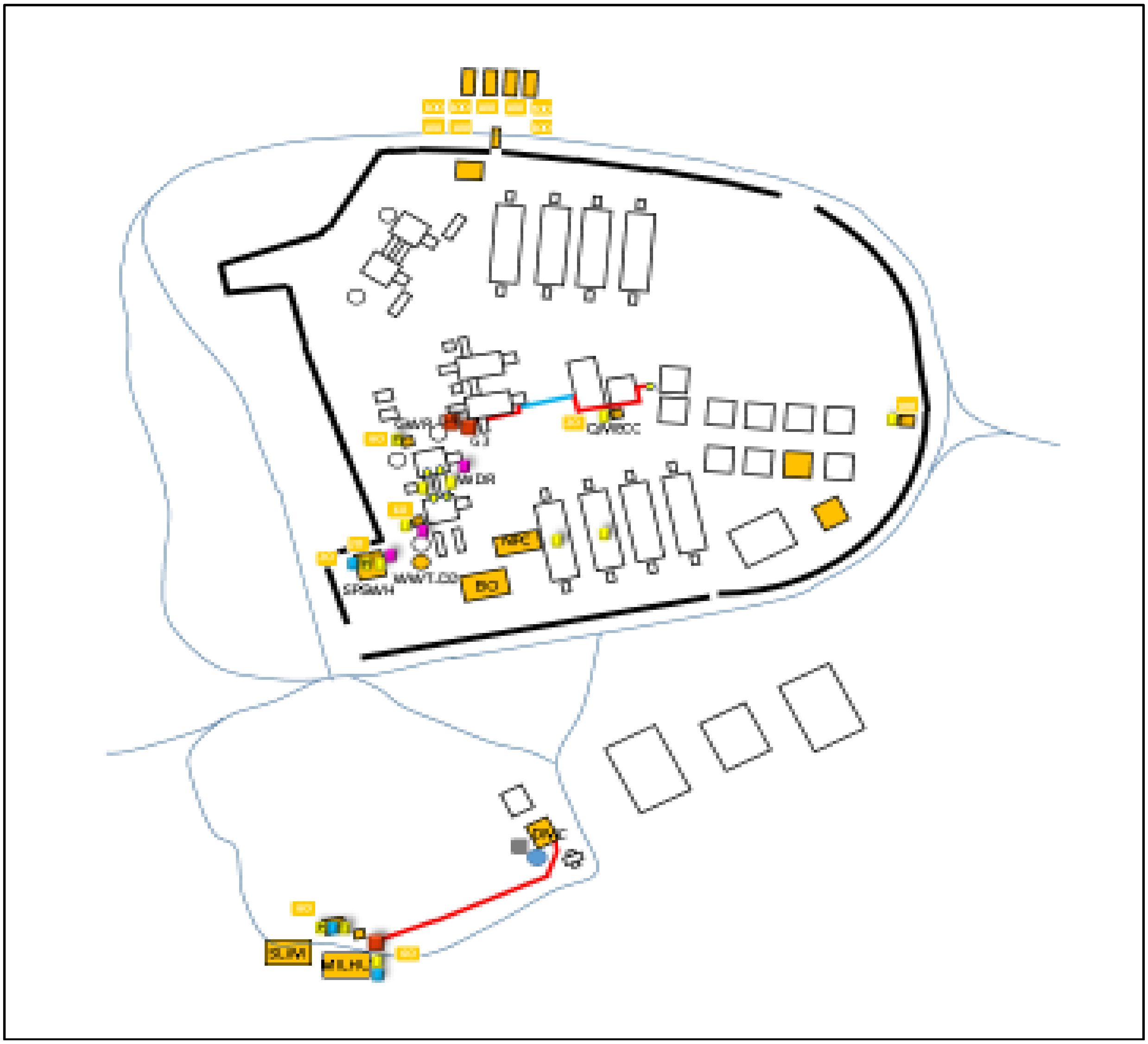


Figure 72: Instrumentation Backbone Sketch

In order to make it easier to see the networks deployed in the South Camp and the southwest satellite camp, the following images are “zoomed in” views of the EDVT instrumentation network diagrams **(Figures 73, 74, 75, 76)**.

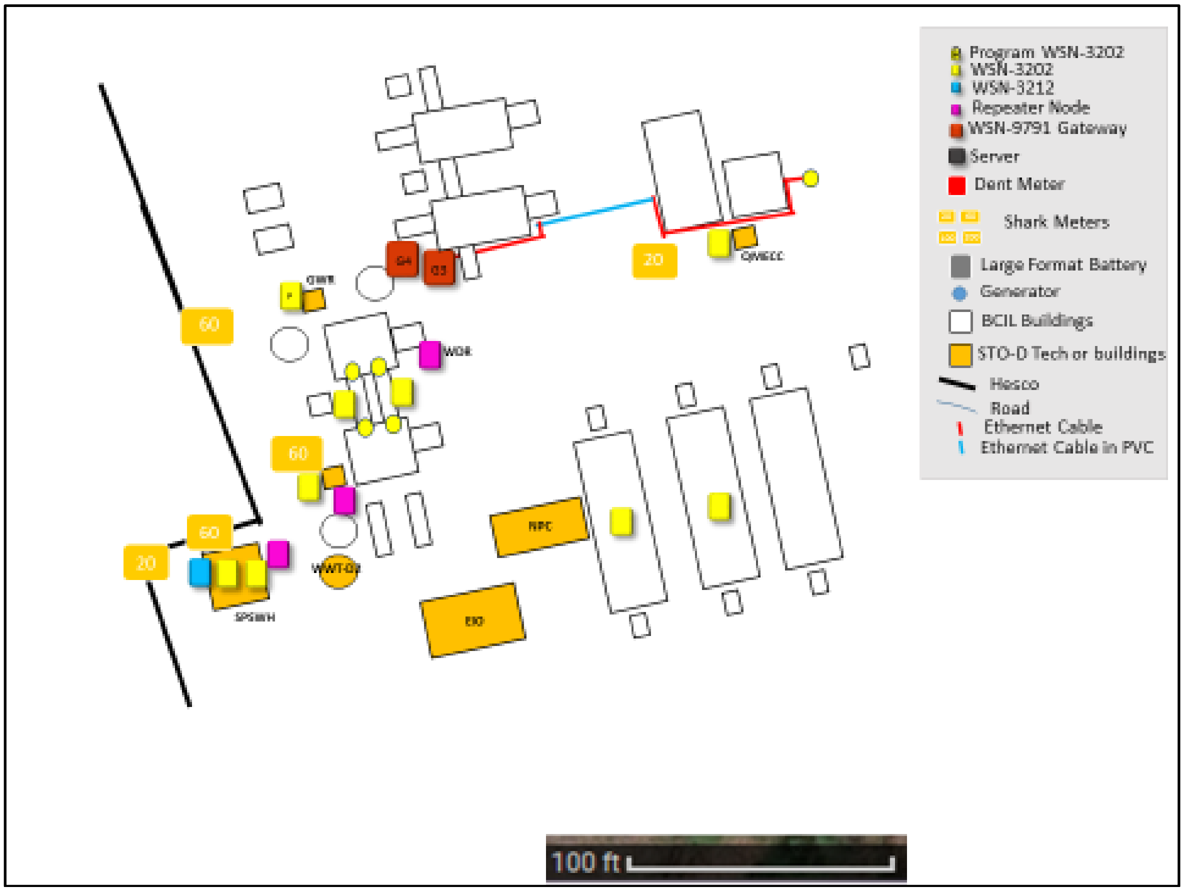


Figure 73: South Camp Instrumentation Sketch

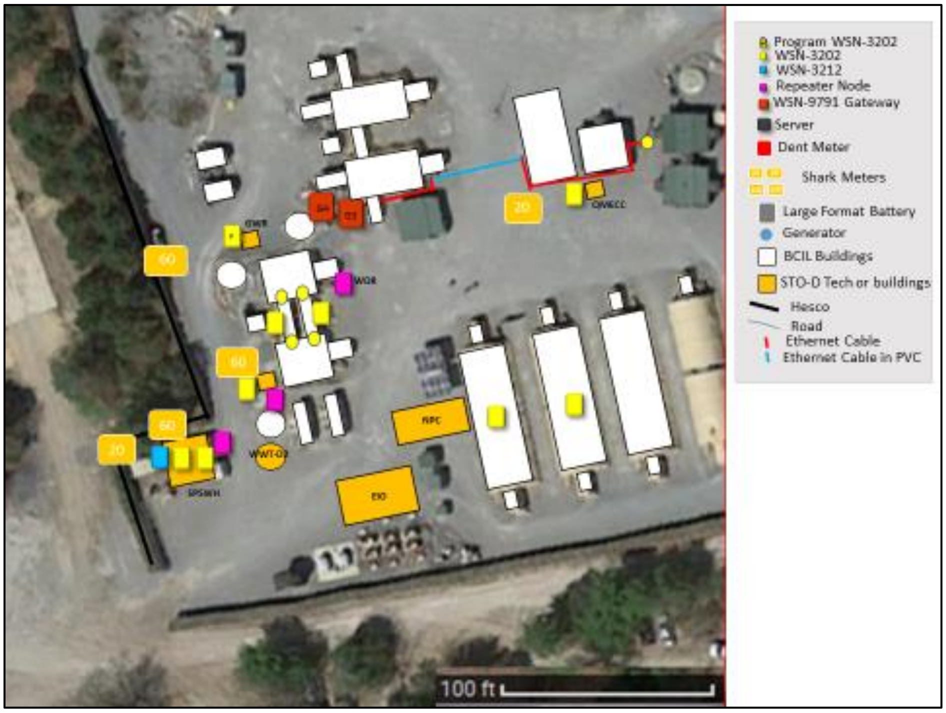


Figure 74: South Camp Instrumentation Sketch with Terrain

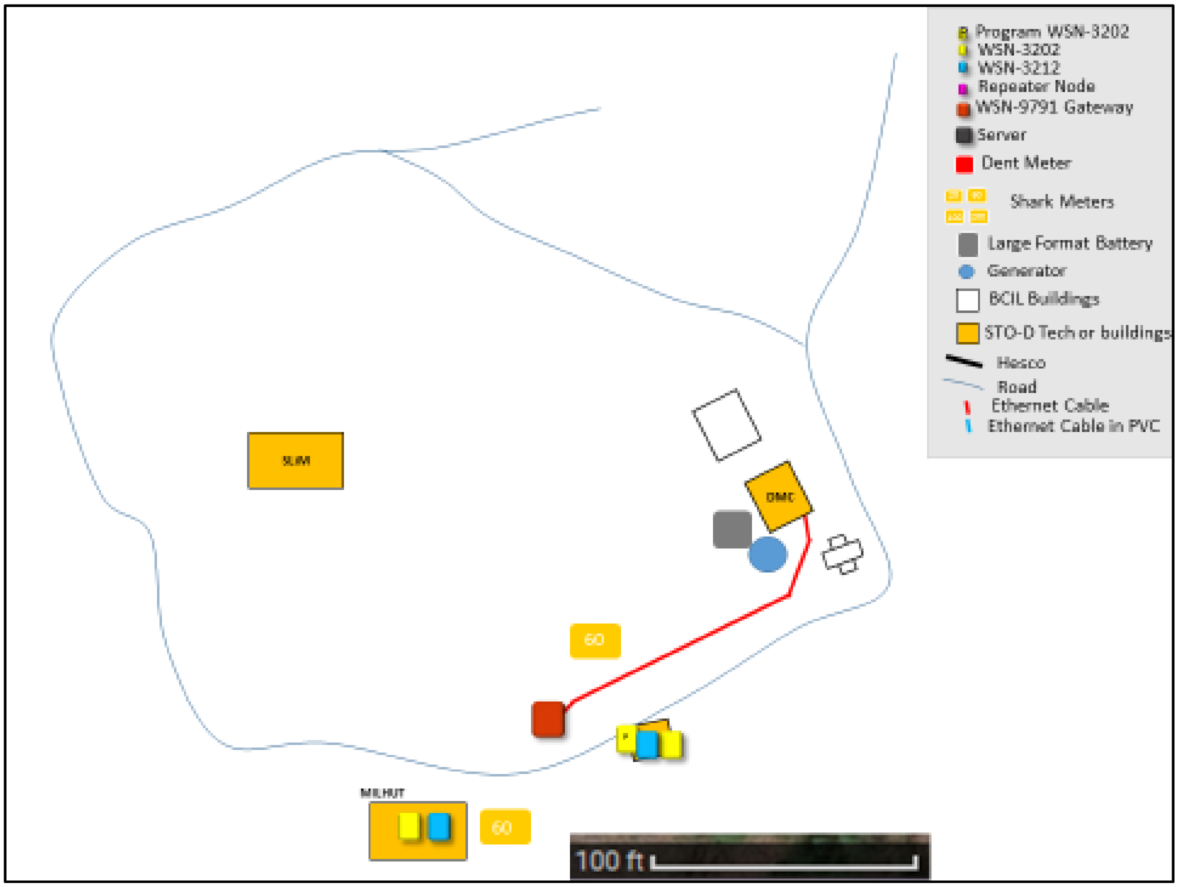


Figure 75: Southwest Satellite Camp Instrumentation Sketch

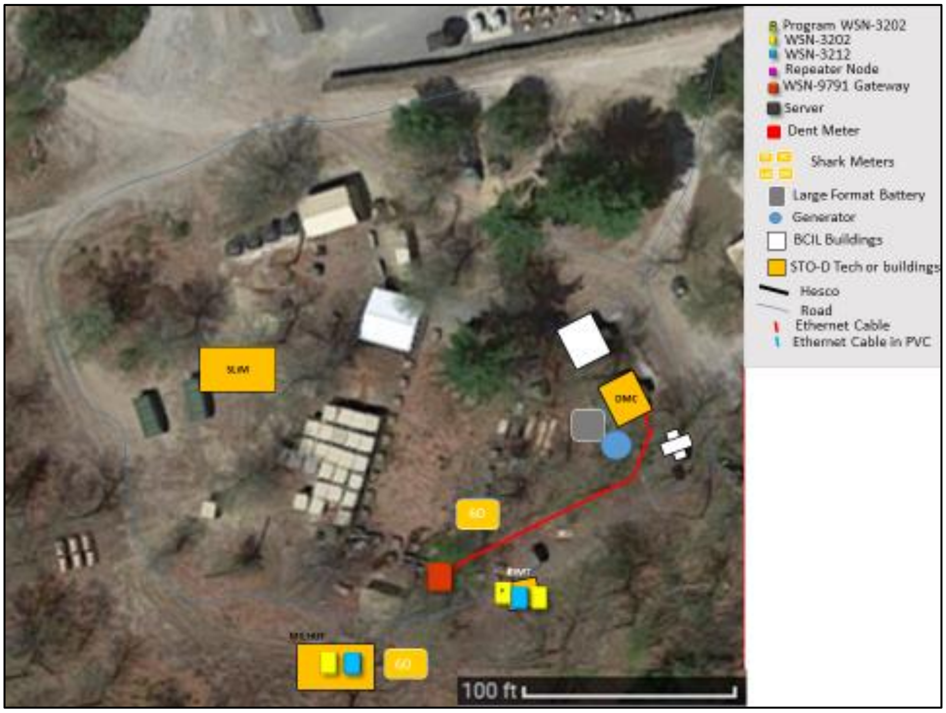


Figure 76: Southwest Satellite Camp Instrumentation Sketch with Terrain

With the network in place, the rest of the methods to collect data were simply the installation of the sensors within the network, the assignment of IP addresses for all the network devices, and installation of the software to collect the data from each of these items. The installation of the sensors are covered for each technology in Chapter 4. The IP addresses of network devices are listed in the Sensor Tracking Matrix in **ANNEX B**.

NOTE: The only instrumentation not shown in the network diagrams above is the DC power meter for the WWT-D2. It was connected directly to the network via Ethernet cable. It did not have a static IP address. It was not configured individually.

3.3.12 Data Review Dashboard

The Data Review Dashboard (DRD) (**Figure 77**) is a custom product developed by NSRDEC for use in the STO-D. As its name implies, it is used to conduct reviews of data in the field. It is a program that allows data to be displayed in an organized dashboard that contains data on weather, power, energy, and other harvested data. It generates charts and graphics, which allows the viewer to have a better visual picture of the data.

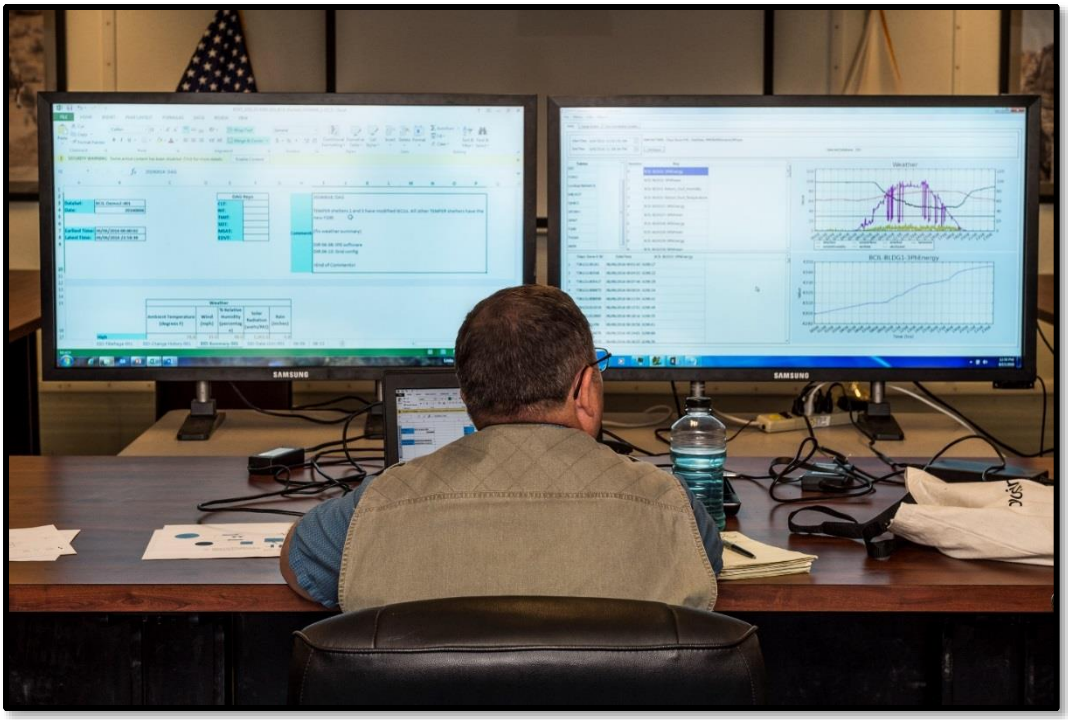


Figure 77: DRD

In the figure, the DRD is shown on the right-hand monitor. The upper left quadrant in the DRD list the data elements available to view. The lower left quadrant is the actual tabulated data. The lower right quadrant is a graph of the data. The upper right quadrant is a graph of the weather data. (NOTE: The monitor on the left shows the DDS that is being viewed in the DRD.)

4. METHODS

The first step to planning the demonstration was to identify and document the data requirements to meet *Objective 1*. EDVT solicited data requirements from the individual Technology Providers, SEIT, and MSAT and collated these into the DSM. The DSM was reviewed by these stakeholders in a conference, then continuously refined and documented until the DSM could be locked. Extracts of the DSM are shown in **ANNEX A**. This section of the report describes the details of instrumentation, the data collection activities and the data handling processes from the start of the integrated demo through authentication of the data to meet those data requirements documented in the DSM. The instrumentation sensors referenced in Section 4.1 are cross-referenced by technology in the Sensor Tracking Matrix in **ANNEX B.**

4.1 CIMT Data Collection

4.1.1 Hardware and Setup

Figure 78 shows the schematic for instrumentation of the CIMT.

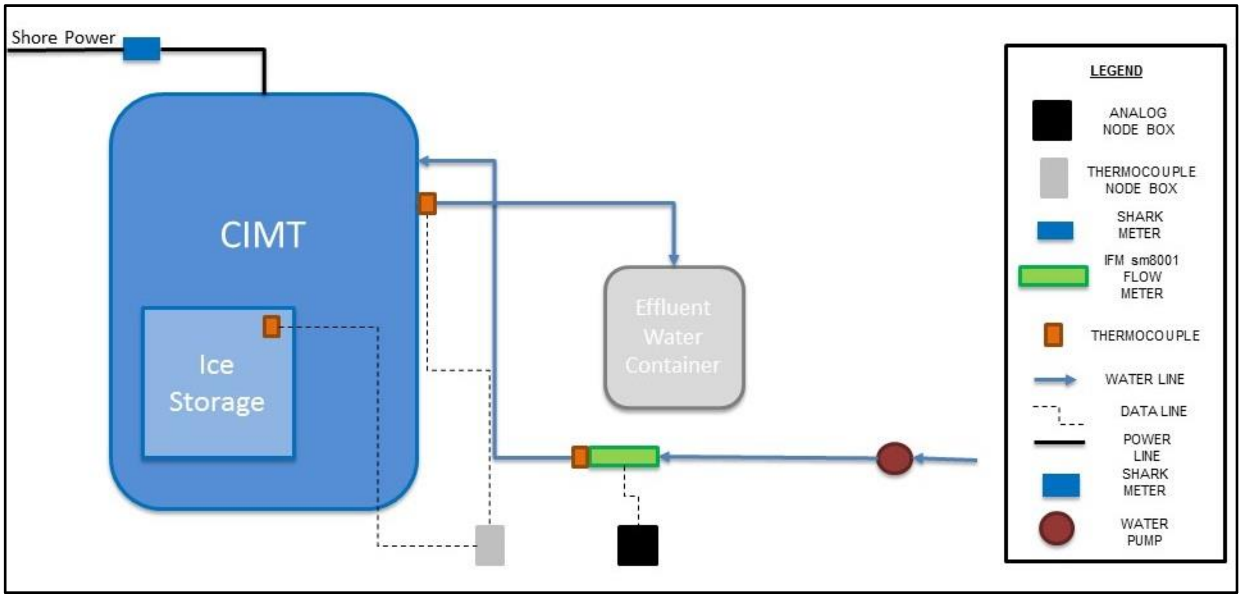


Figure 78: CIMT Instrumentation Schematic

Instrumentation of the CIMT for data collection required the following equipment (see lines 34-42 in the Sensor Tracking Matrix).

EDVT Sensors and Equipment:

- One water flow meter
- One holding tank
- Three thermocouples (two J-type probes, one T-Type)
- One 60 Amp Shark meter
- One Arlyn scale

NI Backbone:

- One 3202 Node
- One 3212 Node

There was also one BCIL sensor

Description:

CIMT is an ice making technology. It required water flow in and water flow out. The "water out" was about 50 gal a day. A holding tank (white barrel in **Figure 79**) on the Arlyn scale was used to weigh "water out."

"Water in" was measured by a water flow meter (**Figure 80**). The water fittings were Garden Hose Type (GHT) hose fittings and they required 60 PSI pressure on the inlet line. Half-inch pipe setups were used for the water meters. Temperature measurements of the two water streams were recorded using thermocouples.

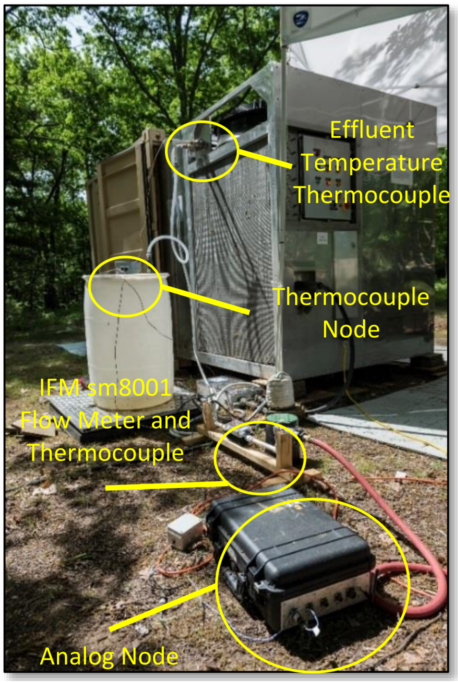


Figure 79: CIMT Instrumented for Data Collection

An extra quick-connect setup was used for the thermocouple in the water line. A second setup was made for the thermocouple output line. The third thermocouple was positioned inside the CIMT unit to monitor the temperature of the ice storage chamber. During the initial temperature data recording, it was evident that there was significant electromagnetic interference in the chamber causing poor temperature readings. Therefore, a shielded thermocouple cable was installed. **Figure 81** shows the original unshielded thermocouple on the left and the shielded thermocouple on the right. **Figure 82** shows the node for the thermocouples positioned on top of the wastewater holding tank.

Figure 80: CIMT Water Flow Meter

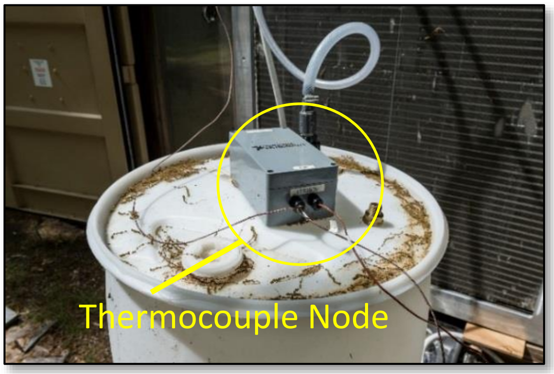


Figure 81: Thermocouples in Ice Storage Area

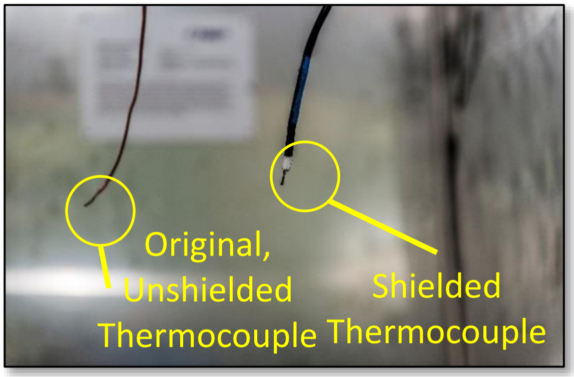


Figure 82: CIMT Thermocouple Communication Node

Figure 83 shows the analog communications node to report the flow meter data.

A lab scale (not shown) was used to weigh ice bags and determine an average weight.

A Shark meter (not shown) was used to monitor the power, which was a three-phase line.

4.1.2 Operational Script

The intent of the CIMT demo was to relate electrical power consumption of the CIMT to the amount ice produced per time period. The only independent variable identified for control was the temperature of the ice storage chamber. Independent variables that could not or were not controlled were the weather and the temperature of the input water stream.

Figure 83: Analog Communication Node

The CIMT was powered continuously during the demo, but the ice making unit was only functional during normal duty hours at the BCIL. The dependent variables measured were the power required, the water required, the wastewater output, the number of bags of ice produced daily and the average weight of the bags of ice.

The Technology Provider submitted the following description of operation:

> The CIMT contains three refrigeration loops. One supplies air to hold the ice storage compartment at freezing temperatures. Another supplies refrigerant to ice heads upon which water is frozen to produce ice cubes. The third pre-chills incoming supply water.
>
> Each "ice head" is a very cold slab of metal that the machine flows water over to build up a slab of ice that is then harvested as cubes. There are six ice heads. The ice heads work in pairs that are called "units". The three units are Unit 1, Unit 2, and Unit 3.

To produce a single "batch" of ice cubes (22 lbs), there are three steps:

- The first step -- "**Filling**" -- is when a reservoir in the lower part of a "unit" fills with ~3 gallons of potable water.
- The second step -- "**Making Ice**" -- is when a pump cascades this water over two ice heads simultaneously while the refrigeration circuit chills the heads to far below freezing. When the reservoir runs out of water, it means the ice slab has grown thick enough for the third step.
- The third step -- "**Harvesting**" -- is when the refrigeration circuit runs hot refrigerant through the ice head to melt enough ice such that cubes will fall off the head into an ice bin below.

To bag and store the ice:

- First a gantry picks up a bag and positions it below a spout.
- An auger in the ice bin pushes the ice up and out the spout.
- A sensor stops the auger when the bag is full.
- The bag is heat sealed.
- A trapdoor opens beneath the bag and it falls down onto a horizontal **conveyor.**
- This horizontal conveyor pushes the bag to an **elevator**.
- The elevator raises the bag up to a portal leading to the ice storage compartment.
- An **exit ram** pushes the bag off the elevator, through the portal, into storage.

4.2 WDR Data Collection

4.2.1 Hardware and Setup

Figure 84 shows the schematic for instrumentation of the WDR.

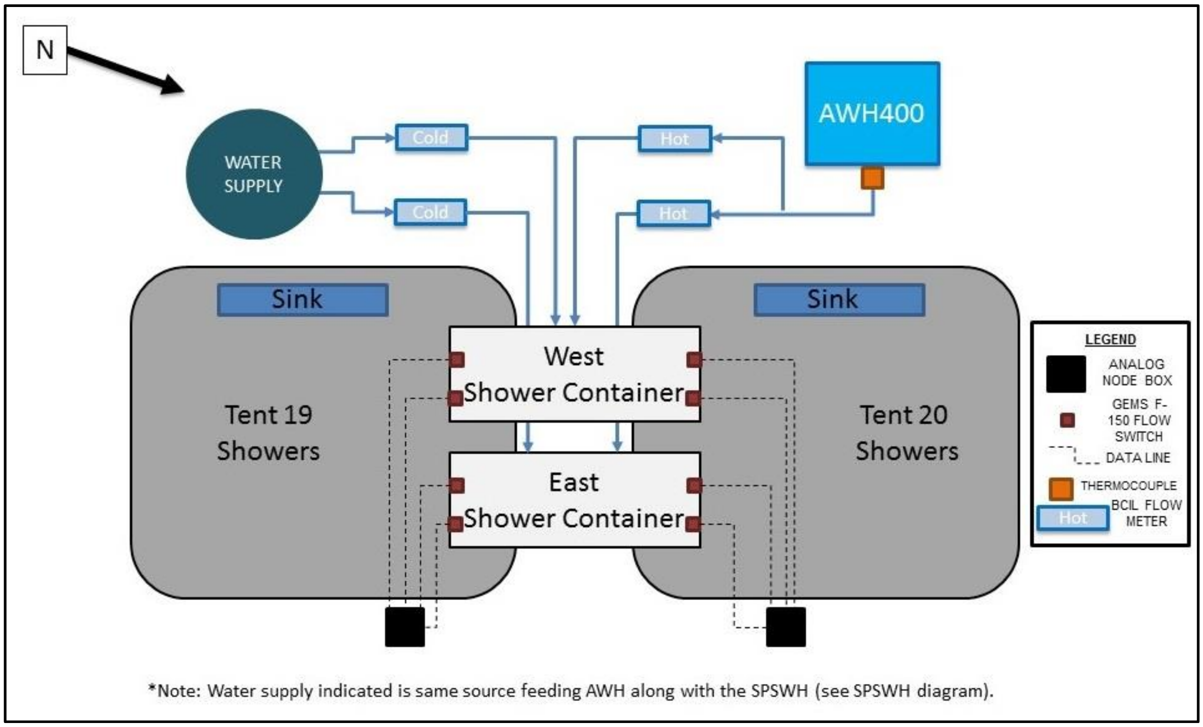


Figure 84: WDR Instrumentation Schematic

Instrumentation of the WDR for data collection required the following equipment (see Sensor Tracking Matrix lines 54-61).

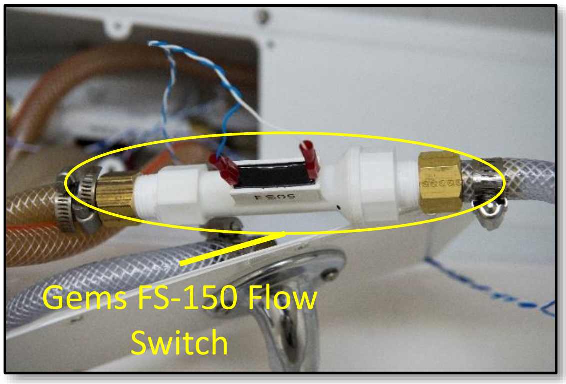


Figure 85: Gems FS-150 Flow Switch

EDVT Sensors:

- Eight water flow switches (**Figure 85**)

NI Backbone:

- Three 3202 Nodes

BCIL Sensors:

- Shower front: Cold SW-942, Hot SW-499
- Shower back: Cold SW-483, Hot SW-487

Description:

This technology demonstration consisted of low-flow showerheads (**Figure 86**) to be compared with the existing (baseline) Force Provider showerheads (**Figure 87**). To this end, the on/off flow through the showerheads was detected via water flow switches.

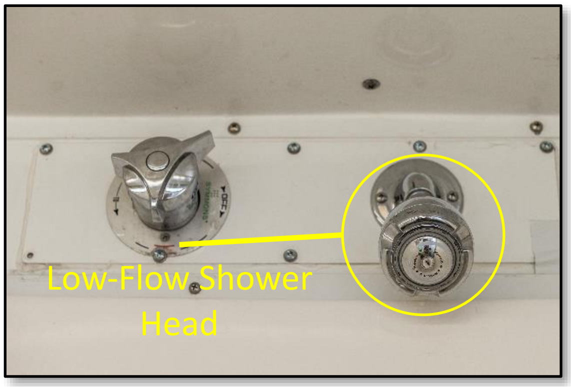


Figure 86: Low-Flow Showerhead

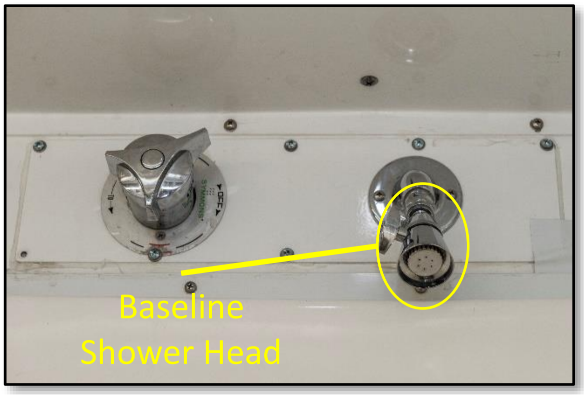


Figure 87: Force Provider Baseline Showerhead

A feasibility study was conducted to decide whether or not to do overall flow and pressure on the system. The results of the study indicated that, for the purpose of the demonstration, it was more feasible and practical to use flow switches placed in line with the showers as pertinent parameters could be calculated based on runtime. Nonetheless, the overall flow was eventually captured by the BCIL water meters, which were already inline.

4.2.2 Operational Script

Table 2: WDR Operational Script

	Showerhead	
Date	Morning	Evening
3-Jun		Demo
4-Jun	Demo	Demo
5-Jun	Demo	Demo
6-Jun	Demo	Demo
7-Jun	Demo	Demo
8-Jun	Demo	Demo
9-Jun	Demo	Demo
10-Jun	Demo	Baseline
11-Jun	Baseline	Baseline
12-Jun	Baseline	Baseline
13-Jun	Baseline	Baseline
14-Jun	Baseline	Baseline
15-Jun	Baseline	Baseline
16-Jun	Baseline	Baseline
17-Jun	Baseline	Baseline
18-Jun	Baseline	Baseline
19-Jun	Baseline	Baseline
20-Jun	Baseline	

The intent of the data collection for the WDR was to allow the Soldiers to shower with no instruction or guidance as to shower length, other than direction from leadership or unit procedures. The only independent variable identified for control was the type of showerhead. The Soldiers were not informed that the showerheads would be replaced or that they were different. Independent variables that were not or could not be controlled were the external pressures on the Soldiers that would affect their shower time, such as training schedule, training conditions, weather conditions, mandated shower hours, leadership policy, water availability, etc.

Since Soldiers were expected to arrive over the weekend, the low-flow showerheads were installed on 3 June. See **Table 2.** The low-flow showerhead remained installed from 6 June through midday on 10 June. The Soldiers generally took showers in the evenings or in the mornings. The STO-D took control of showers during the middle of the day to run other experiments.

On Friday, prior to the departure of the STO-D team for the weekend, the low-flow showerheads were removed and the baseline showerheads were installed. The STO-D left the baseline showerheads installed for the remainder of the demonstration, on 17 June, collecting data on Soldier shower times for a full week with both weekends included. More data were collected for the regular showerheads due to observed abnormal behavior.

4.3 SLiM Data Collection

Information in this section was submitted by the Technology Provider and edited for format.

4.3.1 Hardware and Setup

Instrumentation of the SLiM for data collection required the following equipment.

Equipment: For the purposes of this demonstration the SLiM consisted of two components – the billeting module and the microgrid. The microgrid consisted of:

- I/O Module
  - Outlets – (1) 120/208 3-Phase VAC/60Hz
  - DC inlet/outlet – (2) NATO, 7 Amp; 48V output to AC module
  - Solar charge capacity – 3.36 kW
  - Solar ports – (6) 20 Amp ITT/Cannon twist-lock ports
  - Weight – 130 lb/286 kg

- AC Module
  - Service – 120/208 3-Phase VAC / 60Hz
  - Rated power – 125 Amps / 15 kW
  - Surge power – 30 kW
  - AC outlets – (1) 120/208 3-phase VAC
  - AC charge port – (1) 120/208 3-phase VAC
  - Weight – 190 lb/418 kg

- Battery Module(s)
  - Type – lithium ferrous phosphate
  - Capacity – (4) 8 kWh
  - Lifecycle – 300 cycles or 10 years @ 90% depth of discharge
  - Weight – 170 lb/374 kg

- PV panels: 12 panels with a 3.36 kW solar array capacity
- Generator: 10 kW TQG

Test Equipment:

- AVTRON Liberty load bank: 55 kW capacity
- Distribution Box: 100-Amp to 60-Amp conversion for shelter/load bank compatibility

Description:

The SLiM Microgrid is a hybrid power system designed to significantly reduce generator dependence, thus reducing fuel consumption and running time. The hybrid system uses multiple power sources to provide operational continuity, extend the fuel supply, and operate silently. The SLiM Microgrid system is designed for use with a generator with a rated power of 5 kW – 30 kW.

Establishing a method to determine the state of charge (SOC) of the system and its capacity were the main focus during the system demonstration. This required monitoring the power being drawn by the loads applied to the system using a load bank and measuring the voltage available in the battery modules. **Figure 88** and **Figure 89** show the equipment used to apply the loads and the distribution box that was needed to install the load bank. Additionally, a Shark meter was used to confirm the measurements taken from the Microgrid Battery Monitor/Color Control GX which can be seen in **Figure 90**.


Figure 88: Load Bank


Figure 89: Distribution Box


Figure 90: Shark Meter

4.3.2 Operational Script

The aim of demonstrating the system was to determine:

- SOC of the lithium ferrous phosphate batteries
- Maximum load the system is able to sustain for shorter periods
- Down time required for system reboot
- Approximate load required to verify the stated capacity of the system.

Test Procedures:

- **SOC Test**: Determine an appropriate SOC voltage for the system. The maximum system voltage does not correspond to the maximum SOC of the batteries. This is due to a higher voltage (charging) input from the PV and generator. To determine a more accurate SOC, the battery system was disconnected from the charging/power sources. This was done to allow the batteries time to reach their own internal steady state voltage.

- **System Overload Test**: Determine the maximum load the system is able to sustain for shorter (15-20 min) before overloading. For this test, the system was introduced to different loads using an Avtron load bank (Liberty Load Bank, 55 kW Capacity). Loads were increased incrementally until a system shutdown was achieved. Since the system was stated to be 15 kW, a load of approximately 15 kW was expected to cause the system to fail. The iterations were started using 1.9 kW and increased to 17.5 kW.
- **System Startup Time Lag Test**: Determination of a system restart duration during reboot. For this test, batteries were drained to a charge status of 0% and time elapsed for the system to reboot was recorded. Time and charge status were monitored to determine what charge status triggered the system to reboot.
- **System Capacity Test**: Determine a constant load that represents a realistic daily power draw. For this test, the system was run using only the batteries as a power source (PV was unplugged and the generator was at the E-stop setting). The system was run at constant load until the batteries were drained. Total elapsed time was recorded.

4.4 MILHUT Data Collection

4.4.1 Hardware and Setup

Instrumentation of the MILHUT for data collection needed the following equipment (see Sensor Tracking Matrix lines 2-10).

EDVT Sensor and Equipment:
- One humidity sensor
- Two thermocouples (T-Type or better) (**Figure 91**)
- One door opening sensor
- One 60-Amp Shark meter

NI Backbone:
- One 3212 Node
- Two 3202 Nodes

BCIL Sensors: none

Description:

The instrumentation used for this system is outlined in the Sensor Tracking Matrix lines 2-10. Some of the instrumentation was not used as originally planned (e.g., water meter, sound meter).

Figure 91: Thermocouple in MILHUT Air Duct

The MILHUT is a habitation system that provides billeting, hygiene and food preparation capabilities through the implementation of renewable energy technologies. The ECU for the

MILHUT was non-standard, i.e., commercial, not military-spec, and data collection required the use of two thermocouples to measure temperature within the billeting shelter. The temperature sensors were located in the air duct (**Figure 91**) and on a tripod (**Figure 92**) located near the center of the billeting tent. The only values that were recorded using the 3202 nodes were the door sensor (**Figure 93**) and the humidity sensor on the tripod.

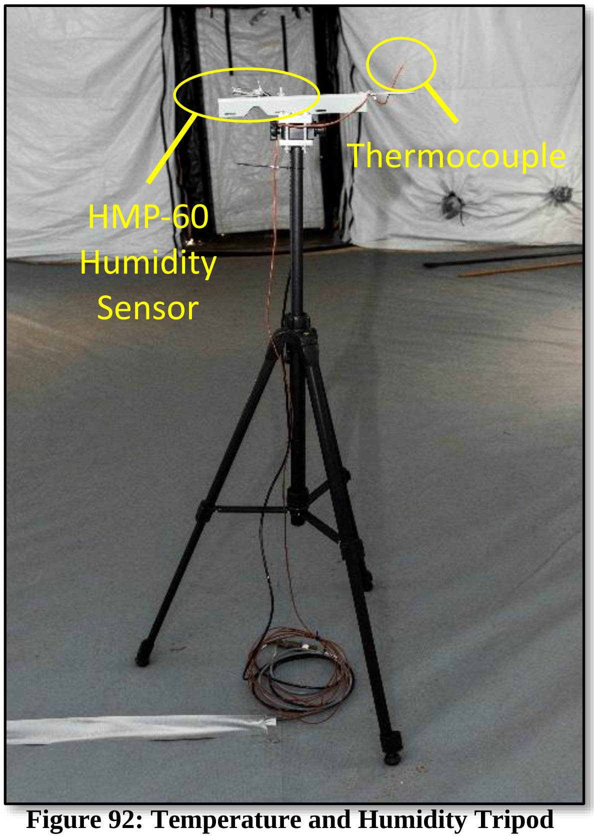


Figure 92: Temperature and Humidity Tripod

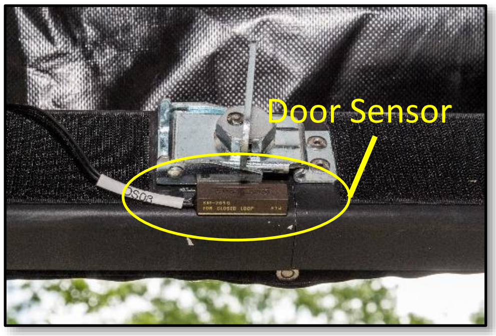


Figure 93: Door Opening Sensor

4.4.2 Operational Script

The only subsystem demonstrated for the MILHUT was the air-conditioning unit. The independent variable identified for control was the thermostat setting. It was set to 65 °F by the Technology Provider. The system operated for 6 days of record runs: 8-10 June and 13-15 June. The system operated overnight 8 and 9 June. Soldiers did not occupy the shelter as originally planned. The Hotel Module was not exercised during the record runs.

4.5 NPC Data Collection

Information in this section was submitted by the Technology Provider and edited for format.

4.5.1 Hardware and Setup

All of the instrumentation used during this demonstration of the NPC was developed in-house for this experiment. There were no BCIL or EDVT sensors utilized.

Project Sensors: Apogee Instrument (SP-110: Self-Powered Pyranometer)

Description:

The NPC demonstration, known more widely as "nano-enhanced photovoltaics" because of the NSRDEC 6.2 program (government in-house research with MIT Lincoln Laboratory and collaboration with PowerFilm, Inc.) involved the demonstration of harvesting solar power using lightweight thin-film PV panels (solar modules or "solar blankets"). These solar blankets were close to satisfying the requirements laid out in the Capability Production Document for the dismounted Soldier for output power, weight, and area. In addition, these solar blankets were flexible and could be, as shown in the demonstration, mounted easily on any surface exposed to the sun's rays. Because the area of the solar panel (and usually weight) is inversely proportional to module efficiency, assuming constant solar power flux, the researcher investigated nanomaterials to enhance the efficiency of thin-film solar cells, by coating the thin-film PV thin film with nanoparticles and nanostructures to enhance absorption and therefore the generated power and current. This enhancement was expected to reduce the weight and area of solar modules. Even if the efficiency under maximum solar flux at noon were not improved, the researcher anticipated that the inclusion of nanoparticles, acting as tiny concentrating lenses, might improve efficiency at low angles (e.g., dusk/dawn), thus extending the harvesting time for the solar blanket and increasing the total energy harvested over the daily operating period.

Three commercial PowerFilm 120W panels (each approximately 30 ft^2 in area) (**Figure 94**) were staked horizontally on the ground, and one commercial PowerFilm 120W panel was positioned at various angles to incident sunlight (**Figure 95**). During the demonstration, data was also collected on experimental 100W CERDEC-sponsored panels composed of gallium arsenide (much higher efficiency and therefore smaller, but much more expensive). These panels were also arranged horizontally on the ground (**Figure 96**).

Figure 94: Commercial PowerFilm 120W Panels

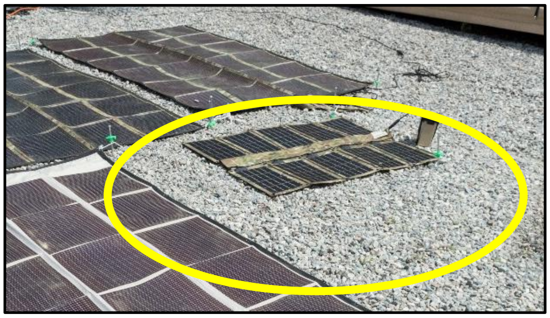


Figure 96: Gallium Arsenide 100W Panel

Figure 95: Solar Panel (angled)

Experimental nano-coated panels, researched under the above-mentioned NSRDEC H98-funded 6.2 effort led by Warfighter and EBCP Directorates, were arranged in an acrylic box and oriented towards the sun at different angles throughout the day (**Figure 97**). The experimental panels consisted of thin film amorphous silicon coated with either sprayed-on nanoparticles, unique anti-reflective coatings, or particles synthesized in a unique hydrogen gas-based process by Professor George Chumanov's group at Clemson University.

Figure 97: Experimental Panels

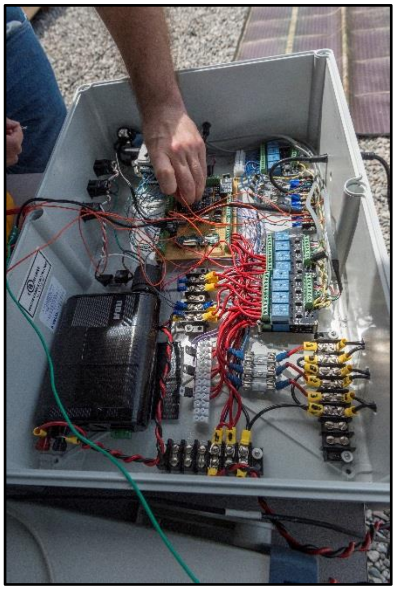


Figure 98: NPC-Unique Instrumentation Suite

Instrumentation (**Figure 98**) and LabView software was developed specifically to record the voltage, current, maximum power, and integrated energy produced by these panels. Data collection required the monitoring of the amount of solar irradiance being produced by the sun, the amount of integrated energy collected by various PV panels, and charging times for BB2590 batteries.

4.5.2 Operational Script

The experimental nano-coated solar panel tracked the sun during the normal BCIL duty hours. The cardinal heading and tilt of the panels was reoriented and recorded every 15 min from set up to break down (approximately 0800-1430 h daily).

Figure 99: Battery Charged by Panel

The PowerFilm 120W panels and CERDEC 100W GaAs panels were staked flat to the ground during set up and remained in the same position until breakdown. One 120W panel was oriented at an angle on top of arranged plywood and pallets. The angle was varied daily and recorded.
BB2590 batteries (**Figure 99**) were connected to the Power 120 panels (horizontal and angled) and

the CERDEC 100W GaAS panels when the power readings were at 0%. The time to charge from 0-100% was recorded for each panel, along with the corresponding solar irradiance from the pyranometer.

4.6 GWR-FORO Data Collection

4.6.1 Hardware and Setup

Figure 100 shows the instrumentation schematic for the GWR-FORO.

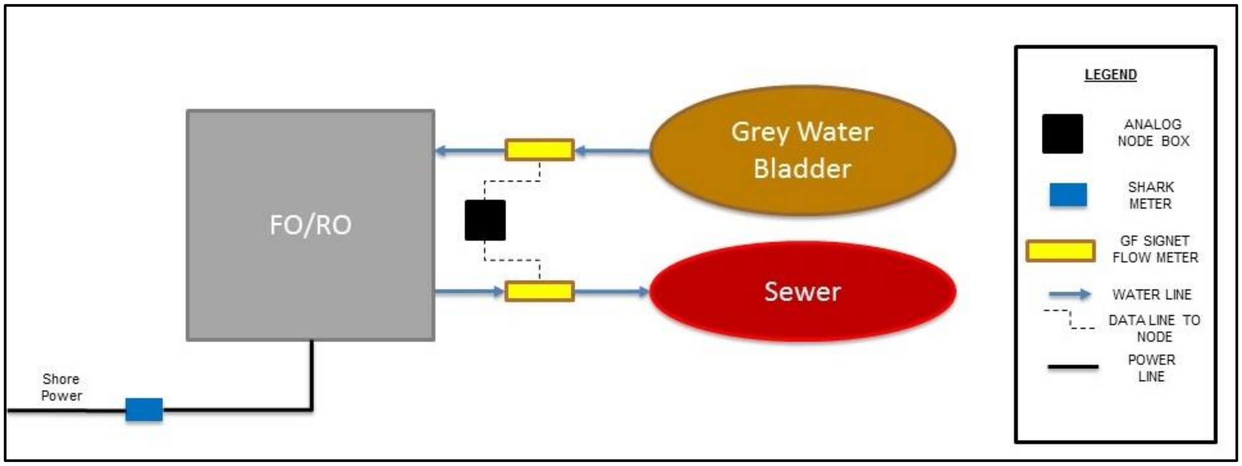


Figure 100: GWR-FORO Instrumentation Schematic

Instrumentation of the GWR-FORO for data collection required the following equipment (see Sensor Tracking Matrix in lines 49-52).

EDVT Sensors:

- Two water flow sensors (GF Signets)
- One 60-Amp Shark meter

NI Backbone:

- One 3202 Node

BCIL Sensors: none

Description:

This technology entailed a FORO graywater treatment system. Data collection required monitoring the amount of flow into the system, the amount of flow out of the system, and the power required to operate the system and treat the water.

The water flow meters consisted of two GF signet meters that were set into U-traps designed to hold water to ensure that the sensor maintained fluid contact and was able to hold signal strength. During the demonstration, it was noted that the trap needed to be turned at an angle, as shown in

Figure 101, to put more water on the sensor and avoid drifting. However, even with all the precautions taken, the sensor drift on the effluent sensor was significant.

Figure 101: GF Signet Water Flow Sensor

The power line on this system required a hard wire to be run into the box to resolve connector issues as the FORO system did not have a standard Army connector on their power line. The Shark meter software was configured in the same way as the others, but due to connectivity issues, all the data from this Shark meter was taken from the internal logs and not over the wireless network.

4.6.2 Operational Script

The GWR-FORO required a graywater source for operation. Adequate amounts of graywater were provided by the Soldiers taking showers and operating the laundry system. The system was able to process multiple batches most record run days during the normal BCIL duty hours.

The only independent variable identified for control was the percentage of product water versus concentrate. The system is sized to treat 400 gal of graywater per batch. The system was set to process 80% of each batch. So typically 320 gal of product water would be output and available for reuse, 80 gal of concentrated wastewater per batch would be output to the blackwater treatment system to be further treated, and then the system would be refilled with graywater and the process repeated.

4.7 V2G/V2V Data Collection

4.7.1 Hardware and Setup

Figure 102 shows the schematic for instrumentation of the V2G/V2V.

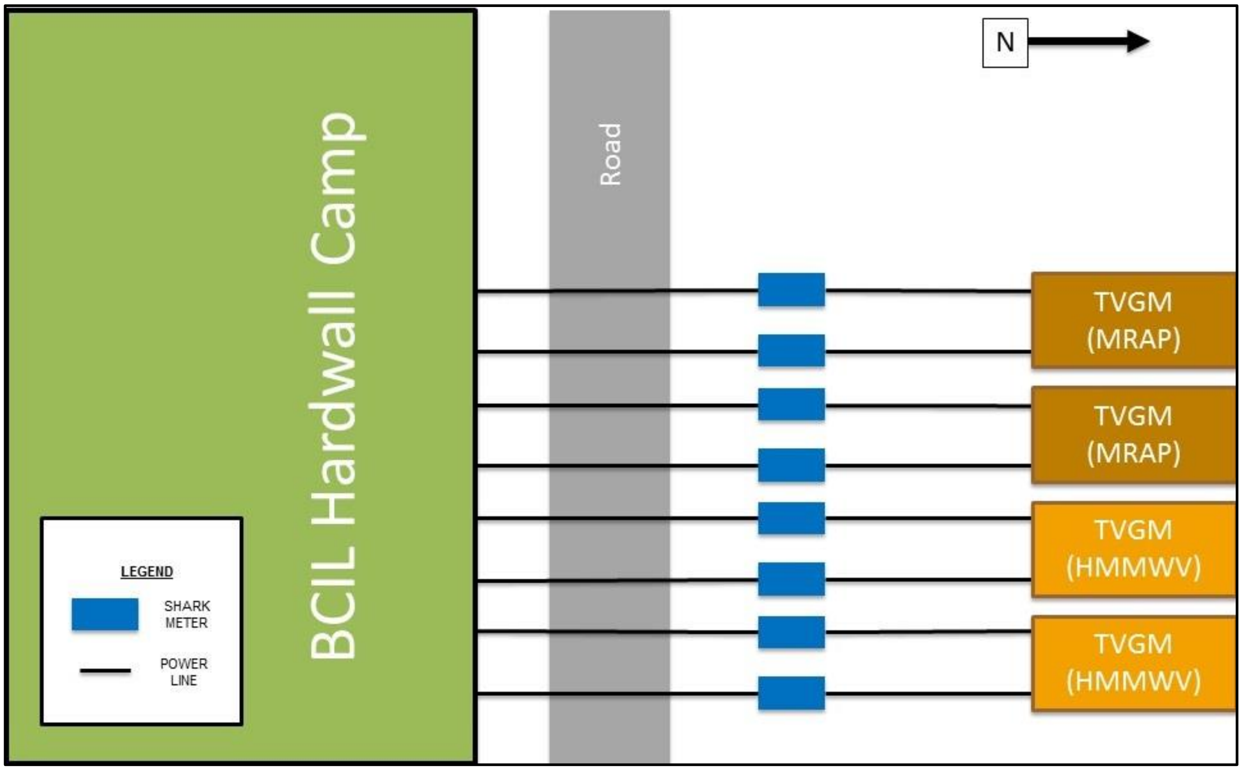


Figure 102: V2G/V2V Instrumentation Schematic

Instrumentation of the V2G/V2V for data collection entailed the following equipment (see Sensor Tracking Matrix lines 25-33).

EDVT Sensors:

- Eight 100-Amp Shark Meters

NI Backbone: N/A

BCIL Sensors: None. However, data from the Shark meters was transmitted over the BCIL data collection wifi network

Description:

This technology consisted of a set of two HMMWVs and two MRAPS that powered the North Camp. Each of the vehicles had a box with two 100-Amp cable outputs. The power out from the 100-Amp cables was monitored with eight 100-Amp Shark meters (**Figure 103**).

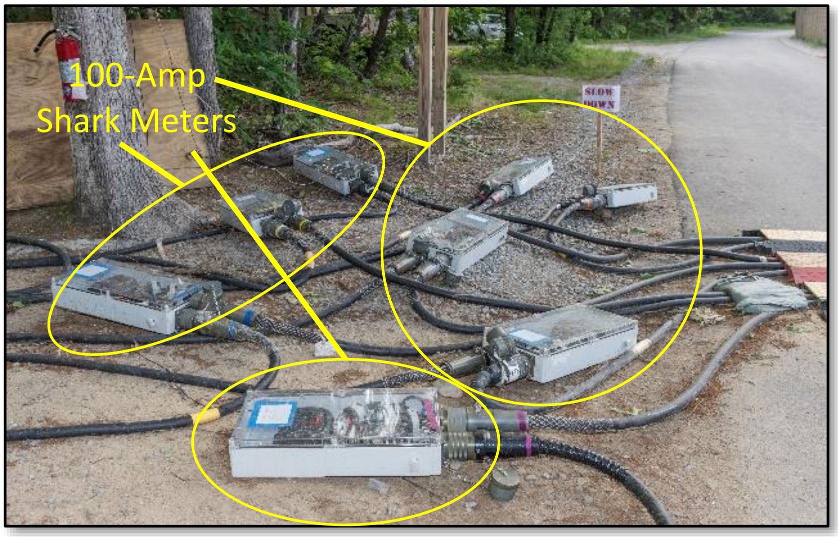


Figure 103: 100-Amp Shark Meters for the V2G/V2V

Vehicles were refueled as needed with the BCIL fuel pump and fuel usage was recorded manually using the data collection application installed in the digital tablets.

The electrical power meters were all Shark meters configured by the Natick fabrication department. There were Army connectors on each cable which allowed a plug-and-play interface for the meters and each meter was tested independently on a 100-Amp load prior to use in the demonstration. It is worth noting that there was a scaling factor of 10 that was applied to the energy output of the meters, as the meters were outputting energy in a 10 kWh format. This is a feature of the Shark meter. Rather than altering the meter configuration, the adjustment was made in data processing.

4.7.2 Operational Script

The V2G/V2V was tasked to power the North Camp facilities. The independent variable was the amount of load put on the system. Since Soldiers were occupying the camp, there was no good opportunity to vary this load under controlled conditions. Instead, the Soldiers set the ECUs, operated facilities, did their laundry, etc. as part of their training and residence in the camp. The V2G/V2V system did power load banks during some testing and were able to control the load in these certain instances.

4.8 WWT-D2 Data Collection

4.8.1 Hardware and Setup

Figure 104 shows the schematic for instrumentation of the WWT-D2.

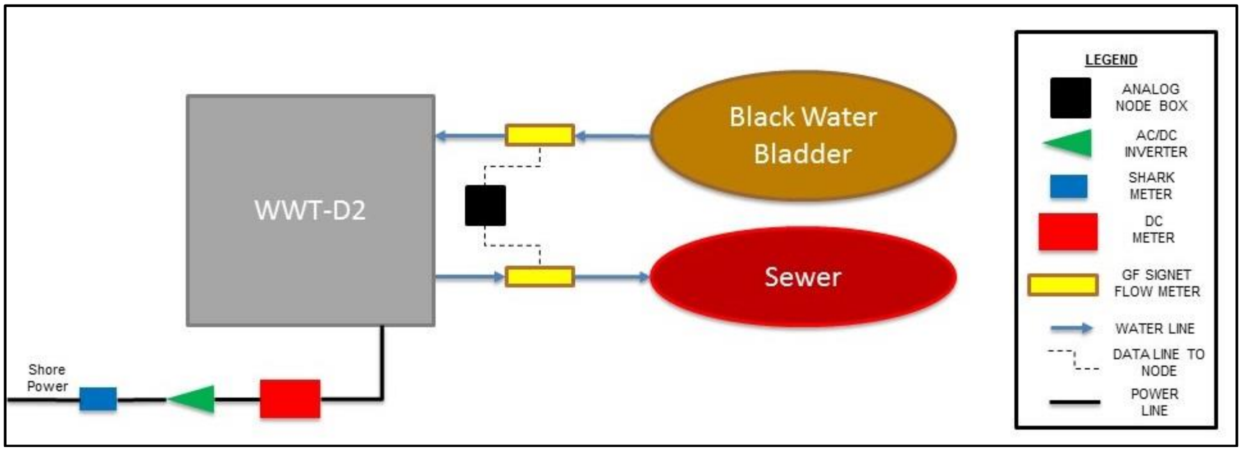


Figure 104: WWT-D2 Instrumentation Schematic

Instrumentation of the WWT-D2 for data collection included the following equipment (see Sensor Tracking Matrix lines 43-48).

EDVT Sensors:

- Two water flow meters (GF Signets)
- One 20-Amp Shark meter
- One DC power meter

NI Backbone:

- One 3202 Node

BCIL Sensors: none

Description:

This technology consisted of a blackwater treatment system that converted the incoming waste into energy to power itself. However, at this stage in its development, the system was not yet able to power itself independently. Therefore supplemental power was provided by an inverter that converted AC power to 28 VDC through a 20-Amp power cable.

A 20-Amp Shark meter was used before the inverter to monitor the AC power into the system. A DC power meter was also utilized to monitor DC power (**Figure 105**), which was authenticated throughout the demonstration period.

The influent and effluent fluid flows were also monitored using GF Signet meters (**Figure 106**), which were piped to 1-inch male quick disconnect fittings at each end. Residual sludge in the wastewater blivet was not weighed.

Figure 105: DC Power Meter Setup

Figure 106: Water Flow Meter

4.8.2 Operational Script

The WWT-D2 operated continuously throughout the demonstration. There was adequate blackwater from the South Camp latrines, kitchen, and GWR-FORO to supply the system. Due to complications with survivability of the biomass, the operator did alter the flow on occasion in attempts to optimize the system performance.

4.9 WQM-PM Data Collection

Information in this section was submitted by the Technology Provider and edited for format.

The WQM-PM analyzed samples manually drawn from the WWT-D2 and the GWR-FORO system inlet and outlet hoses. The same sampling method was used for duplicate samples collected and analyzed by US Army Public Health Command (USAPHC) using the standard procedures for samples analyzed from CONUS and OCONUS Army installations and base camps. There were more WQM-PM samples than USAPHC samples due to laboratory schedules. WQM-PM operation was conducted by US Army civilians managing the contract that developed the prototypes.

4.10 T100 Data Collection

4.10.1 Hardware and Setup

Instrumentation of the T-100 for data collection included the following equipment (see Sensor Tracking Matrix lines 11-15).

EDVT Sensors:

- One Arlyn scale
- One 100-Amp Shark meter

NI Backbone: none

BCIL Sensors: none

Description:

This technology featured a 100-Amp load-following generator mounted on a trailer. The power generated by the T100 was monitored by a Shark meter that was mounted internal to the generator (**Figure 107** and **Figure 108**).

Figure 107: 100-Amp Shark Meter in T100

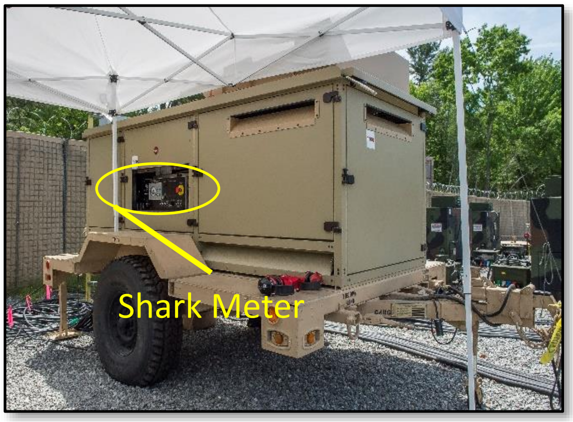


Figure 108: T100 with Shark Meter

Fuel usage was recorded by weighing a 55-gal drum from which the generator pulled fuel. The drum was placed on an Arlyn scale **(Figure 109)**. The scale had a digital readout and fuel consumption was recorded manually using the data collection app.

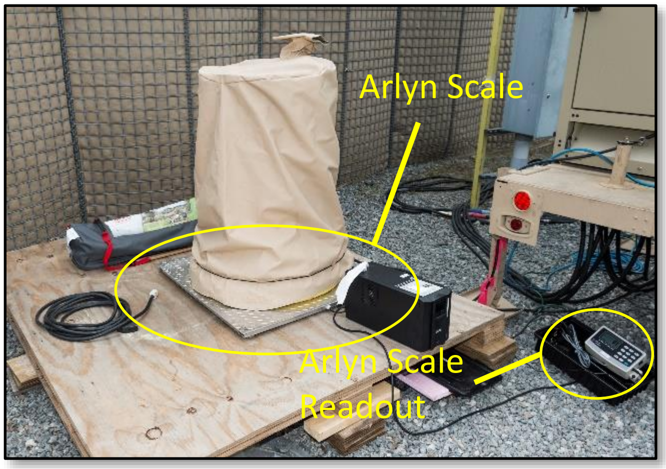


Figure 109: Arlyn Scale Setup for T100

4.10.2 Operational Script

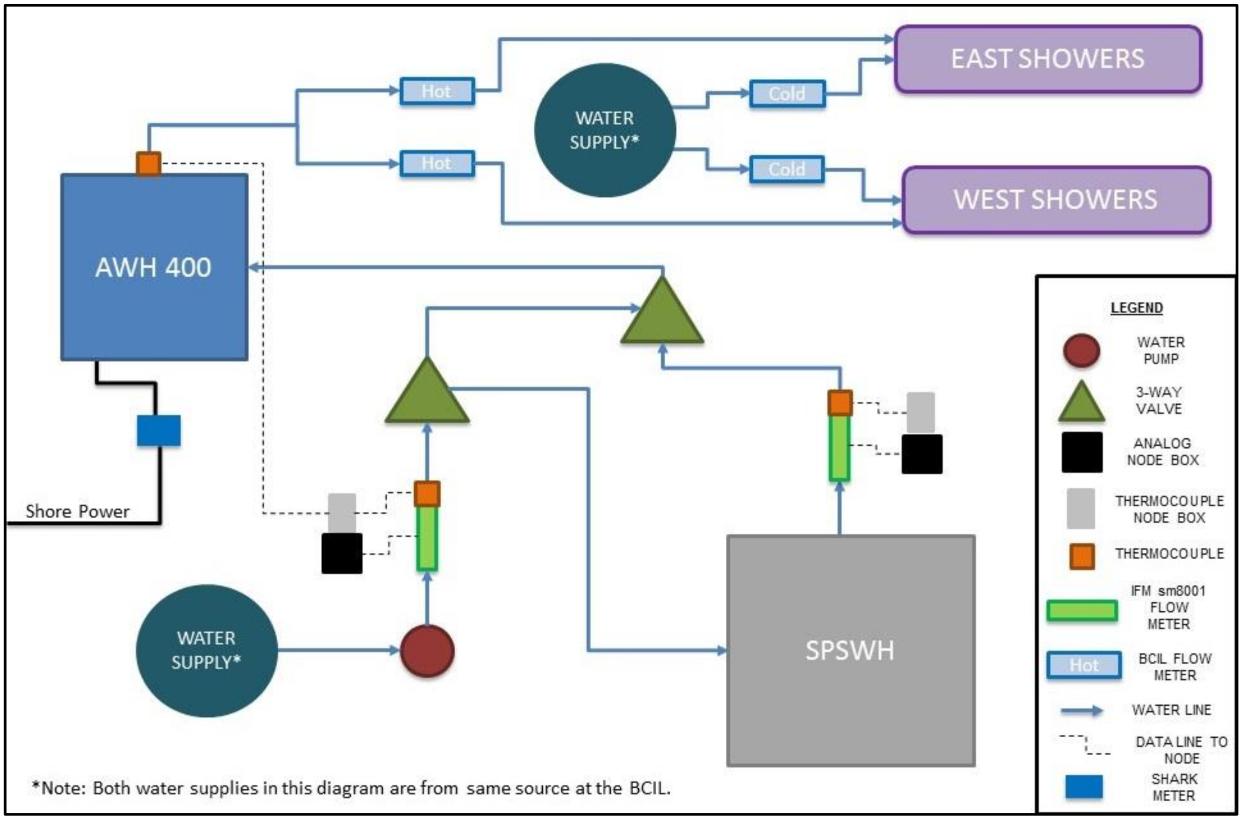
As is typical of the power generation systems, the independent variable is the load placed on the system. To examine this effect, the SEIT established three designs powering some part or whole of the E2RWS camp plus the STO-D display tent with F100 ECU. During the setup period, the T100 successfully executed the three designs. However, during the first day of record runs on 6 June, one of six inverters in the genset failed after just 83 min of operation. The genset was taken out of service and returned to the vendor’s shop for repair. The vendor successfully repaired the system and returned it to the BCIL 1 week later on 13 June.

The T100 successfully powered the E2RWS camp and display tent during record runs 14-17 June. Each day the system powered seven E2RWS billeting modules (ECU, lights, wall heaters), the kitchen (lights, ECU, little refrigerator), TRICOLD, the laundry facility (ECU and lights only, not the washers and dryers), and display tent (F100, lights) during normal BCIL duty hours. It is important to note that the loads were mostly single-phase loads. The only three-phase loads powered in the E2RWS camp were the ECUs and wall heaters.

To make up for lost data collection opportunities, a quick-scan test was devised and executed on 20-21 June. For this demonstration another independent variable was introduced – generator speed. The quick-scan was designed to assess fuel consumption at fixed speed vs. variable speed. During data collection the load was provided by the three-phase version of the Avtron Model LPH load bank. The T100 was warmed up and then a resistive load was applied in 5 kW increments for 10 min at each power setting. Fuel drum weight was recorded at each interval. The engine speed was read visually on the 3-in-diameter tachometer to the nearest 25-RPM increment. The variable speed quick-scan was executed on the morning of 20 June. Following that run, the system powered the camp in the afternoon. The fixed speed scan was executed on the morning of 21 June. This completed the T100 data collection.

4.11 SPSWH Data Collection

Figure 110 shows the instrumentation schematic for the SPSWH.



*Note: Both water supplies in this diagram are from same source at the BCIL.

Figure 110: SPSWH Instrumentation Schematic

4.11.1 Hardware and Setup

Instrumentation of the SPSWH for data collection entailed the following equipment (see Sensor Tracking Matrix lines 62-73).

EDVT Sensors:

- One 60-Amp Shark Meter/Dent Meter
- Two water flow sensors
- Three thermocouples (J-Type, probe thermocouples)

NI Backbone:

- One 3202 node
- One 3212 node

BCIL Sensors:

- Four Omega water flow sensors (sets of two; one hot, one cold)

Description:

The SPSWH used a parabolic dish to concentrate solar energy to heat water. It automatically tracked the sun on a rail system. The system was plumbed to an AWH-400 to provide hot water to the South Camp shower system.

Water flow into and out of the SPSWH system was measured using sensor setups as seen in **Figure 111**. Water temperature was also monitored with a thermocouple in the U-tube setup. The temperature probes were placed into PVC pipes that were connected to the system external to the flow meters. The water connection into and out of the SPSWH was a ¾-in GHT.

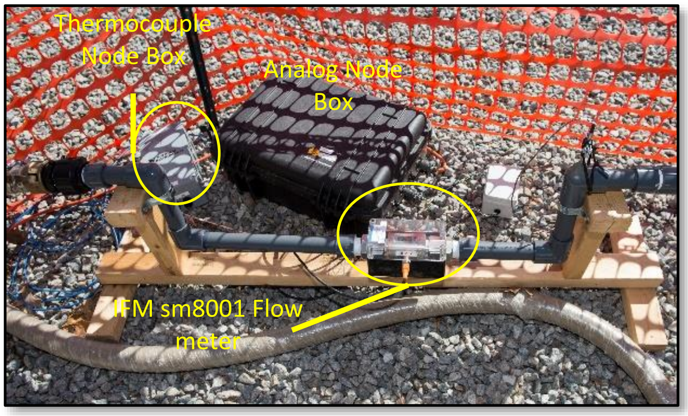


Figure 111: Water Flow Sensor and TC for SPSWH

The water connection coming out of the AWH-400 was a 1-in pipe. Water temperature out of the AWH-400 was also recorded with a thermocouple (**Figure 112**). Total water volume coming into the shower system was monitored by the BCIL water flow sensors (**Figure 113**) on both the front (east) shower container and the rear (west) shower container.

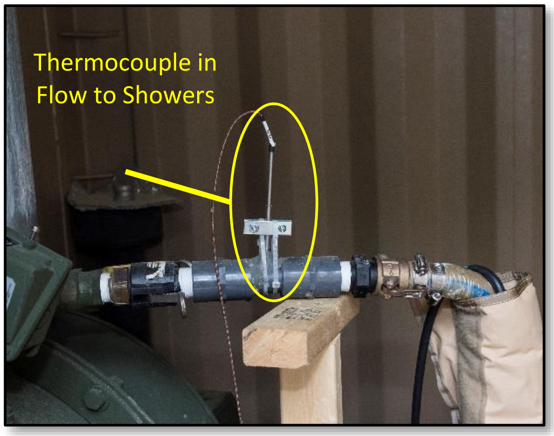


Figure 112: Thermocouple for AWH-400

Figure 113: BCIL Water Flow Sensors for Shower System

The power to the AWH-400 was measured through a 60-Amp connector to a breaker box that fed a 20-Amp twist lock connector. The power was metered by a Shark meter that was installed between the Lex box and the breaker box.

The fuel going into the barrels that held the fuel for the AWH-400 was measured by weighing small cans of fuel (**Figure 114**) before and after the refill (**Figure 115**). The barrels were filled to a specific height using the fill height estimation device shown in **Figure 116** and **Figure 117**.

Figure 114: Fuel Refill Container

Figure 115: Manual Data Collection for Fuel Refill of AWH-400

Figure 116: Fuel Measuring Device

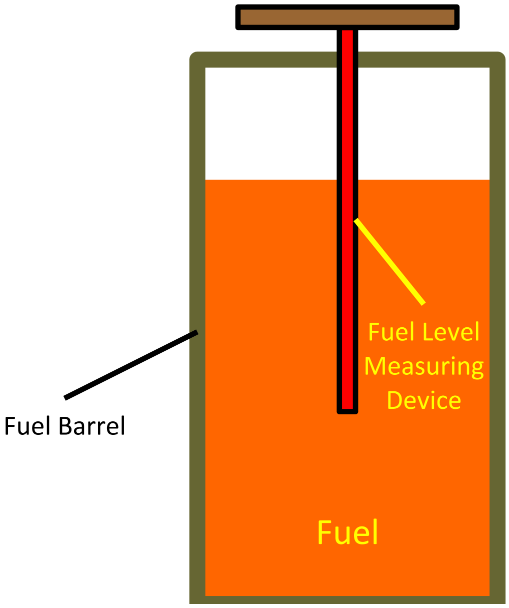


Figure 117: Measuring Fuel

4.11.2 Operational Script

The basic hypothesis of the SPSWH demonstration was “*IF* the SPSWH provides preheated water to the AWH-400 *THEN* the AWH-400 will use less fuel and power to heat water”. To examine this hypothesis the SEIT designed three demonstrations: (a) AWH-400 only with controlled operation, (b) SPSWH inline with controlled operation, and (c) the AWH-400 only under operational conditions with Soldier use. Procedures used for the controlled operations follow.

Design #1 – AWH only

1. 0730 h – Set the output temperature of the AWH-400 at 130 °F.
2. Bypassed the SPSWH using three-way valves.
3. 1200 h – Script start.
4. Placed signs on shower doors to limit use.
5. Diverted graywater to sewer (alternative: generate mock graywater per FORO script).
6. Turned on one showerhead, with the shower at approximately 105 °F.
7. Left showers running for six consecutive showers of 10 min each.
8. Shut off all showers.
9. Returned graywater diversion to original setting.
10. Removed signs from shower doors.
11. Script end time approximately 1330 h.
12. Recorded fuel usage at fuel refill.

Design #2 – SPSWH inline

1. 0730 h – Powered on SPSWH.
2. Set the output temperature of the SPSWH at 130 °F.
3. Set the output temperature of the AWH-400 at 130 °F.
4. 1200 h – Script start.

Note: SPSWH takes several hours of sunlight to heat water. All scripts were scheduled to start at the same time each day, but start times were adjusted based on SPSWH performance.

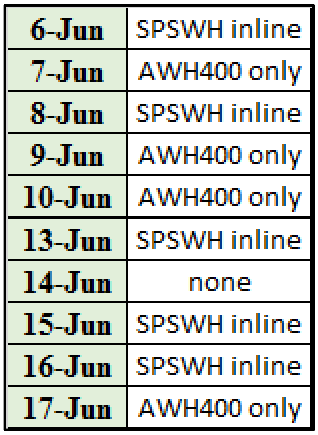
5. Placed signs on shower doors to limit use.
6. Diverted graywater to sewer (alternative: generate mock graywater per FORO script).
7. Set the SPSWH inline using three-way valves.

Note: Waited until script run time to avoid accidentally using the SPSWH's hot water.

8. Turned on one showerhead, with the shower at approximately 105 °F.
9. Left showers running for six consecutive showers of 10 min each.
10. Shut off all showers.
11. Flushed system with potable water (minimum 50 gal of hot water use).
12. Returned graywater diversion to original setting.
13. Removed signs from shower doors.
14. Script end time approximately 1330 h.
15. Recorded fuel usage at fuel refill.

Table 3 shows the daily schedule of record runs for the SPSWH demonstration. There were no record runs on 14 June due to camp-wide water shortage. Each record run lasted 90 min.

Table 3: SPSWH and AWH-400 Record Runs



6-Jun	SPSWH inline
7-Jun	AWH400 only
8-Jun	SPSWH inline
9-Jun	AWH400 only
10-Jun	AWH400 only
13-Jun	SPSWH inline
14-Jun	none
15-Jun	SPSWH inline
16-Jun	SPSWH inline
17-Jun	AWH400 only

4.12 EIO-C Data Collection

4.12.1 Hardware and Setup

Instrumentation of the EIO-C for data collection included the following equipment (see Sensor Tracking Matrix lines 16-20).

EDVT Sensors:

- Four humidity sensors

NI Backbone:

- Two 3202 nodes

BCIL Sensors: see **Table 4**

Description:

The EIO-C system was comprised of a set of generators that powered the South Camp. The power and energy usage was monitored for all of the loads using the BCIL meters and sensors as listed in **Table 4**.

Table 4: BCIL Meters and Sensors for EIO-C

BCIL-BLDG1-3PhEnergy	PM92
BCIL-BLDG2-3PhEnergy	PM55
BCIL-BLDG3-3PhEnergy	PM63
BCIL-BLDG4-3PhEnergy	PM62
BCIL-BLDG5-3PhEnergy	PM64
BCIL-BLDG6-3PhEnergy	PM54
BCIL-BLDG7-3PhEnergy	PM75
BCIL-BLDG8-3PhEnergy	PM74
BCIL-BLDG17-3PhEnergy	PM66
BCIL-BLDG18-3PhEnergy	PM65
BCIL-BLDG19-3PhEnergy	PM29
BCIL-BLDG20-3PhEnergy	PM30
BCIL-BLDG24Dryer-3PhEnergy	PM34
BCIL-BLDG24Washer-3PhEnergy	PM31
BCIL-BLDG22-3PhEnergy	PM51
BCIL-BLDG1-Return_Duct_Temperature	TC-509
BCIL-BLDG2-Return_Duct_Temperature	TC-329
BCIL-BLDG3-Return_Duct_Temperature	TC-345
BCIL-BLDG4-Return_Duct_Temperature	TC-349

In addition to the thermocouples in each billeting shelter, EDVT installed a humidity sensor (**Figure 118**) in the return duct of each of the BCIL tents #1-4. The thermocouple and the humidity sensor measurements provided information to determine how much power the loads were drawing and what modes the ECUs were in at any given time.

Figure 118: Humidity Sensor

Figure 119 shows the instrumentation schematic for the billeting shelters.

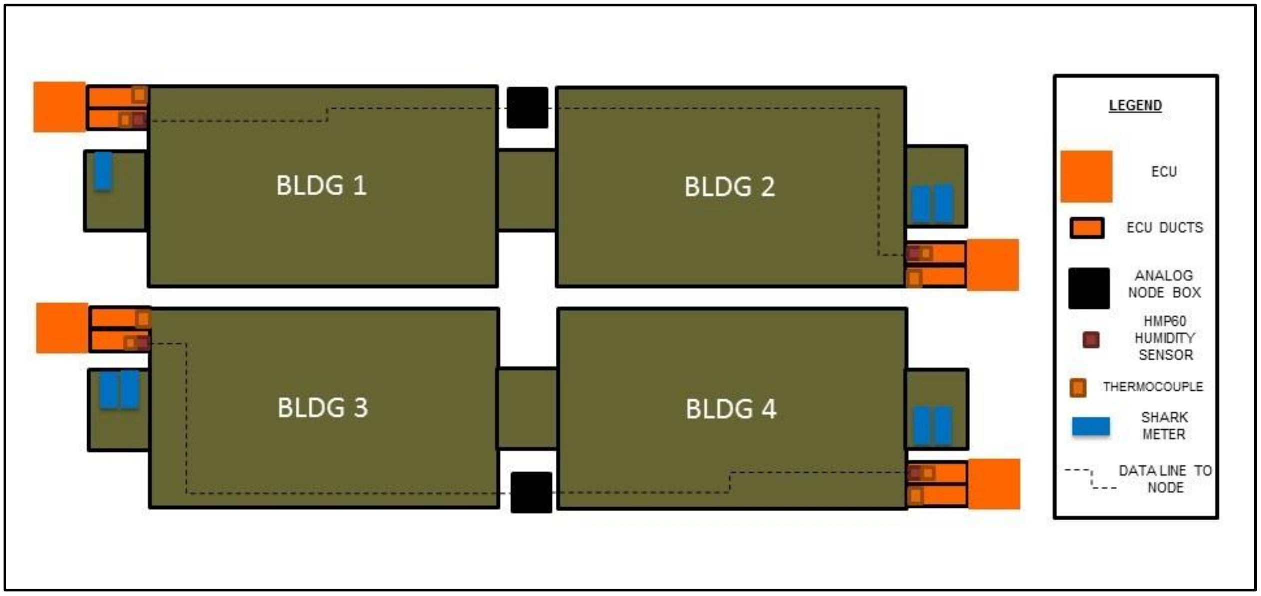


Figure 119: EIO-C Instrumentation Schematic for Billeting Shelters

The EIO-C Technology Provider collected additional data independently through the EIO-C computer application.

4.12.2 Operational Script

The EIO-C demonstration involved two independent variables – the quantity of the load on the microgrid and the composition of the microgrid. Since the South Camp was occupied by Soldiers of the 542d Quartermaster Company during this demonstration, the ability for the EIO-C to vary the load was limited. The only variations came from operational use of the ECUs and the occasional use of the laundry facility. A new feature of the microgrid for this demonstration was the addition of the battery and inverter. Some record runs included the battery and inverter. **Table 5** shows the daily operation of the EIO-C during record runs.

Table 5: EIO-C Operations

Date	Start Time	Stop Time	Load	Grid
6-Jun	9:40	14:20	South Camp (per SV-2)	
7-Jun	8:45	14:00	South Camp less the shower systems	
8-Jun	8:30	14:15	South Camp	with inverter
9-Jun	12:45	14:30	South Camp	
10-Jun	10:00	14:45	South Camp	
13-Jun	10:00	14:40	South Camp	
14-Jun	9:45	14:45	South Camp	inverter only initially, then brought up generators
15-Jun	8:00	15:00	South Camp	inverter only initially, then brought up generators
16-Jun	8:45	14:45	South Camp, plus washer and dryer	
17-Jun	8:00	12:45	South Camp	

4.13 Soldier Training and Feedback

A key feature of this demonstration was the opportunity to work with Soldiers and gather their feedback on technologies being demonstrated. Soldiers participating in the demonstration were assigned to two different commands – U.S. Army Reserve and U.S. Army Forces Command.

The STO-D has a historical relationship with the 542d Quartermaster Company (Force Provider) from the U.S. Army Reserve. During early planning for this demonstration, the STO-D coordinated with the unit to determine the timing of their summer Annual Training event typically conducted at Fort Devens, and more specifically the BCIL. At that time the unit and STO-D agreed to collaborate during the demonstration and initiated joint planning. The 542d agreed to employ base camp technologies as required to support STO-D data collection and assigned Soldiers to be trained and assist with operation and maintenance of select candidate technologies. STO-D requested that Soldiers with certain MOSs be offered this opportunity. There were 11 Soldiers assigned to support the STO-D.

Nine Soldiers were requested by NSRDEC through U.S. Army Forces Command to travel to Fort Devens to participate in the demonstration. The tasking document requested Soldiers that had previous experience living and operating overseas in a contingency base camp. A squad of eight Soldiers from the 82d Airborne Division were tasked to support the request, and of these, two Soldiers had experience living in base camps.

The methods for Soldier participation in this demonstration can be classified into two areas – Familiarization Training and Systems Operation/Maintenance.

4.13.1 Familiarization Training

Soldiers from both the 82d and the 542d participated in round robin familiarization training of the various demonstration technologies during the period 6-9 June. Each Technology Provider briefed their system to the Soldiers (**Figure 120**). The Soldiers observed operation and had the opportunity to ask questions. Following the training the NSRDEC Consumer Research Team conducted focus group sessions with the Soldiers to capture their feedback (**Figure 121**).

Figure 120: Soldiers Receive System Brief

Figure 121: Soldiers in Focus Group

4.13.2 Systems Operation and Maintenance

In addition to familiarization training, the Soldiers from the 542d Quartermaster Company (Force Provider) worked with the Technology Providers during the week of 13-17 June. This training was focused on the water treatment technologies – GWR-FORO, WWT-D2 (**Figure 122**), WQM-PM – and the power generation technologies – EIO-C (**Figure 123**), V2G/V2V, T100. Within the limits of the respective Safety Release, the Soldiers had the opportunity to operate some systems and participate in routine maintenance tasks.

The USAPHC participated in this demonstration by taking samples for water quality analysis related to the water treatment technologies. Their team included the Non-Commissioned Officer-in-Charge (NCOIC) of Drinking Water and Sanitation Program. In **Figure 124** the NCOIC is taking water samples at the GWR-FORO system.

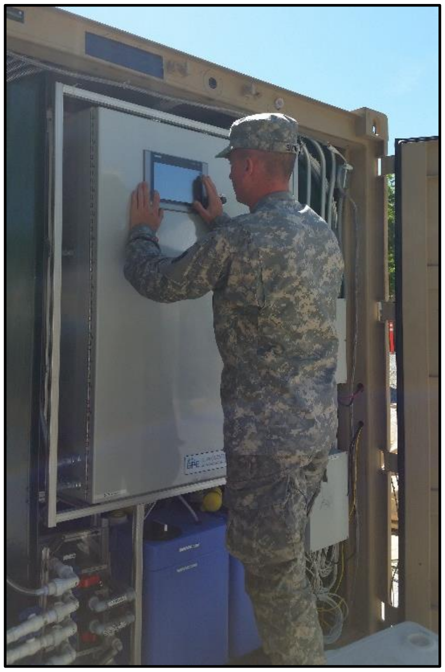


Figure 122: Soldier Operating the WWT-D2

Figure 123: Soldiers Working with EIO-C

Figure 124: Soldier Performing Water Analysis Tasks

4.14 Data Management Processes

As documented in the DAMP, the SLB-STO-D follows a seven-step process to manage demonstration data. These steps are:

Step 1 – Identify Data Needs
Step 2 – Identify and Procure Instrumentation
Step 3 – Execute Data Collection
Step 4 – Harvest Data
Step 5 – Reduce and Process Data
Step 6 – Conduct Data Authentication
Step 7 – Deliver Data

The methods employed for Steps 1, 2, and most of 3 have been described earlier in this section. The remainder of this section will expand on Step 3 and describe methods used for Steps 4-7.

4.14.1 Manual Data Collection

All manual data collections were performed using the Manual Data Collection Application (MDCA). The MDCA is an Android-based mobile application designed to run on Android tablets and smart phones. Similar to the previously used paper forms the MDCA was developed based on data identified in the DSM for each of the technologies.

The MDCA provided data collectors the ability to enter manual data for all technologies within a single application. The use of a digital MDCA reduced the chances of transcription errors during data collection. With the previous paper forms there were multiple locations in the end-to-end process where humans were in the loop, including the filling out of the form and the transcription of the data into the technology's DDS workbook. The MDCA allowed for single or multiple input data readings. When multiple readings were required, the MDCA would handle calculation of the data. The application was designed to handle the standard arithmetic operators: addition (+), subtraction (-), multiplication (*), and division (/).

Members of the SEIT, the EDVT, and the Technology Providers manually collected data and entered values in the MDCA daily for each of the technologies. The MDCA saved all of the manually collected data in a comma-separated-value file that was easily included in the technology's DDS workbook.

Figure 125 is a screenshot of the MDCA graphic user interface.

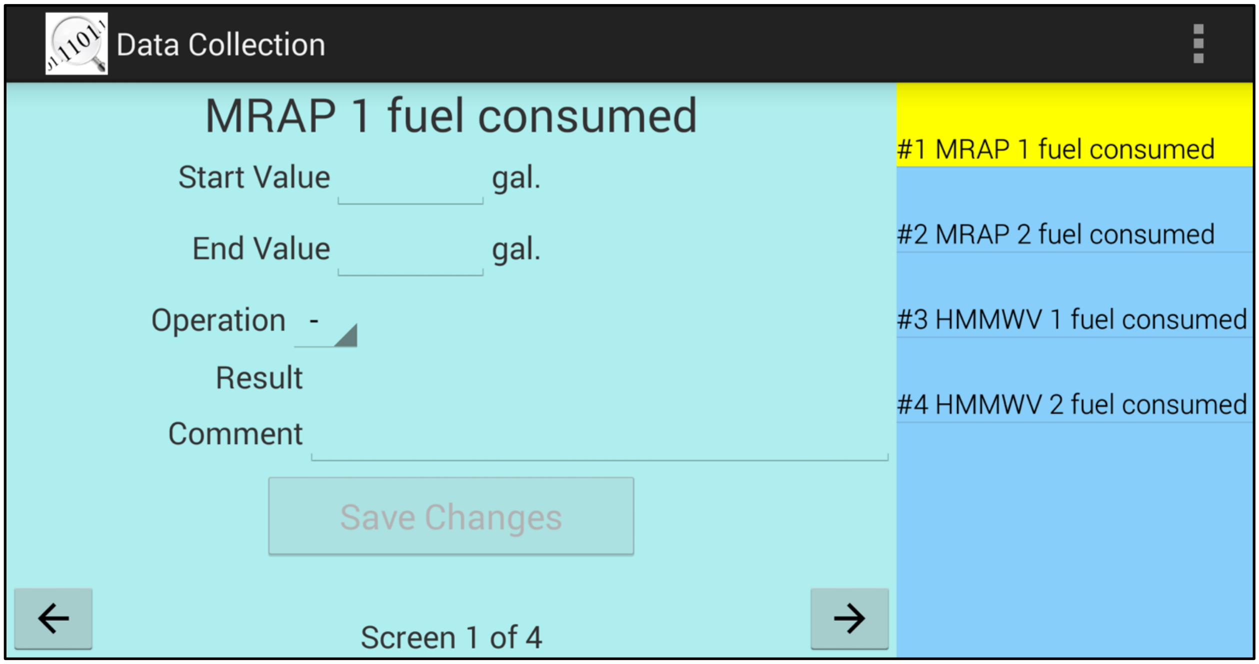
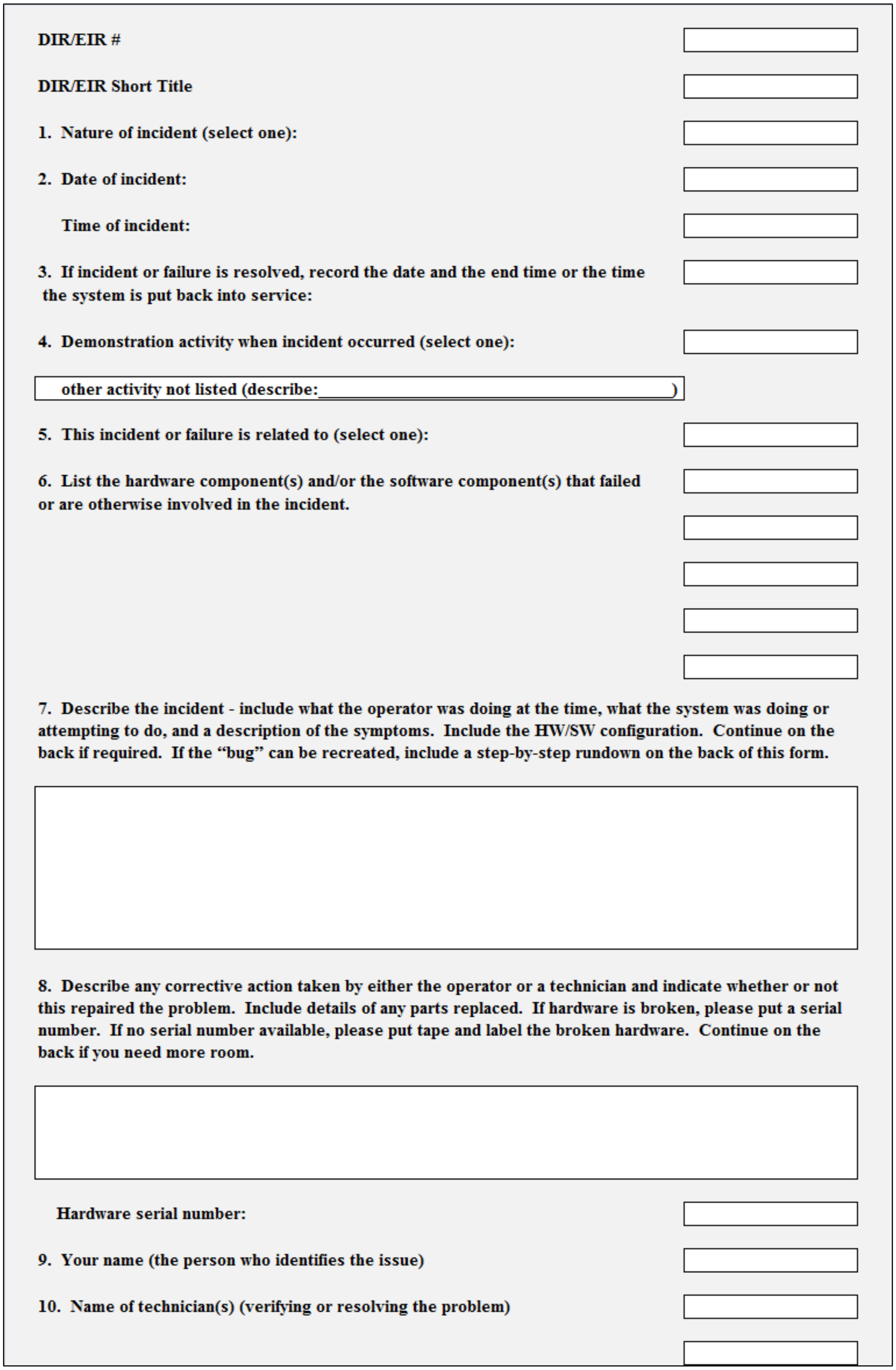


Figure 125: MDCA

4.14.2 Demonstration Incident Reports

The Demonstration Incident Report (DIR) was used to collect data on system and component failures, anomalies, repairs, and performance data not included in the MDCA, etc. The DIR was also used to document administrative data, such as start times of record runs, site meetings, key stakeholder visits, etc. For this demonstration paper copies of the DIR data collection form were completed by all demonstration personnel as events warranted. Paper copies were submitted to the Demonstration Director daily, edited, transcribed into Excel files, and then packaged with the DDS. The DIRs were presented to the DAG for authentication. The DIR template is shown in **Figure 126** and **Figure 127**.



DIR/EIR #

DIR/EIR Short Title

1. Nature of incident (select one):

2. Date of incident:

Time of incident:

3. If incident or failure is resolved, record the date and the end time or the time the system is put back into service:

4. Demonstration activity when incident occurred (select one):

other activity not listed (describe:_______________________________________)

5. This incident or failure is related to (select one):

6. List the hardware component(s) and/or the software component(s) that failed or are otherwise involved in the incident.

7. Describe the incident - include what the operator was doing at the time, what the system was doing or attempting to do, and a description of the symptoms. Include the HW/SW configuration. Continue on the back if required. If the "bug" can be recreated, include a step-by-step rundown on the back of this form.

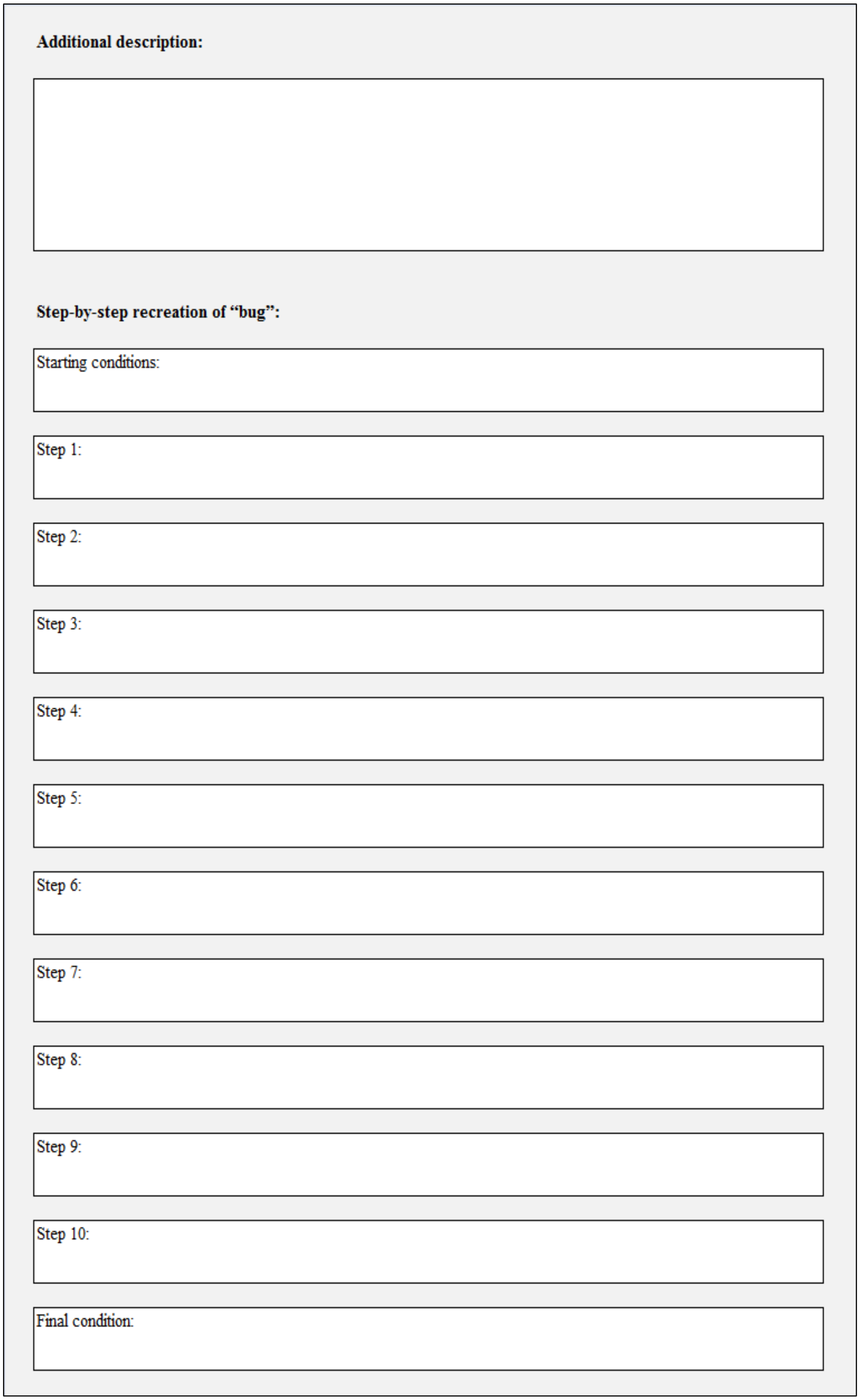
8. Describe any corrective action taken by either the operator or a technician and indicate whether or not this repaired the problem. Include details of any parts replaced. If hardware is broken, please put a serial number. If no serial number available, please put tape and label the broken hardware. Continue on the back if you need more room.

Hardware serial number:

9. Your name (the person who identifies the issue)

10. Name of technician(s) (verifying or resolving the problem)

Figure 126: DIR Front Page



Additional description:

Step-by-step recreation of “bug”:

Starting conditions:

Step 1:

Step 2:

Step 3:

Step 4:

Step 5:

Step 6:

Step 7:

Step 8:

Step 9:

Step 10:

Final condition:

Figure 127: DIR Back Page

4.14.3 Data Harvest

The EDVT, in general, worked with two types of data: (a) data electronically collected by sensors/instrumentation (described in Section 3.3), and (b) data collected manually by staff at the event (described in Section 4.14.1). Manually-collected data was harvested daily by members of the EDVT. At the end of each collection day, Manual Data Collection devices were collected and connected to the Data Management Center's primary server where data was uploaded and archived.

Electronically-collected data was harvested EDVT instrumentation data being stored directly in the New Core Database (NCD). Data from other instrumentation systems like the BCIL's organic instrumentation was imported into the NCD by querying the BCIL's database and writing the results into the NCD.

For the few systems like the WWT-D2 and GWR-FORO that were found to have poor connectivity over the data collection network, their data were harvested by collecting exported data files from the instrumentation. This data was harvested daily on the day following the collection of the data. Once harvested, the data was integrated into the NCD where it joined the EDVT's LabView-collected data and the BCIL's organic sensor data.

Throughout the harvesting and reduction process, backups of the demonstration data were stored on a network attached storage (NAS) device. This NAS provided the members of the EDVT with easily accessible secure storage for working on data during the onsite period of the demonstration.

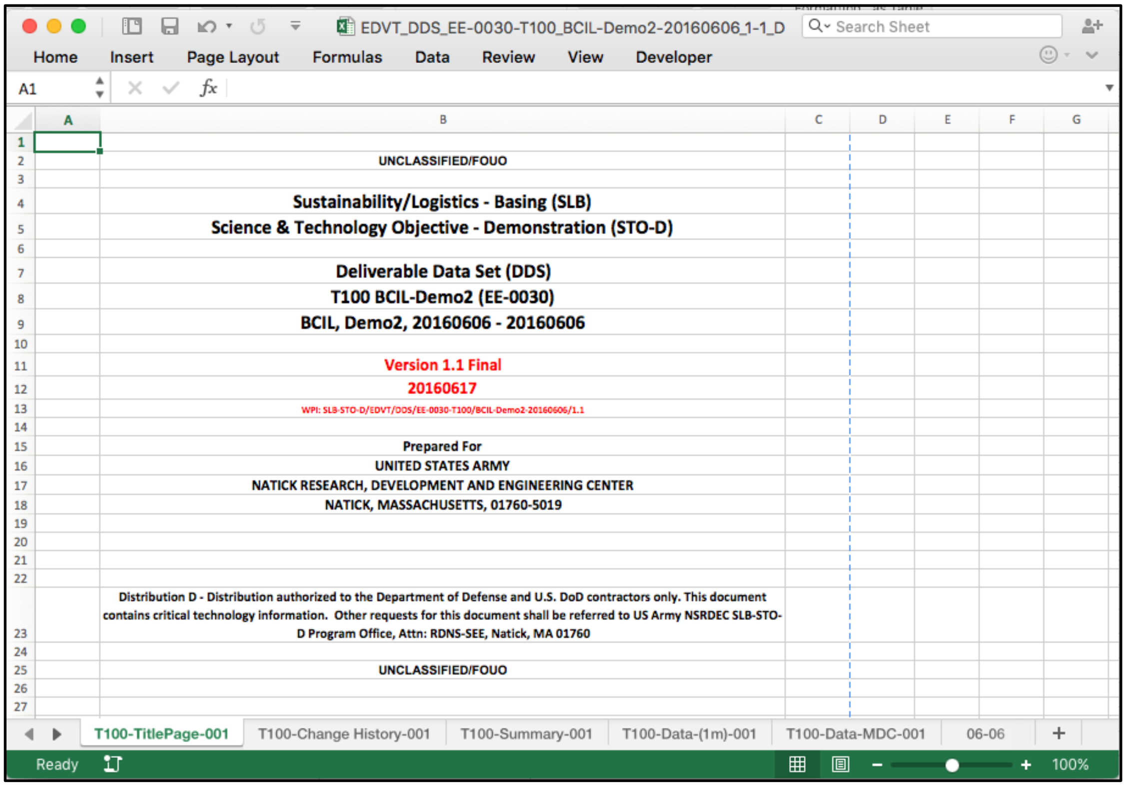
4.14.4 Data Reduction and Processing

While the DRD and the raw time series data provide the perfect review mechanism, deliverable data has additional requirements to make it useful to analysts who may not see the data for months or years after the event. To satisfy those requirements, the EDVT worked with the project configuration management (CM) coordinator to understand and meet the project's CM requirements. A deliverable data workbook format was conceived and software was written to help package the raw, time-series, demonstration data in the deliverable format. The workbooks also package summary data, any manual data that is collected, and provide a place to record comments about the data during proceedings of the DAG. The DAG is discussed in greater detail in Section 4.14.5.

The workbooks have a very proscribed and predictable format. The EDVT used Microsoft Excel to house the data and used multiple 'sheets' (where each sheet is represented by a tab) to organize the data.

The initial tab is the Title Page. **Figure 128** below shows the title page from the T100 technology on 6 June, the first day of record runs.

In the tabs at the bottom of the figure can be seen the Title Page highlighted in green, and also the tabs for the Change History sheet, the Summary data sheet, the actual collected time series data sheet, a manual data collection sheet, and one of the two DIRs that were logged for this technology on this day. Each is explained in detail below.



UNCLASSIFIED/FOUO

Sustainability/Logistics - Basing (SLB)
Science & Technology Objective - Demonstration (STO-D)

Deliverable Data Set (DDS)
T100 BCIL-Demo2 (EE-0030)
BCIL, Demo2, 20160606 - 20160606

Version 1.1 Final
20160617
WPI: SLB-STO-D/EDVT/DDS/EE-0030-T100/BCIL-Demo2-20160606/1.1

Prepared For
UNITED STATES ARMY
NATICK RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
NATICK, MASSACHUSETTS, 01760-5019

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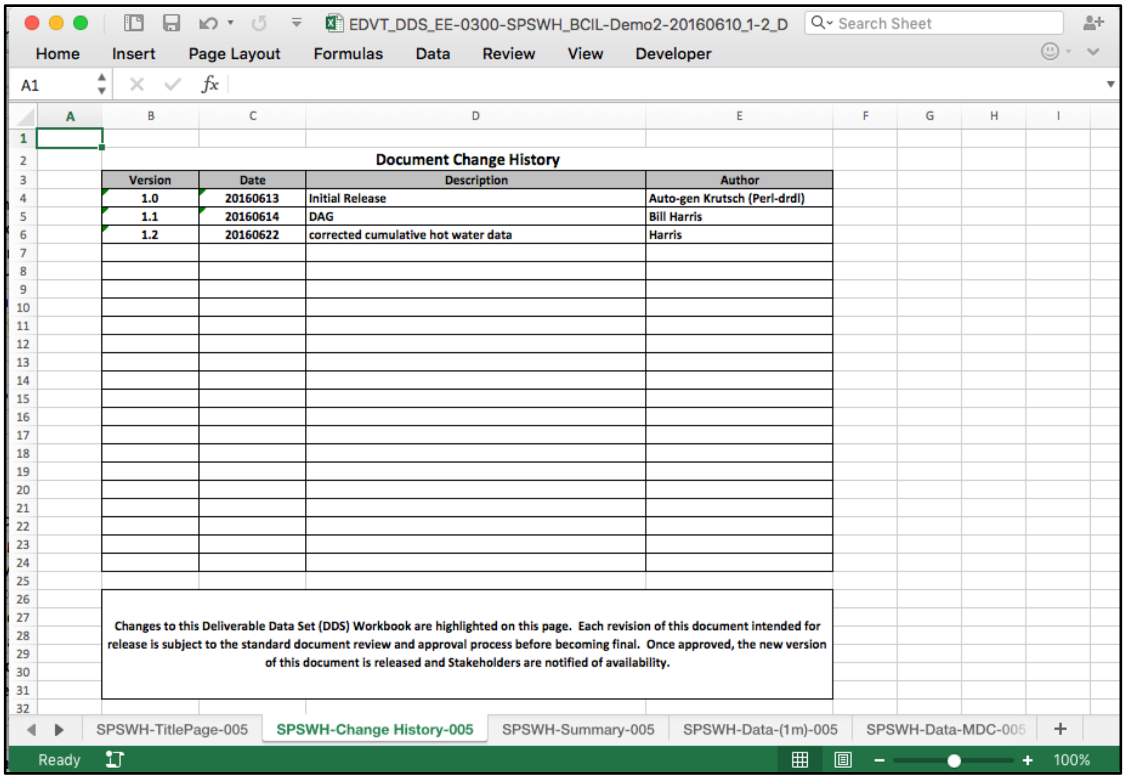
Figure 128: T100 Workbook Title Page

Figure 129 shows the change page from the SPSWH technology for 10 June. This page shows the date the document was generated (20160613), the date the data was reviewed by the DAG (20160614), and a subsequent change (20160622). The additional change was made to the workbook correcting an error that was discovered during the final review process. Any changes made to the workbook were documented here, providing the analysts and future users with a full disclosure on the treatment of the data.



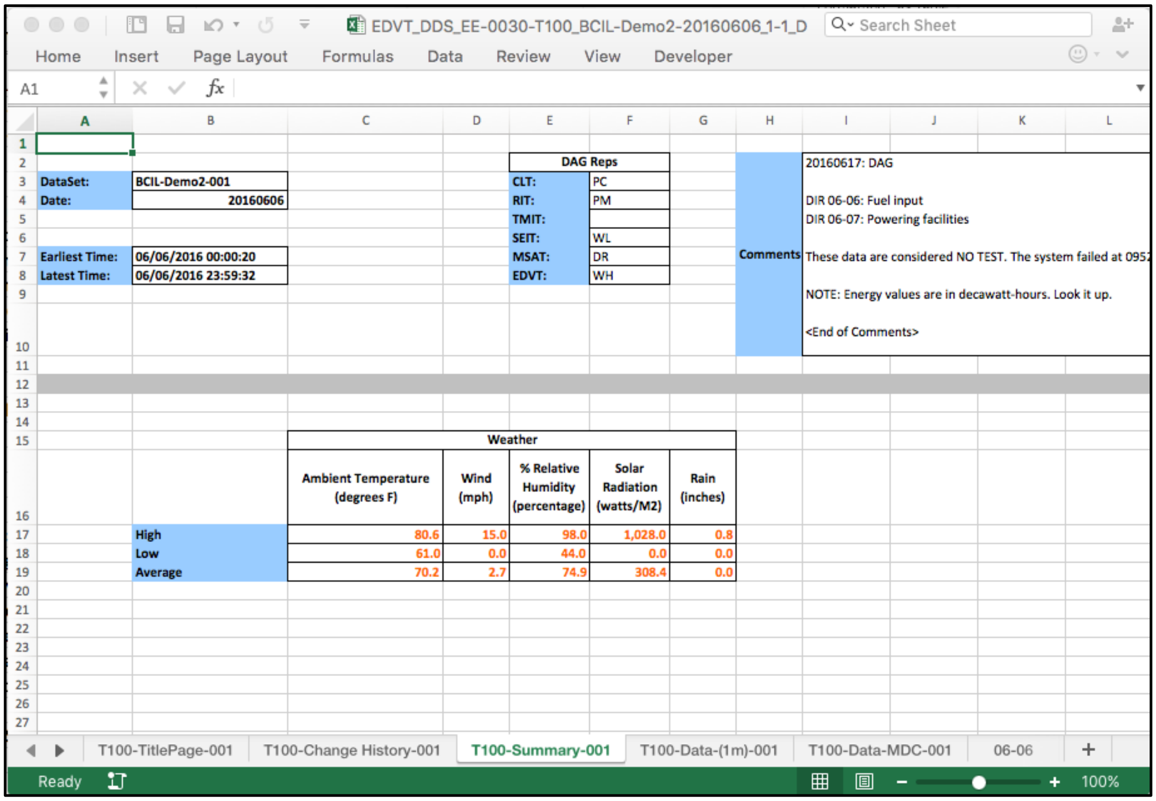
Document Change History

Version	Date	Description	Author
1.0	20160613	Initial Release	Auto-gen Krutsch (Perl-drdl)
1.1	20160614	DAG	Bill Harris
1.2	20160622	corrected cumulative hot water data	Harris

Changes to this Deliverable Data Set (DDS) Workbook are highlighted on this page. Each revision of this document intended for release is subject to the standard document review and approval process before becoming final. Once approved, the new version of this document is released and Stakeholders are notified of availability.

Figure 129: SPSWH Change History Sheet

The summary sheet follows the change history sheet. This sheet provides summary weather data, summary technology data, and the comments captured during the DAG meeting. This sheet also documents the initials of the voting DAG members. **Figure 130** shows that the DAG recommended that this data should be considered ‘NO TEST’ because of an equipment failure. There were also two DIRs written for this technology and they are listed here. Any special notes, like the note about data scaling in the figure, are also listed here.



DataSet: BCIL-Demo2-001
Date: 20160606

Earliest Time: 06/06/2016 00:00:20
Latest Time: 06/06/2016 23:59:32

DAG Reps	
CLT:	PC
RIT:	PM
TMIT:	
SEIT:	WL
MSAT:	DR
EDVT:	WH

Comments

20160617: DAG

DIR 06-06: Fuel input
DIR 06-07: Powering facilities

These data are considered NO TEST. The system failed at 095

NOTE: Energy values are in decawatt-hours. Look it up.

<End of Comments>

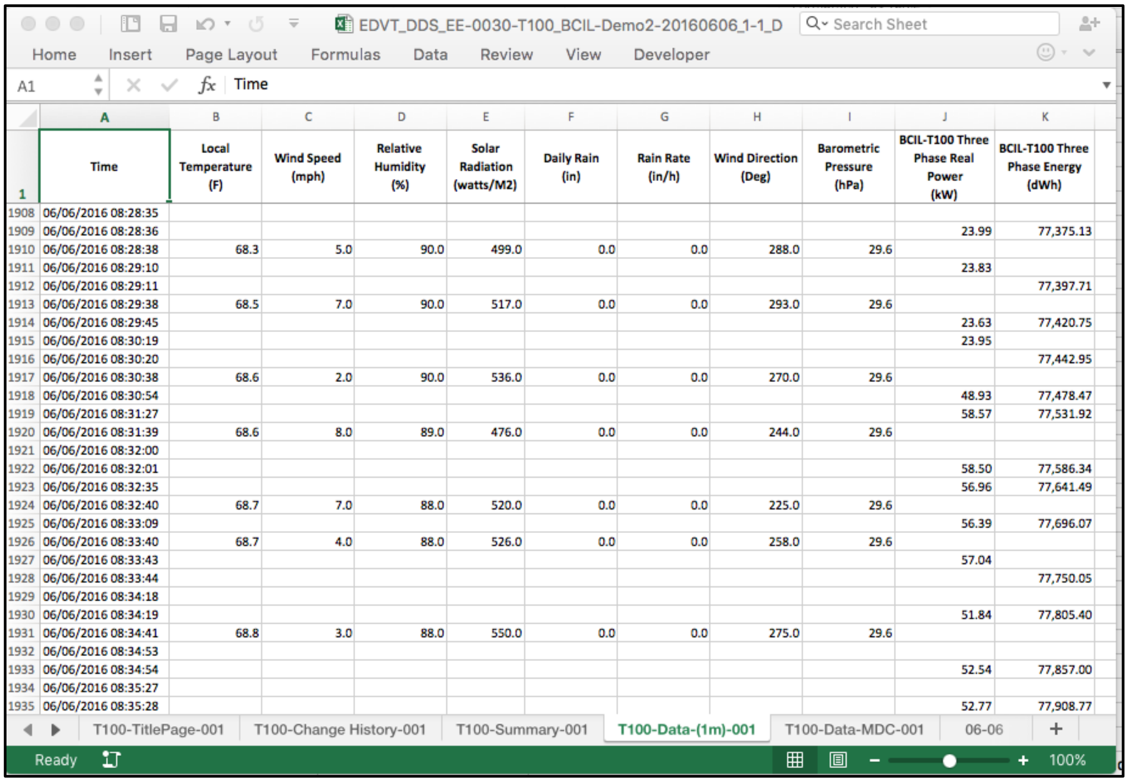
	Weather				
	Ambient Temperature (degrees F)	Wind (mph)	% Relative Humidity (percentage)	Solar Radiation (watts/M2)	Rain (inches)
High	80.6	15.0	98.0	1,028.0	0.8
Low	61.0	0.0	44.0	0.0	0.0
Average	70.2	2.7	74.9	308.4	0.0

Figure 130: T100 Summary Sheet

The fourth sheet contains the raw time series data collected by the EDVT's array of sensors. The data columns map back to the DSM developed earlier in the year for this demonstration and the rows contain samples collected during the time slice. **Figure 131** below shows roughly 7 min of data from 08:28:35 AM to 08:35:28 AM.

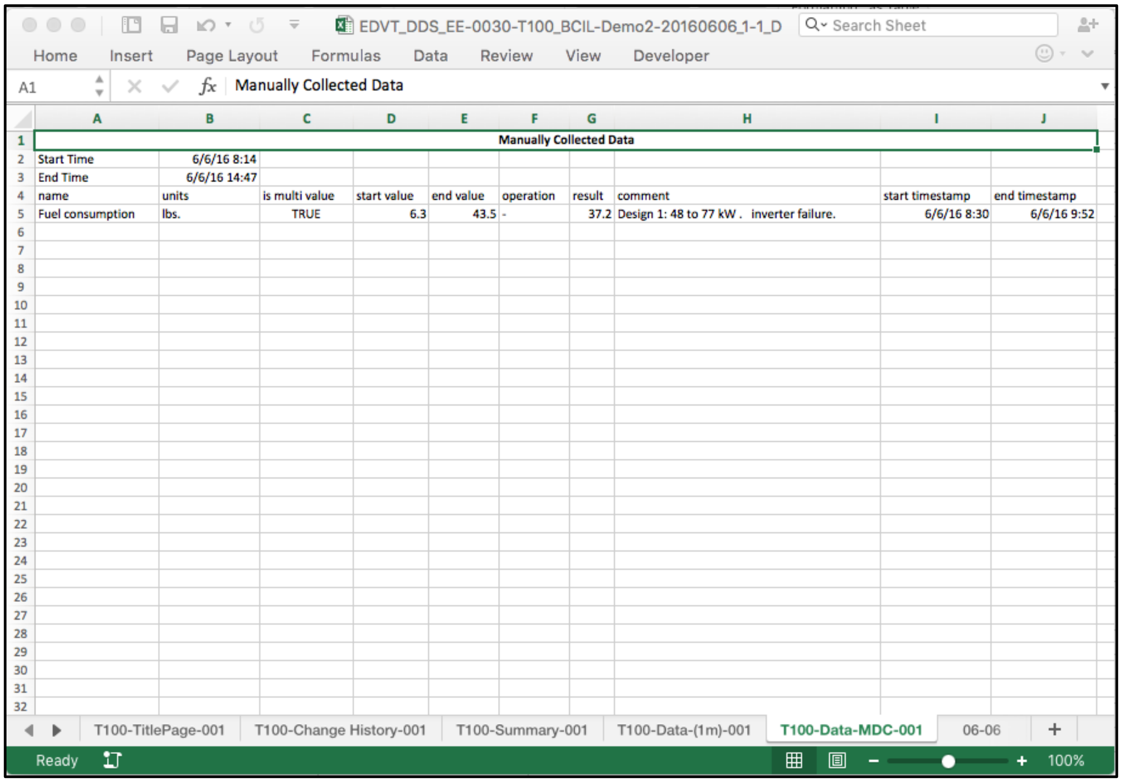
Some technologies, e.g., the T100, have data such as fuel measures that must be collected and recorded manually. In the case where there is manual data collection, that sheet will follow the time series data sheet. The sheet shown in **Figure 132** below shows that the T100 was fueled on this day (20160606) and that it took 37.2 gal of fuel.

If there is an incident that occurs with this technology, either intentional like refueling, or unintentional like a failure, that incident is recorded on a DIR. The DIRs were written, transcribed, and included in these workbooks to provide better context and pedigree to the data. **Figure 133** below shows a portion of DIR 06-07 written because the T100 experienced an unexpected failure in one of its inverters.



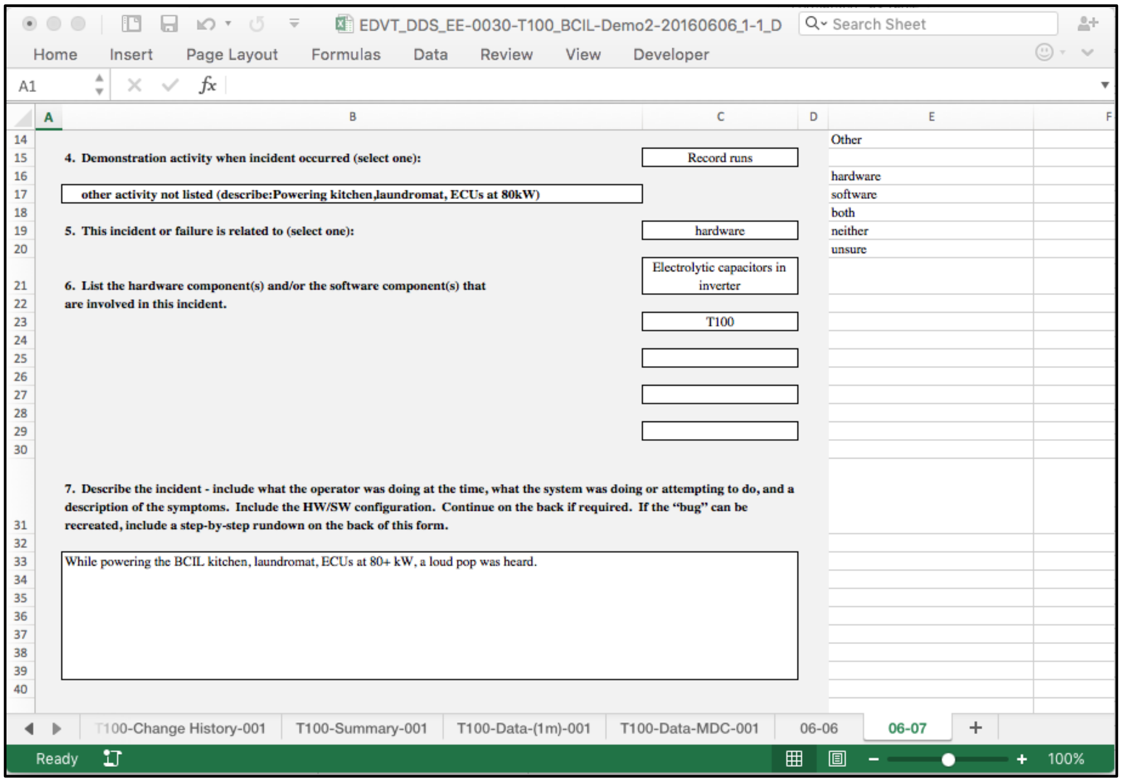
	A	B	C	D	E	F	G	H	I	J	K
1	Time	Local Temperature (F)	Wind Speed (mph)	Relative Humidity (%)	Solar Radiation (watts/M2)	Daily Rain (in)	Rain Rate (in/h)	Wind Direction (Deg)	Barometric Pressure (hPa)	BCIL-T100 Three Phase Real Power (kW)	BCIL-T100 Three Phase Energy (dWh)
1908	06/06/2016 08:28:35										
1909	06/06/2016 08:28:36									23.99	77,375.13
1910	06/06/2016 08:28:38	68.3	5.0	90.0	499.0	0.0	0.0	288.0	29.6		
1911	06/06/2016 08:29:10									23.83	
1912	06/06/2016 08:29:11										77,397.71
1913	06/06/2016 08:29:38	68.5	7.0	90.0	517.0	0.0	0.0	293.0	29.6		
1914	06/06/2016 08:29:45									23.63	77,420.75
1915	06/06/2016 08:30:19									23.95	
1916	06/06/2016 08:30:20										77,442.95
1917	06/06/2016 08:30:38	68.6	2.0	90.0	536.0	0.0	0.0	270.0	29.6		
1918	06/06/2016 08:30:54									48.93	77,478.47
1919	06/06/2016 08:31:27									58.57	77,531.92
1920	06/06/2016 08:31:39	68.6	8.0	89.0	476.0	0.0	0.0	244.0	29.6		
1921	06/06/2016 08:32:00										
1922	06/06/2016 08:32:01									58.50	77,586.34
1923	06/06/2016 08:32:35									56.96	77,641.49
1924	06/06/2016 08:32:40	68.7	7.0	88.0	520.0	0.0	0.0	225.0	29.6		
1925	06/06/2016 08:33:09									56.39	77,696.07
1926	06/06/2016 08:33:40	68.7	4.0	88.0	526.0	0.0	0.0	258.0	29.6		
1927	06/06/2016 08:33:43									57.04	
1928	06/06/2016 08:33:44										77,750.05
1929	06/06/2016 08:34:18										
1930	06/06/2016 08:34:19									51.84	77,805.40
1931	06/06/2016 08:34:41	68.8	3.0	88.0	550.0	0.0	0.0	275.0	29.6		
1932	06/06/2016 08:34:53										
1933	06/06/2016 08:34:54									52.54	77,857.00
1934	06/06/2016 08:35:27										
1935	06/06/2016 08:35:28									52.77	77,908.77

Figure 131: T100 Data Sheet



	A	B	C	D	E	F	G	H	I	J
1	Manually Collected Data									
2	Start Time	6/6/16 8:14								
3	End Time	6/6/16 14:47								
4	name	units	is multi value	start value	end value	operation	result	comment	start timestamp	end timestamp
5	Fuel consumption	lbs.	TRUE	6.3	43.5	-	37.2	Design 1: 48 to 77 kW . inverter failure.	6/6/16 8:30	6/6/16 9:52

Figure 132: T100 MDC Sheet



4. Demonstration activity when incident occurred (select one): Record runs

other activity not listed (describe:Powering kitchen,laundromat, ECUs at 80kW)

5. This incident or failure is related to (select one): hardware

6. List the hardware component(s) and/or the software component(s) that are involved in this incident.

Electrolytic capacitors in inverter

T100

Other
hardware
software
both
neither
unsure

7. Describe the incident - include what the operator was doing at the time, what the system was doing or attempting to do, and a description of the symptoms. Include the HW/SW configuration. Continue on the back if required. If the "bug" can be recreated, include a step-by-step rundown on the back of this form.

While powering the BCIL kitchen, laundromat, ECUs at 80+ kW, a loud pop was heard.

Figure 133: DIR 06-07

Section 4.14.5 describes the process by which the EDVT conducted data authentication and delivery of the final demonstration data set uii.

4.14.5 Data Authentication and Delivery

The final step at the demonstration venue was authentication and delivery of the data. Data authentication is the process of authenticating and validating data, ensuring that demo data accurately reflect the component/system performance during the demo, and provide the single demo database of record—the ground truth—for all users of the demo data. The data was reviewed and approved by the DAG, using processes modeled after those in the U.S. Army Operational Test Command's Test and Experiment Data Management Requirements (OTC, 2003) document. The DAG was chartered by the Program Management Integrated Process Team (PMIPT), chaired by the EDVT, and consisted of voting members from each of the functional teams—CLT, TMIT, SEIT, RIT, and MSAT. Technology Providers attended as SMEs during DAG proceedings to answer questions about data and system performance.

Meetings of the DAG were convened on 8, 17, 20, 21, and 22 June. The DAG followed the Standard Operating Procedure (SOP) as detailed in the DAMP. The DAG used the DRD (Section 3.3.12) to review the data and make informed judgements on the completeness and accuracy of the data. The technical data were assessed to determine if they were a consistent representation of the base camp technologies' performance during the demonstration. Where data were deemed questionable the DAG wrote a Data Investigation Ticket (DIT) to initiate a follow-up. In this demonstration a total of four DITs were written to resolve questions or issues with data. All four were satisfactorily resolved prior to final adjournment of the DAG.

In addition to the graphed data in the dashboard, the DAG examined the DDS Excel files on a neighboring monitor. As previously mentioned, the DDS files include all tabulated data, any manually collected data, and all relevant DIRs. During the DAG meeting the DDS files were annotated with information that would be helpful to data consumers and registered the votes of the DAG members. Minutes of each DAG meeting were prepared and distributed. The minutes contain a summary of discussion and the authentication decision for each file reviewed. At the conclusion of the complete authentication process all DDS files were compiled, cataloged, and delivered to the Lead Systems Engineer. The catalog of deliverables is attached to this report at ANNEX C.

> **NOTE:** To researchers, analysts, other end users – Requests for the demonstration data should be made directly to the SLB-STO-D Lead Systems Engineer. EDVT may not deliver or release data directly. However, EDVT support does not end upon delivery. Contact the EDVT for assistance with any issues parsing or understanding the data received from the Lead Systems Engineer.

4.15 Strategic Communications

The SLB-STO-D developed and executed strategic communication activities to ensure that stakeholders are properly informed of the status, important events, and technical accomplishments of the program. To this end, the SLB-STO-D launched specific Strategic Communications initiatives to support the demonstration documented in this technical report. This section describes the scope and breadth of specific Strategic Communications efforts for this demonstration.

4.15.1 Banners

Banners (**Figure 134**) were created for each of the technologies and displayed in proximity to the corresponding technology. The banners contained information related to the technology’s contribution to reducing fuel and the need for water resupply, or reducing waste generated for backhaul. It also included information on the technology’s purpose, products, payoffs, linkages to DoD and Army-wide significant initiatives, and the system’s engineering context diagram. At a glance, banners served to inform stakeholders of the important technical characteristics of a technology and its relevance to the overall objectives of the SLB-STO-D program.

Figure 134: Typical Banner

4.15.2 Display Tent

A display tent (**Figure 135**) was set up at the BCIL to house banners of technologies from previous demonstrations, models of base camps (**Figure 136**) of various sizes (e.g., 50, 300, and 1000 personnel), and to provide an area for interactive displays (**Figure 137),** and briefings. Also, the Ration Packaging and Reconfiguration project was exhibited here, as well as the future printed LED project.

Figure 135: Tent Display Setup

Figure 136: Basecamps Sandbox Models

Figure 137: Interactive Display

4.15.3 Leadership Day

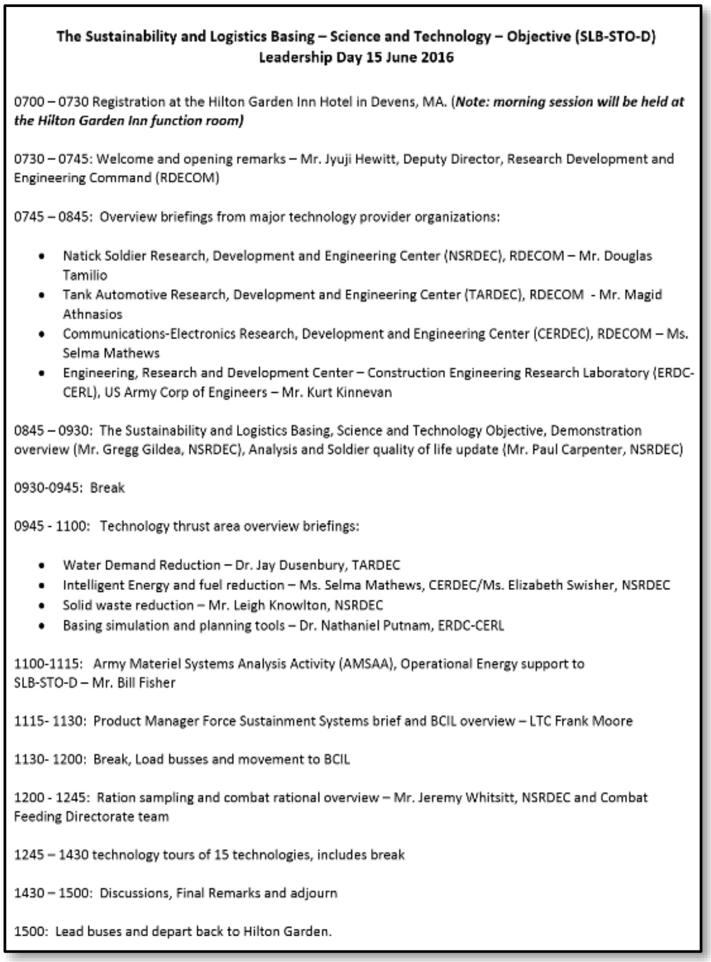
The SLB-STO-D held a Leadership Day on 15 June 2016. Leaders such as the ASA IEE, Program Executive Office for Combat Support and Combat Service Support, and other high-level stakeholders were invited and participated in Leadership Day.

The first objective of the Leadership Day was to inform SLB-STO-D stakeholders of the present state of the SLB-STO-D program. The second objective was to highlight the integrated technology demonstration for the second iteration of the 300 personnel base camp scenario. The third objective was to use the final integrated technology demonstration as a culmination event for the five integrated technology demonstrations. Also, part of the third objective was to underscore the importance for the systems engineering and integrated technology demonstration capability to continue past the end of the SLB-STO-D program in FY17.

The Leadership Day agenda (**Figure 138**) was divided into four principal timeslots. During the first timeslot, an overview was presented from the major SLB-STO-D program Technology Provider organizations. The second timeslot contained a briefing on the SLB-STO-D program overview and accomplishments to date, as well as the Soldier QoL tool update. The third timeslot consisted of the overview of technology thrust areas in intelligent energy/fuel and water demand reduction, solid waste reduction, and basing simulation and planning tools. For the fourth timeslot, the Army Materiel Systems Analysis Activity (AMSAA) finalized the morning section with an overview of the operational energy support to the SLB-STO-D. To conclude the Leadership Day, the stakeholders toured the 15 technologies being demonstrated at the BCIL, followed by a review of the path forward and exchanges of final remarks.

4.15.4 Booklet

A program booklet (**Figure 139**) was generated as part of the Leadership Day SLB-STO-D outreach strategy. Different from previous demonstrations, the booklet was not tailored for just the 300 personnel integrated technology demonstration but in the context of providing an enduring SLB-STO-D strategic message. The booklet consisted of detailed SLB-STO-D program information, organization, and current approach. Also, the book depicted the foreseeable future approach to basing resource reduction, a complete portfolio of demonstrated technologies, and SLB-STO-D related news and articles.



The Sustainability and Logistics Basing – Science and Technology – Objective (SLB-STO-D)
Leadership Day 15 June 2016

0700 – 0730 Registration at the Hilton Garden Inn Hotel in Devens, MA. (***Note: morning session will be held at the Hilton Garden Inn function room)***

0730 – 0745: Welcome and opening remarks – Mr. Jyuji Hewitt, Deputy Director, Research Development and Engineering Command (RDECOM)

0745 – 0845: Overview briefings from major technology provider organizations:

- Natick Soldier Research, Development and Engineering Center (NSRDEC), RDECOM – Mr. Douglas Tamilio
- Tank Automotive Research, Development and Engineering Center (TARDEC), RDECOM - Mr. Magid Athnasios
- Communications-Electronics Research, Development and Engineering Center (CERDEC), RDECOM – Ms. Selma Mathews
- Engineering, Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL), US Army Corp of Engineers – Mr. Kurt Kinnevan

0845 – 0930: The Sustainability and Logistics Basing, Science and Technology Objective, Demonstration overview (Mr. Gregg Gildea, NSRDEC), Analysis and Soldier quality of life update (Mr. Paul Carpenter, NSRDEC)

0930-0945: Break

0945 - 1100: Technology thrust area overview briefings:

- Water Demand Reduction – Dr. Jay Dusenbury, TARDEC
- Intelligent Energy and fuel reduction – Ms. Selma Mathews, CERDEC/Ms. Elizabeth Swisher, NSRDEC
- Solid waste reduction – Mr. Leigh Knowlton, NSRDEC
- Basing simulation and planning tools – Dr. Nathaniel Putnam, ERDC-CERL

1100-1115: Army Materiel Systems Analysis Activity (AMSAA), Operational Energy support to SLB-STO-D – Mr. Bill Fisher

1115- 1130: Product Manager Force Sustainment Systems brief and BCIL overview – LTC Frank Moore

1130- 1200: Break, Load busses and movement to BCIL

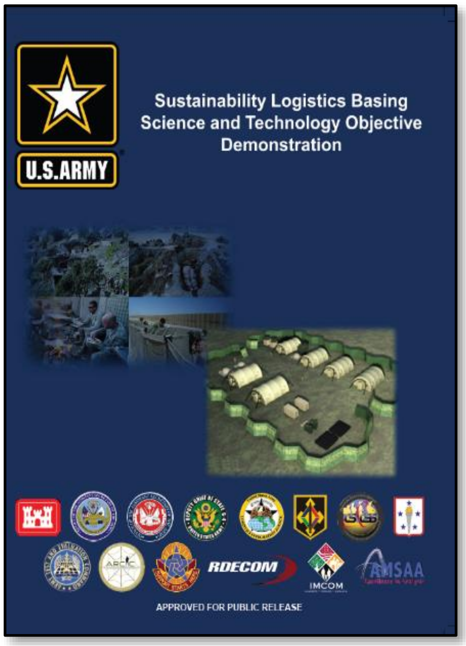
1200 - 1245: Ration sampling and combat rational overview – Mr. Jeremy Whitsitt, NSRDEC and Combat Feeding Directorate team

1245 – 1430 technology tours of 15 technologies, includes break

1430 – 1500: Discussions, Final Remarks and adjourn

1500: Lead buses and depart back to Hilton Garden.

Figure 138: Leadership Day Agenda



Sustainability Logistics Basing
Science and Technology Objective
Demonstration

APPROVED FOR PUBLIC RELEASE

Figure 139: Program Booklet

5. RESULTS AND DISCUSSION

The following sections present the results for each technology. Graphed and tabulated data are presented for information and are not meant to be a substitute for the authenticated dataset. Analysts are encouraged to obtain the dataset from the Lead Systems Engineer as described in Section 4.14.5.

5.1 CIMT Results and Discussion

Table 6 shows the daily results of CIMT operation during record runs from 6-10 June and 13-17 June. The CIMT produced ice each day of record runs. Most days the system operated 6 or more hours. On Tuesday, 14 June, the system shut down early due to a camp-wide water shortage. And the system shut down early on the final day, but there was no failure.

Table 6: CIMT Results

Date	Total Hours of Operation	No. of Bags Ice	Total Power Consumed (kWh)	Total Water Consumed (gal)	Total Wastewater (lbs)	Description of Events
6-Jun	6.00	51	25.89	63.8	34.6	Made ice, bagged ice, reprogrammed defrost, replaced switch that influences bag pickup, reprogrammed conveyor timing relative to the elevator movement.
7-Jun	7.50	80	37.56	96.3	41.0	Ran all day with no issues to report. Made 80 bags of ice.
8-Jun	7.50	80	27.40	88.1	50.6	Ran all day with no issues. Filled 80 bags. Average bag weighs 7.7 lbs.
9-Jun	7.15	67	25.77	78.4	14.4	Made 67 bags of ice. Had issue with conveyor slipping at the beginning of the day.
10-Jun	7.50	69	25.03	85.4	63.0	Conveyor belt temporarily frozen.
13-Jun	6.25	77	27.98	79.6	90.7	Produced 77 bags of ice.
14-Jun	2.50	18	6.26	15.2	66.4	Produced 18 bags of ice. Shut down early due to water shortage.
15-Jun	7.00	77	33.34	84.7	92.0	At 1110 hours allowed precool compressor/fan to come on as temperature inside exceeded 95°F. Power increase due to this activity should be seen in the data. Water stopped during part of the day.
16-Jun	6.00	52	27.47	59.9	(nm)	Produced 52 bags of ice. Attempted to fix bevel gear. Scale failed. No measurement on wastewater.
17-Jun	2.75	24	9.68	28.8	43.4	Produced 24 bags of ice. Experienced intermittent water supply and a power glitch. Shut down after 2 hours, 45 minutes.

There were some minor issues with the operation of the prototype, but overall the system performed as expected. Either the contractor or the Technology Provider was on-site daily to operate the system, troubleshoot issues with the prototype, and assess how the system might be improved moving forward. It can be seen from the data in the table that the system produced roughly 9.6 bags of ice per hour of operation, ranging from about 7 to 11 bags per hour. For reference, the weather data for 13 June are shown in **Figure 140.** The relevant data for 13 June, a typical day of ice production, is graphed in **Figure 141**. In the weather graph, the solar radiation is the purple plot, ambient temperature is red, relative humidity is green, and wind speed is yellow.

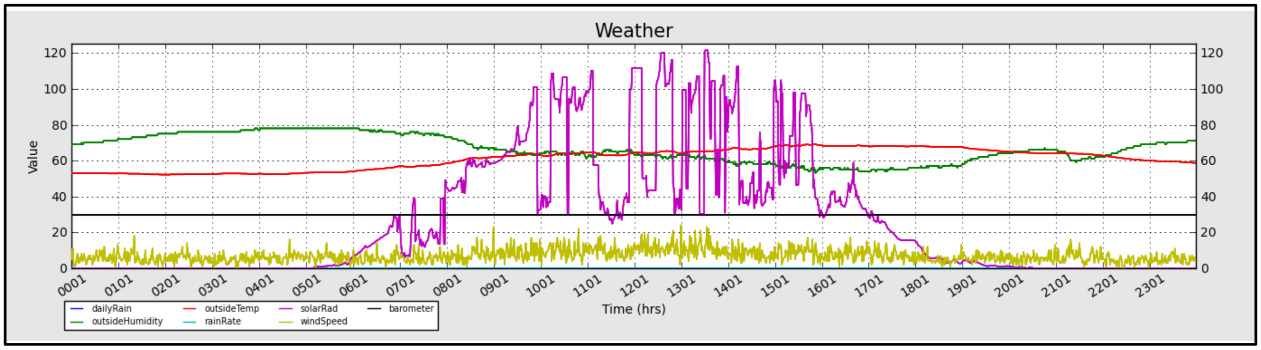


Figure 140: Weather Graph for 13 June

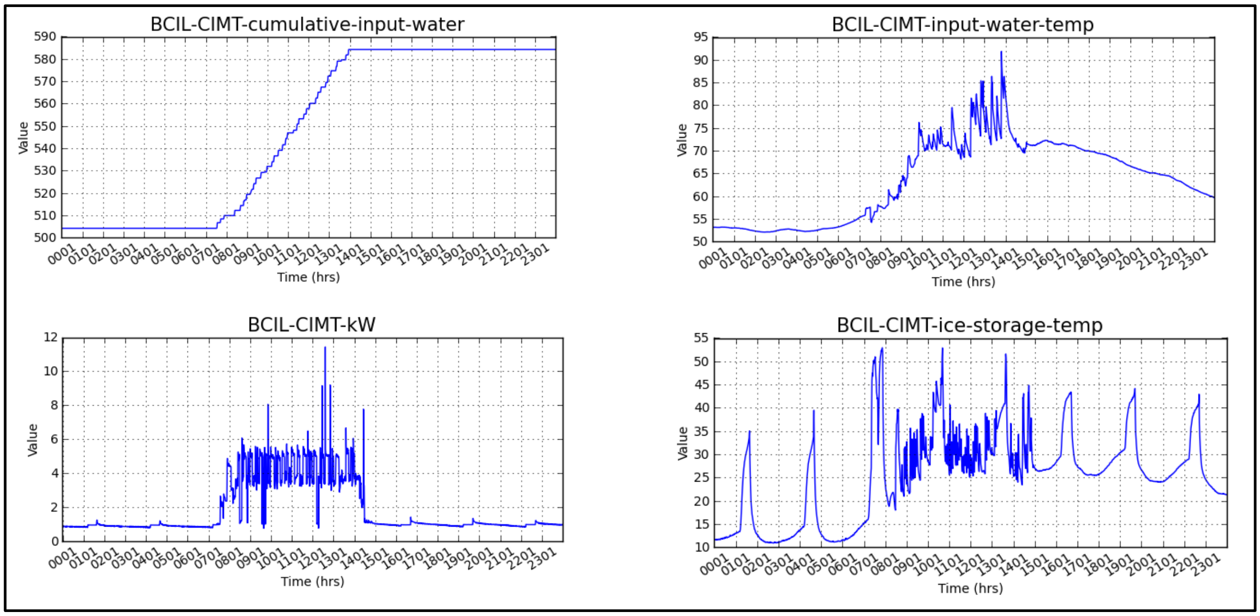


Figure 141: CIMT Graphed Data for 13 June

Demonstration data is typically harvested from midnight to midnight for systems that operate continuously, and the data in Figure 141 follow this pattern. The CIMT operated continuously to keep the ice storage area cold, but only produced ice during the duty day. The cumulative water input is shown in the upper left graph of the figure. Water input to the system is steady throughout the ice-making operation. The temperature of the input water is graphed in the upper right. The water passed through a rubber hose laying on the ground and the water in the hose heated up with the rise in ambient temperature and fluctuated with the variations in sunshine and passing clouds, i.e., solar radiation. The system power draw is graphed in the lower left. There is a minimum power draw during the night to keep the ice storage area refrigerated. Then the power is seen to fluctuate with the machinery duty cycles during the ice-making operation. The temperature of the ice storage area is graphed in the lower right of the figure. During the ice making operation there is much fluctuation. This can be explained by the opening and closing of the doors to inspect or remove the ice bags. The spikes in the temperature during the “off” hours are from the system defrost cycles.

Lessons Learned: This system is a first-generation prototype. While a final production unit should require only minimal human interaction, this unit required constant supervision to keep making ice continuously. The Technology Provider kept excellent notes and is aware of the issues to be addressed as this technology matures. The important feature was shipping this system out of the lab and getting it into the field and operational under realistic conditions. The vendor learned much about minor issues in the mechanical operation (bagger, conveyor, etc.) as well as improvements required in the software (harvesting, defrosting, etc.).

5.2 WDR Results and Discussion

Low flow and regular flow showerheads were demonstrated at the BCIL. The regular and low flow showerheads were expected to use 3 gal per min and 1.5 gal per min, respectively. There was concern as to whether the low flow shower head would result in a full 50% reduction in water use, for shower times may increase due to the low flow rate. The shower durations for the different showerheads were compared at the BCIL. Ultimately, it was found that the low flow showerheads resulted in shorter shower times.

The findings from the BCIL demonstration were surprising. Beyond external factors, one possible explanation for this result is the quality of the shower experience. It is assumed that a better shower experience will lead to shorter showers, for the Soldier needs less time to feel clean. Assuming the relationship between shower experience and duration, the quality of the shower may depend on more than simply the water flow rate. The low flow showerheads had a wider and more evenly dispersed water flow than the regular showerheads. This could have delivered a better shower experience, therefore leading to shorter durations. Another possibility is that the assumption that better shower experiences lead to shorter durations may be false. If low flow showers were less enjoyable, this could have led to the Soldiers staying in the shower for a shorter time. Ultimately, the only thing that is known presently is that the low flow showerheads result in 327 ± 19 s showers and the regular flow shower heads result in 370 ± 27 s showers.

An algorithm was written to parse though the raw shower data, which included “ON” and “OFF” states, and to calculate the shower durations. Data was then filtered based on manual observations of the abnormal data and for when the SEIT was interacting with the system, i.e., not taking representative showers. During the weekdays, the SEIT had control of the showers between 0900 and 1500 h. Sensor errors did occur during data collection, so these were also removed. Many instances of short duration shower runs were observed. It is unlikely that a Soldier took a shower for less than 30 s; therefore, these were removed. Finally, a few sensor readings caused significantly long showers; these were removed. A summary of data filters is shown in **Table 7**.

Table 7: WDR Data Filters

6 June	Exclude{Time < 15:00:00}
7 June	Exclude{Time > 09:00:00 & Time < 15:15:00}
8 June	Exclude{Time > 08:09:00 & Time < 15:15:00}
9 June	Exclude{Time > 09:00:00 & Time < 15:15:00}
10 June	Exclude{Time > 09:00:00 & Time < 15:15:00} Exclude{Time > 06:50:00 & Time < 07:17:00}
11 June	
12 June	
13 June	Exclude{Time > 09:00:00 & Time < 15:15:00}
14 June	Exclude{Time > 09:00:00 & Time < 15:15:00}
15 June	Exclude{Time < 16:00:00}
16 June	Exclude{Time > 09:00:00 & Time < 15:15:00}
17 June	Exclude{Time > 09:00:00 & Time < 15:15:00}
All Dates	Exclude{Duration < 30} Exclude{Duration > 3000}

Summary statistics of the collected data for each date are shown in **Table 8**. These results indicate that the expected shower duration is 329 ± 18 s with a low flow showerhead and 366 ± 16 s with a regular showerhead. Not every day is a reasonable representation of operations in a fully functioning base camp in the field. For example, late on 13 June the camp ran out of water and showers were mostly suspended. Water was returned early on 15 June. Additionally, the data observed on Friday, 10 June, and Saturday, 11 June, show different behaviors than the other days, potentially due to reduced schedule. For these reasons, only some days were included in the final numbers delivered.

Table 8: Shower Duration Sample Means with Confidence Interval

Date	Samples	Average (s)	95% Lower Bound (s)	95% Upper Bound (s)
6 June	62	358	296	421
7 June	166	283	257	308
8 June	99	358	321	394
9 June	101	351	308	395
10 June*	92	371	329	412
11 June	100	405	367	444
12 June	100	399	348	449
13 June	96	370	332	407
14 June	20	194	100	287
15 June	103	342	304	379
16 June	90	321	280	362
17 June	98	386	340	431

** Showerheads were switched midday from low flow to regular*

A MATLAB algorithm called "*allfitdist*" was used to fit a distribution to each day's data. A histogram of the data and the resulting best four best distribution fits are shown for each day in

Figure 142. As can be seen, the distributions Gamma, Log Logistic, and Log Normal commonly best fit the data. The days that do not display this behavior were removed from analysis. The days included in final analysis are 6-9 June, 12 June, and 16-17 June. The revised values are that the low flow showerheads result in 327 ± 19 s showers and the regular flow showerheads result in 370 ± 27 s showers.

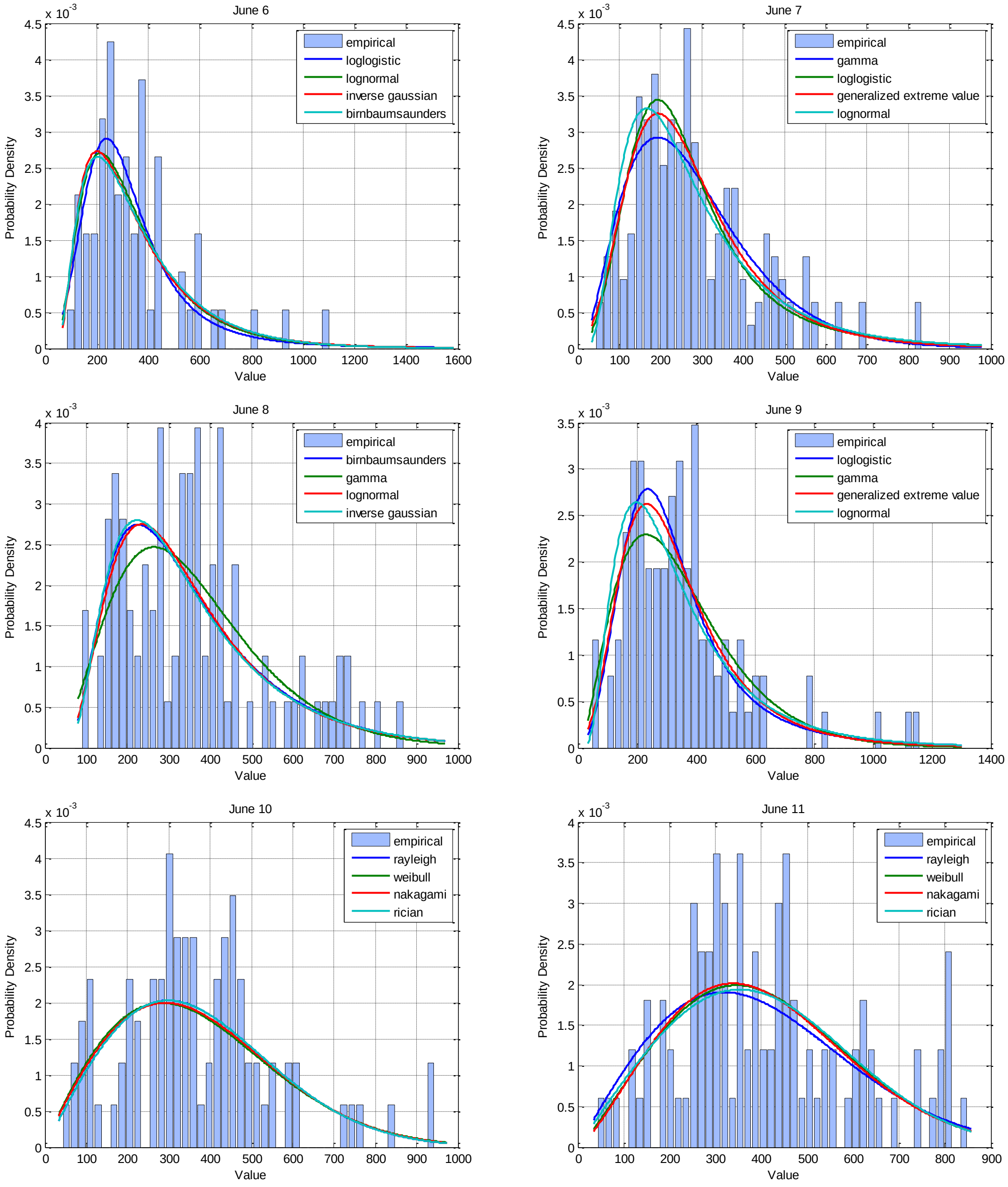


Figure 142: Shower Data Histograms with Optimal Distribution Fits for Each Day

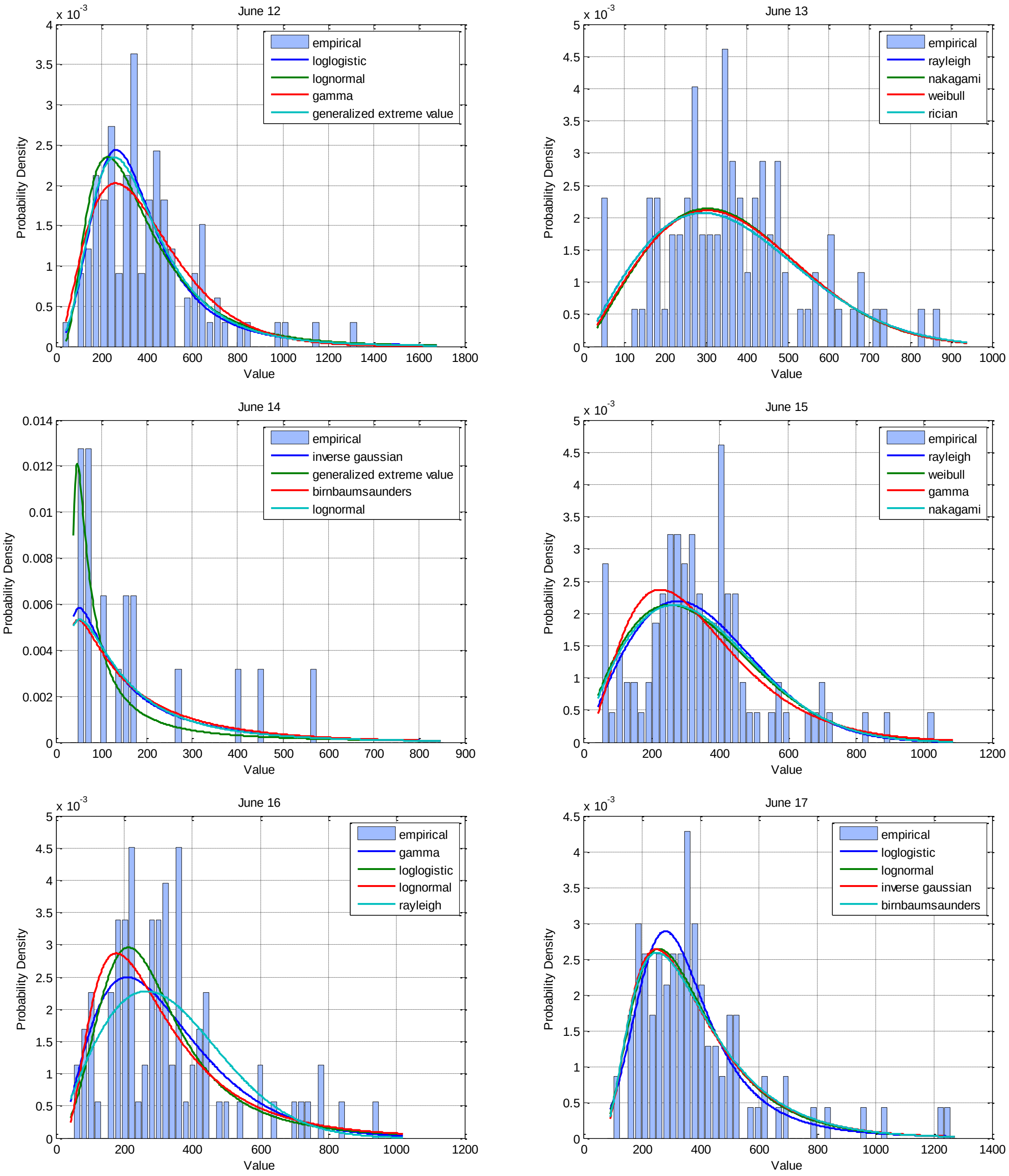


Figure 142 (continued): Shower Data Histograms with Optimal Distribution Fits for Each Day

Lessons Learned: The hypothesis driving this data collection was not as straightforward as originally thought. There are numerous operational variables that could drive the length of showers aside from the rate or quality of the water flow. Schedule pressure, leadership, enemy situation, unit standard operational procedures, seasonal time of year, water resupply expectations, etc. could have various and perhaps significant impacts on shower water usage. Low-flow versus standard showerheads are just a piece of the bigger picture for water conservation.

5.3 SLiM Results and Discussion

Information in this section was submitted by the Technology Provider and edited for a common format.

SOC:
Voltage was monitored for approximately 3 h before reaching a steady state. True steady state was never achieved due to a small internal power draw from the module itself. **Table 9** and **Figure 143** show how the discharge rate slowed over time. The discharge rate decreased exponentially at first. As it neared steady state, the curve flattened out. When the voltage discharge rate reached 0.003 V/min, the test was stopped. This small discharge rate was assumed to be driven by the system's internal electronics. Based on this data, it was determined that the batteries should be considered at full capacity (100% SOC), when the voltage was between 53.2–53.5 V.

Table 9: Voltage and Time Measurements

Time	Voltage
10:56 AM	56.94
11:01 AM	56.44
11:06 AM	55.76
11:11 AM	55.33
11:16 AM	55.09
11:21 AM	54.87
11:26 AM	54.68
11:31 AM	54.51
11:36 AM	54.37
11:41 AM	54.24
11:46 AM	54.12
11:51 AM	54.02
11:56 AM	53.93
12:01 PM	53.85
12:06 PM	53.78
12:11 PM	53.71
12:16 PM	53.65
12:21 PM	53.60
12:26 PM	53.55
14:12 PM	53.24

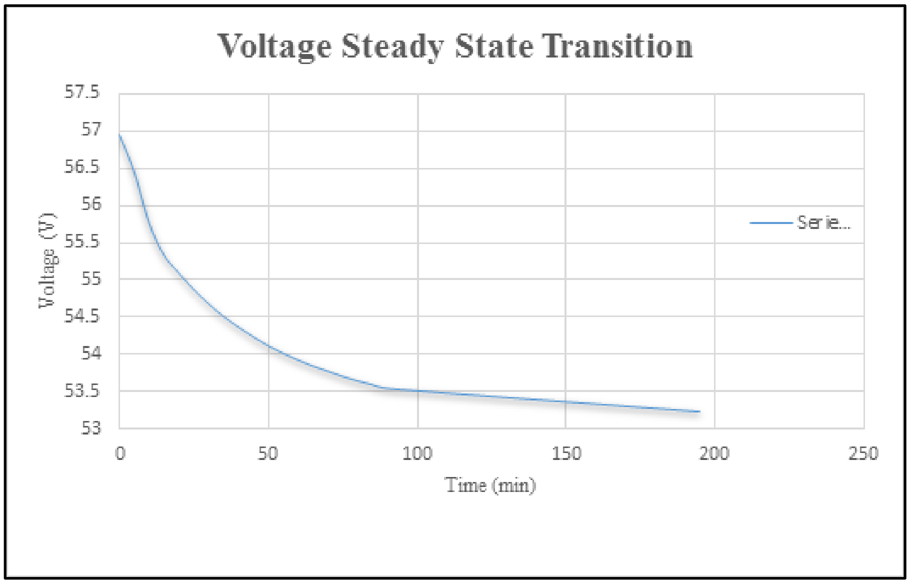


Figure 143: Voltage Steady State Transition

System Overload:
The system maximum capacity was determined using the following load iteration process. It was noticed that any loads higher than 16 kW would cause the system to overload (instantaneous shutdown) (see **Table 10**). The highest load setting that the system was able to manage was 15.7 kW even though it is not recommended to apply loads at this level, because some power intermittency was experienced while loading the system at this rate.

Table 10: Maximum Load Capacity

Maximum Load Capacity		
Load (W)	**Voltage (V)**	**Notes**
1900	51.2	-
5800	49.5	-
13200	46.5	-
14500	45.6	-
17500	-	System shuts off quickly
15700	45.33	Max capacity
> 16000	-	System shuts off quickly

System Startup Time Lag:

After running the battery draining tests at different discharge rates (15 kW, 7.9 kW and 4.7 kW loads) a range for system shut off voltage was determined. When the system registered a voltage capacity lower than 44.5 V at high discharge rates, the system would shut off automatically as part of a safety feature to protect itself from damaging the batteries. The same was noticed for lower discharge rates, even though at lower rates the system shutoff feature kicked in a little bit later when system voltages were below 43.5 V. As soon as the system shut itself off, the batteries were charged using PV with and without the 10K TQG. It was determined that instead of using time as a baseline for how long the system would be offline it was more useful to determine at which voltage the system would energize automatically. After several draining tests, it was determined that the system will automatically energize at 45.5–46 V. This translates to charging the batteries for about 10 min with PV only at a capacity of around 1800 W.

System Capacity Test:

The batteries were charged with the generator and PV in parallel to reach a SOC of 100%. Full charge was attained when the generator input dropped to about 500 W and the PV dropped to 0 W. At full charge, the generator and PV were disconnected, leaving the batteries to settle to their steady state voltage (53.52 V). The SOC of the system was reset at the I/O module and the subsequent test was started.

Table 11: System Capacity Voltage, SOC and Load Measurements

Draining Batteries with 3.0 kW load				
Time	**Voltage (V)**	**SOC (%)**	**Load (W)**	**Notes**
10:02	53.52	100	3040	Voltage dropped to 52.5 V as soon as loads were added
10:17	51.77	98	3098	
10:32	51.68	96	3089	
10:47	51.54	94	3116	
11:02	51.43	92	3112	
11:17	51.11	90	3088	
11:32	51.28	87	3010	
11:47	51.21	85	2987	
12:02	51.15	83	2991	
12:17	51.10	81	2976	
12:32	51.08	80	2973	
12:47	50.98	77	2983	
13:02	50.94	75	1583	Overheated heating unit
13:17	50.85	74	3011	Added fan to prevent the heater from overheating
13:32	50.73	72	3021	
13:47	50.59	69	3031	
14:02	50.46	68	3056	
14:17	50.28	66	3045	
14:32	50.15	64	3031	
14:54	49.91	60	3016	

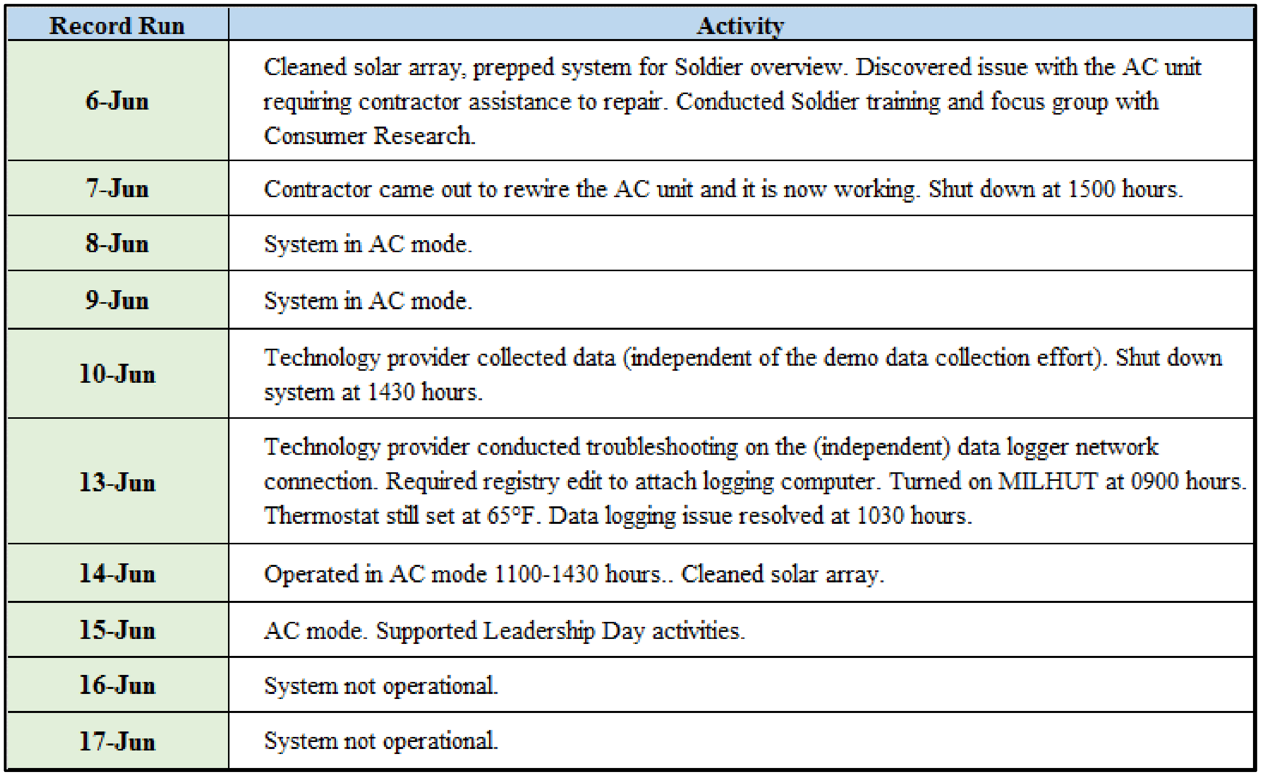
The system was tested to 14.7 kWh capacity and at a SOC of 60%. Further testing would be required, but it’s likely that the system is capable of achieving its rated capacity of 20 kWh. Other tests were performed using higher discharge rates and it was noticed that the system capacity is greatly diminished. In a real world scenario, it is believed the batteries can achieve 20 kWh, but not at high loads. At higher loads, the generator and/or PV will be required.

5.4 MILHUT Results and Discussion

The MILHUT participated in this demonstration to showcase the air conditioning features. The system recently participated in the demonstration at CBITEC where the Hotel Module and the shelter heating capability were demonstrated. A Safety Release had been obtained and Soldiers occupied the shelter and used the Hotel Module for showers and laundry during the CBITEC demonstration. There was no plan to repeat the operation of the Hotel Module at the BCIL during this demonstration.

The MILHUT Power Module comes equipped with both an evaporative cooler and an air conditioning unit to cool the adjacent air-supported TEMPER shelter. The evaporative cooler was assessed during the setup period. The shelter was consistently muggy and uncomfortable. This was likely due to the humidity and lack of air flow in the shelter. It was decided to abandon any assessment of the evaporative cooler and instead exercise the air conditioning unit during record runs. **Table 12** shows the daily activity for the record runs.

Table 12: MILHUT Results



Record Run	Activity
6-Jun	Cleaned solar array, prepped system for Soldier overview. Discovered issue with the AC unit requiring contractor assistance to repair. Conducted Soldier training and focus group with Consumer Research.
7-Jun	Contractor came out to rewire the AC unit and it is now working. Shut down at 1500 hours.
8-Jun	System in AC mode.
9-Jun	System in AC mode.
10-Jun	Technology provider collected data (independent of the demo data collection effort). Shut down system at 1430 hours.
13-Jun	Technology provider conducted troubleshooting on the (independent) data logger network connection. Required registry edit to attach logging computer. Turned on MILHUT at 0900 hours. Thermostat still set at 65°F. Data logging issue resolved at 1030 hours.
14-Jun	Operated in AC mode 1100-1430 hours.. Cleaned solar array.
15-Jun	AC mode. Supported Leadership Day activities.
16-Jun	System not operational.
17-Jun	System not operational.

While no power data were collected, it was observed that the solar panel array appears to have been sufficient to power the unit each day. The on-board generator was not observed to automatically turn ON. Instead, the solar panels kept the system batteries adequately charged to power the air conditioning unit.

The air conditioning unit was found to keep the shelter cool while operational. Temperature and humidity data for 14 June are shown in **Figure 144**. Comments in the table above indicate that the air conditioning was operational 1100-1430 h on 14 June. In the figure, it can be seen that during this period the temperature in the shelter was brought down to the set point of 65 °F and maintained the set point. As expected, the temperature in the supply duct was quite a bit cooler to maintain the desired temperature in the center of the shelter. The humidity was observed to increase slightly during operation of the air conditioning unit.

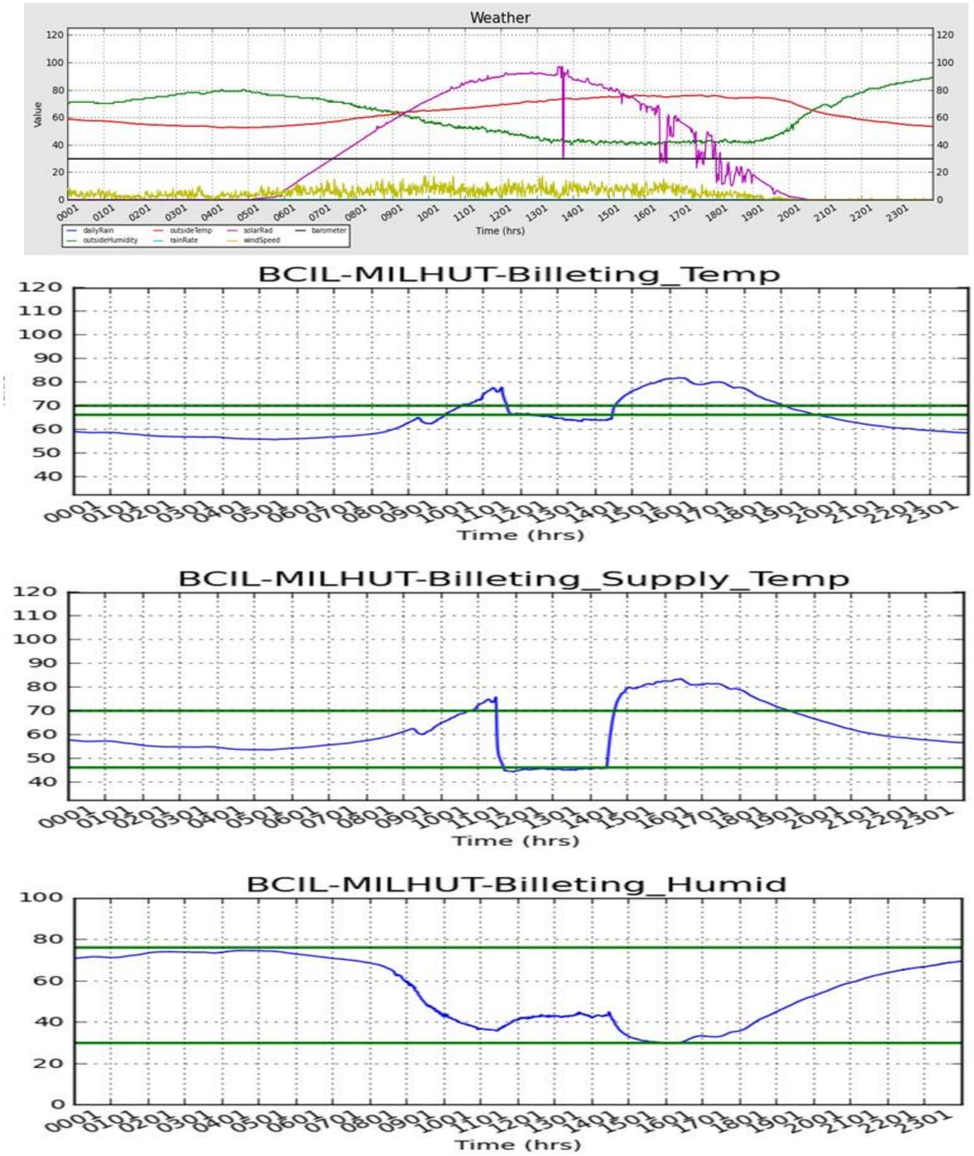


Figure 144: MILHUT Temperature and Humidity

Lessons Learned: The evaporative cooler is likely not a suitable solution under the conditions experienced during this demonstration. The air conditioner was effective for cooling, but unlike an ECU, there was no return duct to move and recirculate air through the shelter.

5.5 NPC Results and Discussion

Information in this section was submitted by the Technology Provider and edited for format.

During the demonstration, more than 37,000 current-voltage curves were obtained from the PVs. In addition, there was an indication that the PV with nanoparticles showed an improvement over the control PV, at off-normal angles of incidence. Because of the large volume of data collected, and the potentially publishable results of improved low-angle power harvesting (which the researcher is seeking to reproduce in small-scale experiments at NSRDEC if funding can be secured), this data and analysis will be reported in a separate report.

5.6 GWR-FORO Results and Discussion

The GWR-FORO performed as intended. **Table 13** shows the daily record of activity during the record runs. The system processed 1-3 batches, or 400-1200 gal, of graywater each duty day. Soldiers from the 542d QM Company were able to participate in the system operation and maintenance.

Table 13: GWR-FORO Results

Date	Total Hours of Operation	No. of Batches	Total Gal Input (gray)	Total Gal Output (product)	Total Energy Consumed (kWh)	Comments
6-Jun	6	2	800	640	11.77	Operated system. Replaced FO filter. Calibrated system product flow meter. Identified problem with chlorine injection.
7-Jun	3.25	1	416.3	425.9	5.5	Processed one batch, 400 gallons. Limited by the lack of graywater. Briefed two groups of Soldiers. Replaced the peristaltic tubing in the chlorine pump.
8-Jun	7	2.75	1054.7	1059.9	12.74	Operated system. Replaced chlorine injection tubing. Having issues with chlorine flow. Trained 542d QM detachment on system operation. Participated in focus groups with 82d and 542d.
9-Jun	8	2+	1159.4	746.4	10.55	Soldiers started the system today. TARDEC/NASA replaced the chlorine pump. System is now working properly. Replaced the FO filter. Soldiers shut the system down.
10-Jun	8	2	732	809.1	11.18	The Soldiers started the system this morning. Completed training with the new system operator. Soldiers trained on filter replacement and membrane cleaning. Installed new solenoid valve. Collected product water into 5-gallon buckets, times 3. This is noted so that we know 15 gallons of product water did not go through the effluent meter.
13-Jun	8	1	373.2	642.1	9.84	Soldiers operated the system, replaced FO filter, and filled up OA tank and the salt tank. Refilled chlorine tank and pH tank. Calibrated chlorine dosing (not completed, will continue tomorrow).
14-Jun	8	3	1203.9	856	12.25	Operated system continuously; 3 batches. Filled up the salt tank. Calibrated the chlorine injection. Participated in the rehearsal.
15-Jun	8	3+	1208	1220	13.61	Soldiers operated the system. Replaced the FO filter and refilled the salt tank. Calibrated the chlorine injection. Briefed visitors.
16-Jun	8	2	798.1	921.9	12.38	Processed 3 batches. Filled salt tank.
17-Jun	8	1+	796.6	555.9	8.21	Ran one batch today. System was drained, rinsed, and prepared for shipment.

When examining the gallons of graywater input and the gallons of product water output, it is important to consider that the holding tanks may not start or end completely empty or completely full each day. This would result in what looks like partial batches. It is also important to understand that the holding tank for a batch is 400 gal. The system was set to process 80% of that, or 320 gal, into reusable product water. The concentrate, representing 20% of each batch, or 80 gal, was routed to the WWT-D2 for further processing (see the SV-2).

The data for operations on 14 June are shown in **Figure 145**. This day was one of the busiest in terms of the amount of graywater processed. The graph of influent flow in the upper left clearly shows the three batches of graywater being drawn into the system. The graph in the upper right shows the power profile of the system as the graywater is processed. The graph in the lower left shows the energy consumed to process the graywater. The graph in the bottom right shows the relatively steady flow of product water out of the system.

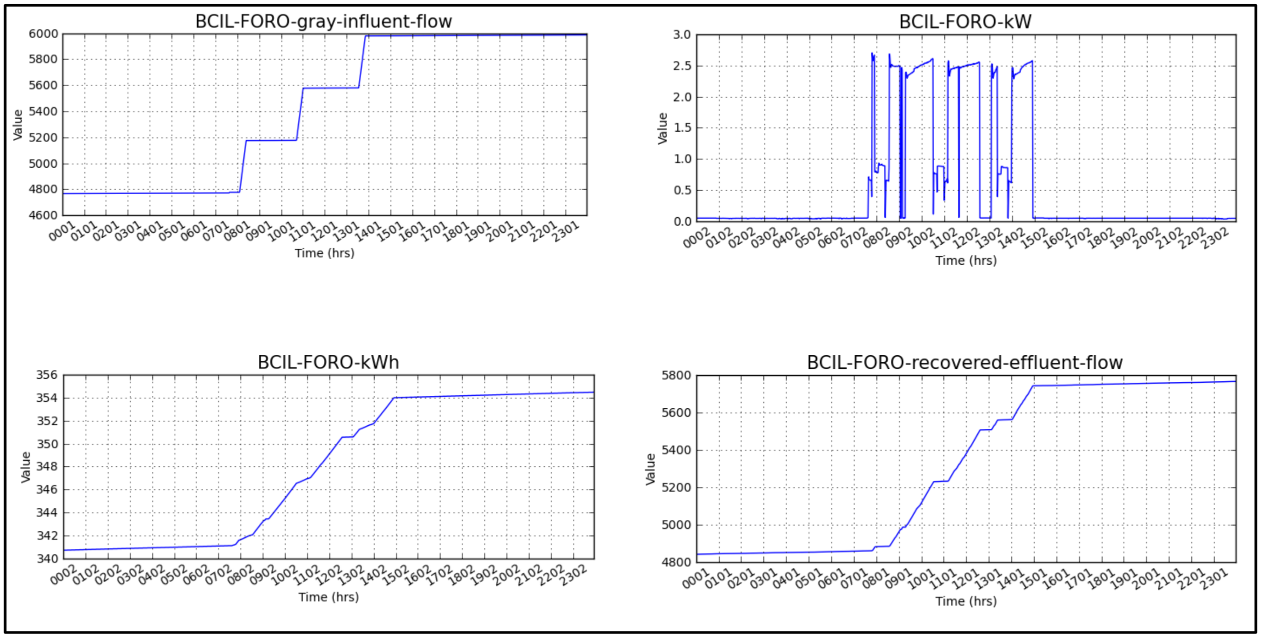


Figure 145: GWR-FORO Data for 14 June

Lessons Learned: This system operated as intended. The only issues the Technology Provider had to deal with were a failure of the control module and some adjustments to the chlorine injector. A replacement control module was immediately shipped, received, and installed the next day.

5.7 V2G/V2V Results and Discussion

Table 14 shows the daily results of V2G/V2V operation during record runs from 6-10 June and 13-17 June. The V2G/V2V experienced a grid collapse on 6 June due to the ground fault detection (GFD) feature. The GFD feature was removed on 7 June and the system started record runs on 8 June. As described in previous chapters, the V2G/V2V system provided power to facilities in the North Camp. The total energy drawn by the camp in each case was less than the energy harvested from the vehicles. The difference in energy would be stored in the ESU or consumed as part of the parasitic overhead for operating the system, e.g., powering controls, displays, etc.

Table 14: V2G/V2V Results

Date	Total Hours of Operation	# Vehicles Operated	Total Energy Supplied by Vehicles* (kWh)	Total Energy Draw by Camp (kWh)	Total Fuel Consumed (gal)	Description of Events
6-Jun	N/A	N/A	N/A	N/A	N/A	Grid collapsed during switch-over. Immediately switched back to shore power. GFDs caused the crash. TM3 systems engineer will be on hand tomorrow to disable GFDs. 3 of 4 ESUs offline due to various causes.
7-Jun	N/A	N/A	N/A	N/A	N/A	Restored all ESUs to operational status. Removed all GFDs from TVGMs.
8-Jun	4.5	3	358	268	46.4	Returned all TVGMs and ESUs to service. Ran average of 80kW into three load banks for 4 hours until TVGMs #1 and #3 were deliberately tripped by GFD (to test a theory by the TM3 rep). TVGM #3 crashed, shedding its load. TVGM #1 stayed operational. Ran from 50kW to 120kW for an average of 80kW per hour.
9-Jun	5.5	4	472	342	36.2	Powered billeting shelters #25-32 and latrine #42 on V2G/V2V system power for 5.5 hours, 0900-1430. Other camp loads remained on shore power while TVGMs 3&4 powered load banks. Objective is to power all the North Camp loads tomorrow.
10-Jun	5.5	2	274	201	39.5	Powered all assigned loads for 5.5 hours. No faults reported
13-Jun	5.33	1	197	125	19.5	Fueled vehicles this morning to capture Friday's fuel usage data. Switched power to North Camp at 0830 with Soldier assistance. All loads connected and ran all day without faults.
14-Jun	6	2	326	238	29.8	Switch-over started at 0809 and finished at 0821 hours. Switched back at 1430. No faults registered. Successfully powered the North Camp loads.
15-Jun	6.15	2	249	177	22	Switched over to power the North Camp facilities at 0812 hours. The total load at switch-over was 30-40kW. The North Camp loads were successfully powered until 1430 hours and then switched back to shore power.
16-Jun	5.6	2	378	298	35	Switched over to power the North Camp facilities at 0844 hrs. The load on the TVGM ring-bus shortly after switch-over was 100kW-105kW. During the day the loads fluctuated between 50kW-85kW. Switched back to shore power at 1430 hrs.
17-Jun	5.75	2	257	184	N/A	Switched over to power the North Camp facilities incrementally to test voltage regulation improvements in preparation for safety testing at the APG. Half of the camp loads were switched over at 0845 (load 14kW). At 0920 three quarters of the camp facilities were switched over (load 35kW) and at 0950 all of the camp facilities were switched over (load 50-55kW). Maintained power to the North Camp until switched back to shore power at 1430. Loads fluctuated between 50-65kW. (Did not refuel in preparation for transportation.)

* The "Total Energy Supplied by Vehicles" data was collected by the Tecnology Provider and is not part of the deliverable dataset.

Figure 146 shows the power profiles for the camp loads powered by the V2G/V2V.

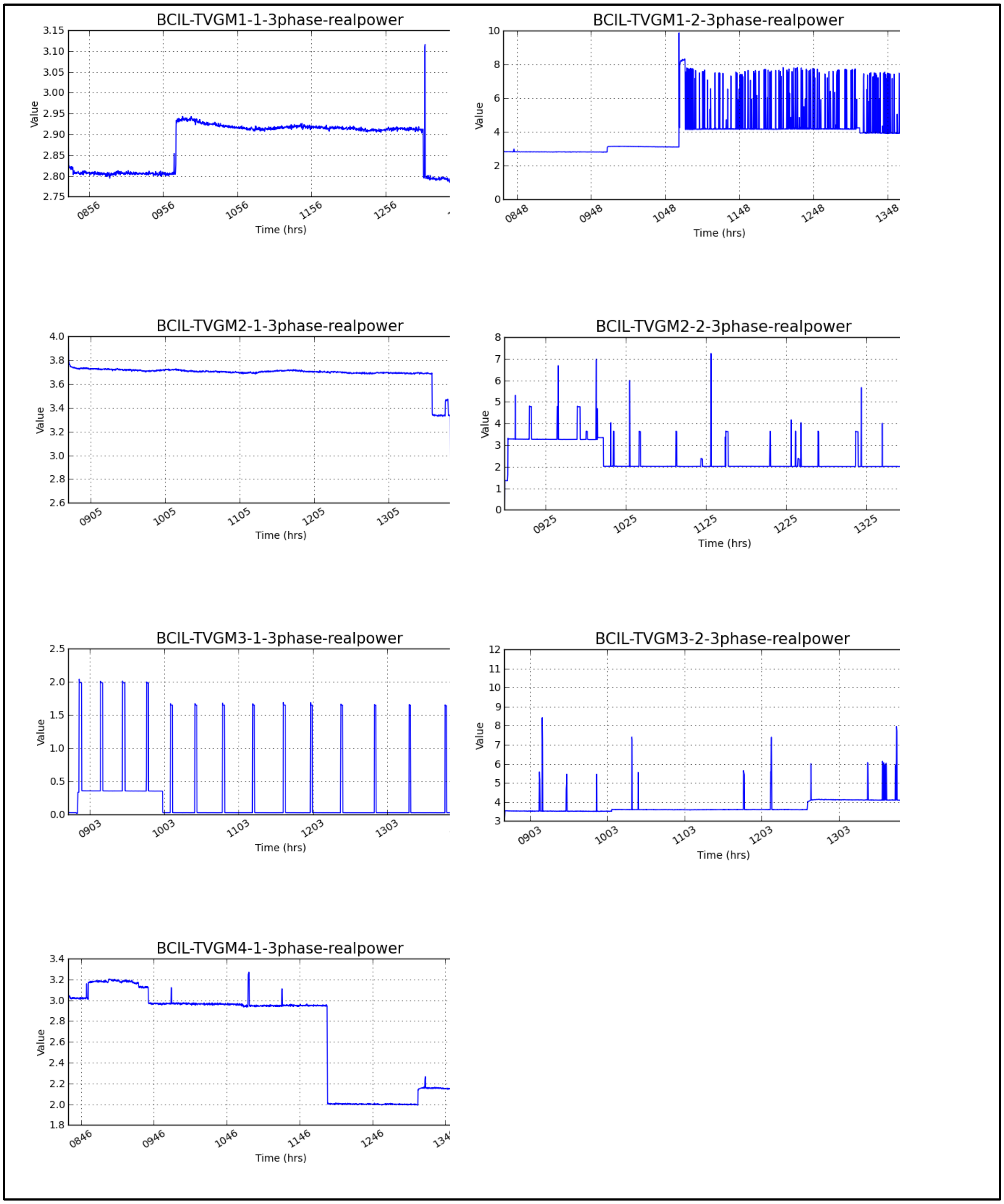


Figure 146: Power (kW) Supplied to North Camp from V2G/V2V on 13 June

Per the SV-2 in Section 5.7, the TVGMs powered the following loads:

- TVGM1 – four billeting shelters with F100s
- TVGM2 – four billeting shelters with F100s, plus a latrine

- TVGM3 – two changing tents with F100s and laundry unit with washer, dryer, and ECU
- TVGM4 – dining facility tent with F100, a shower container, and the other latrine

The load profiles in the figure are typical of ECUs in vent mode (a few kW) with spikes from 4-8 kW when the air conditioner compressor runs. Indications are that the ECUs did not work very hard on this particular day and therefore did not require much power from the grid. The weather data in **Figure 147** show the temperature only around 70 °F or less during the day with frequent cloud cover.

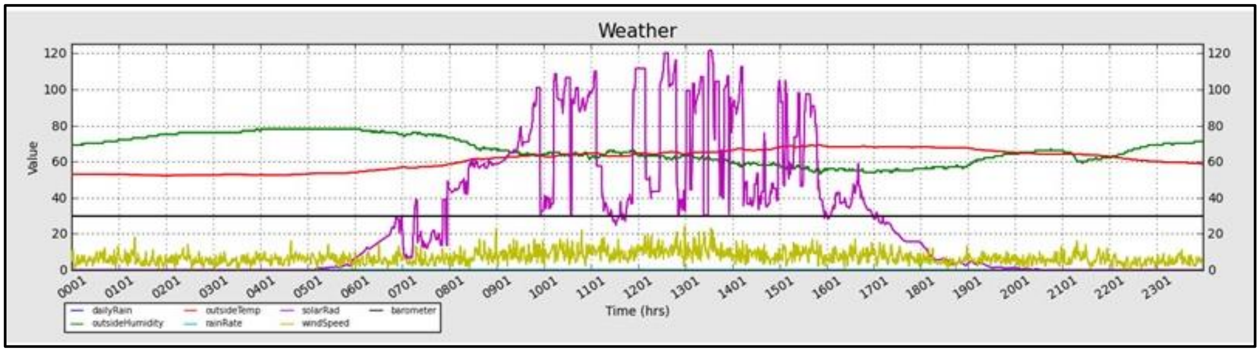


Figure 147: Weather Data 13 June

The weather three days later on 16 June (**Figure 148**) was warmer with temperatures above 80 °F and more sunshine in the morning hours.

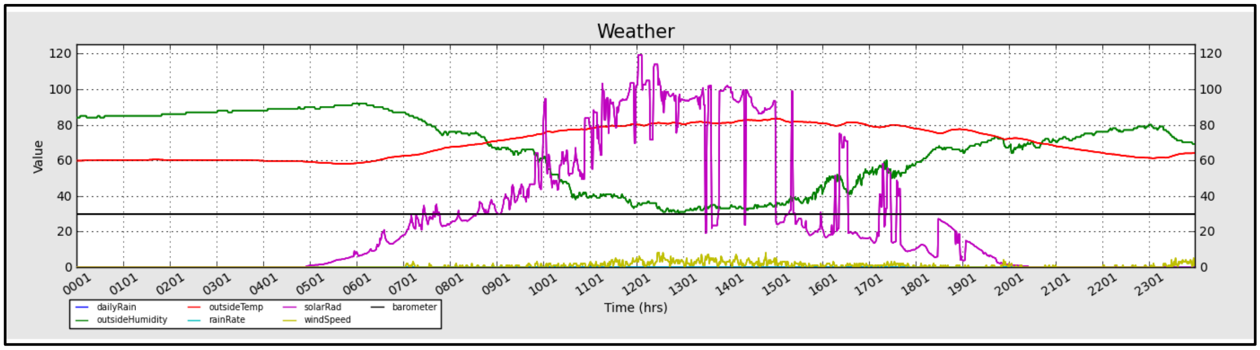


Figure 148: Weather Data 16 June

The increased temperature is very likely responsible for the additional power draw by the North Camp as seen in **Figure 149**. The data for TVGM3 also show the duty cycles for the washer and dryer as the Soldiers operated that unit on this particular day.

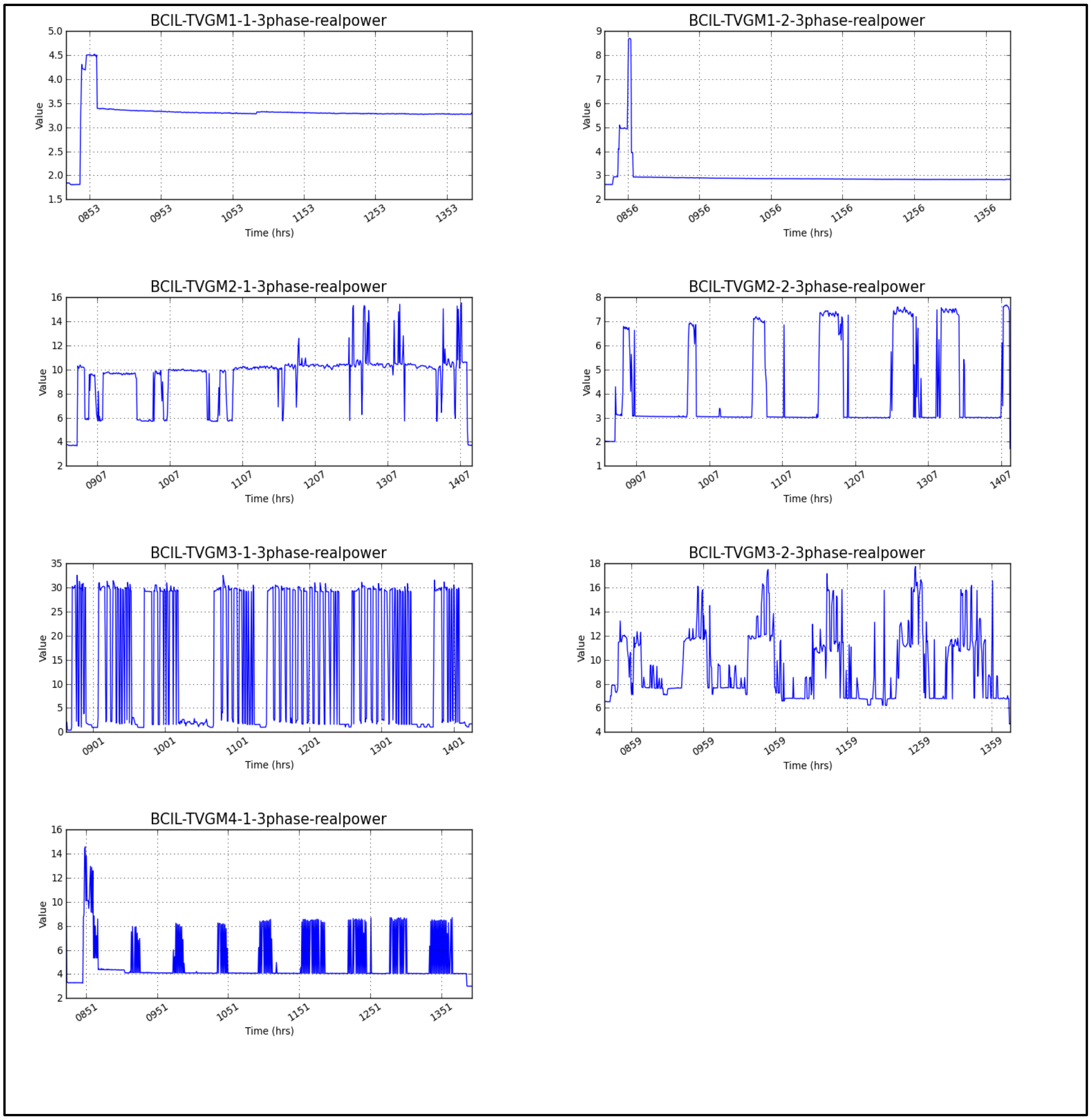


Figure 149: Power (kW) Supplied to North Camp by V2G/V2V on 16 June

Lessons Learned: The Technology Provider submitted the following Lessons Learned:

TARDEC's participation with the Tactical V2G/V2V Demonstration system presented system IPT stakeholders with lessons learned and opportunities for improvement. Generic lessons-learned talking points from the 16 June AAR, such as "Things don't always go as planned in the field as they do in the lab", and "Proper preparation contributes to a successful demo" were mentioned, but a more detailed, technology-specific lessons-learned review is appropriate here.

GFD: Most of the lessons learned came from the TVGM GFD circuits. Most GFD trips occurred whenever ground systems from different TVGMs interacted with each other, resulting in disabling some or all of the system outputs.

1. **Ground wire cross-conduction**: Sole symptom was TVGM outputs being disabled, causing grid at load end to partially collapse. Cause was identified by taking ground resistance measurements, and tracing all possible points of contact (ground wires and metallic cable shields/wire meshes) between separate TVGMs. Confirmed by deliberately touching two ground wires together, triggering a GFD trip. This was mitigated/remediated by separating and insulating ground wires and cable shields from each other.
2. **Ground moisture**: Wetter/damper ground also caused GFD trips, where dry ground did not. Remediation plan – equip all TVGMs with grounding kits that have insulated ground wires from system connection to grounding spikes.
3. **Shore-power switchover**: Cable shields touching at the PDISE boxes (load end), for even an instant, caused trips. This was remedied by disconnecting all loads for a particular TVGM from shore power BEFORE connecting them to the PDISEs, thus eliminating load-end cross-conduction.
4. **Spurious (undetermined) GFD trips**: Causes were never identified. To eliminate further nuisance trips, this was remedied by disabling the GFD circuit's trip function while retaining its advisory function only. GFD detection was maintained at the energy storage units and vehicles.
5. **GFD location/implementation**: As was done on TQGs, it was recognized that GFD is not implemented at the TQG and is implemented at/near the load. As experienced, the further upstream the GFD function is placed, the wider the power disruption when trip(s) occur.

As the project moves forward to further develop the V2G/V2V technology, TARDEC has identified several areas for improvement. First is weight and size. This is a prototype system. Making sure the system worked and management of time were most critical, so acceptance on size and weight was relaxed. With improved packaging, TVGM and ESU weight and size will come down by two-thirds and one-half, respectively. Eliminating GFD as well as decreasing system boot-up time will increase system robustness. Identified opportunities for improvements in V2G system efficiency are:

- Trickle charging of vehicle low voltage batteries to prevent them from draining and running the engine only to charge the low voltage battery – 3%
- Variable speed engine management of the MRAP engines – 3%
- Minimizing energy storage unit cycling – 1%
- More time for system optimization – 2%

5.8 WWT-D2 Results and Discussion

Table 15 shows the results for continuous operation of the WWT-D2 for the period 6-19 June.

Table 15: WWT-D2 Results

Date	Hours of Operation	Energy Consumed (kWh)	Wastewater Influent (gal)	Product Water Effluent* (gal)	Description of Events
6-Jun	24	5.30	72.8	90.5	Troubleshooting effluent flow. Due to gravity discharge, the exit piping added too much back pressure to the system which reduced the discharge flow. Disconnected long discharge line and drained to the septic system.
7-Jun	18	5.56	243.4	85.2	Found system in an idle state – no flow. System is designed to operate continuously. Influent flow started at 0941 and ended at 1007 hours. Continued troubleshooting flow problem, dissolved oxygen, and level transducers. Added chlorine (bleach) to feed chemical tote. Added an additional discharge port for the BioVolt reactor discharge. (NOTE: This new additional line was not metered.)
8-Jun	22	5.94	319.8	69.5	System is now operating but did not produce effluent for two hours today. Conducted maintenance on broken chlorine line. Provided overview and attended focus groups to/for the 82d and 542d.
9-Jun	20	5.78	229.6	118.4	Collected water quality samples. System operated until 0930 before pump failure occurred. Pump was replaced at 1345 hrs and the system was restarted.
10-Jun	23	5.81	379.9	110.6	Continued monitoring the system and operation. Trained the Soldiers on starting the system and monitoring the activity. Replaced temporary feed pump with the original model pump. System down for 1 hour. Power still supplied to the batteries and blowers. Over the weekend Soldiers will check the system twice a day to verify no foamovers. Will also begin collecting effluent in the collection tank on Sunday for sampling on Monday.
11-Jun	24	6.22	515.2	141.3	Unattended weekend operation.
12-Jun	24	6.24	531.4	162.3	Unattended weekend operation. Effluent flow rate decreased around 0800; membranes likely fouled.
13-Jun	24	6.63	516.8	96.9	System operated throughout weekend. Processed 1526 gallons. Continued to monitor the system throughout the day – no faults, no foam-overs.
14-Jun	24	6.60	504.1	104.8	Continued monitoring the system. Collected water quality samples (influent/effluent). Participated in the Leadership Day rehearsal. Soldiers conducted routine maintenance as required on the system.
15-Jun	24	6.58	466.6	90.2	Continued monitoring the system. Not getting the expected quality product water as tested in the laboratory. Collected influent/effluent samples. Provided technical overview information to visitors.
16-Jun	24	6.80	480.2	170.8	Based on 24 hour operation. Continued to monitor the system. Cleaned the DO probe to verify measurement. Compared recorded data with collected data. Collected influent and effluent samples. Began cleaning the area.
17-Jun	24	6.55	412.9	106.1	Processing info for the 7 hour while monitoring. Processed 136 gals.
18-Jun	24	7.00	434.3	135.5	Unattended weekend operation.
19-Jun	24	~6.9	467.2	148.8	Unattended weekend operation. Energy value is extrapolated due to data loss.

*An additional effluent line was added during operation on 7 June to manage the water flow in the system. This additional line was not metered. Therefore, the effluent values captured and reported in this demonstration do not reflect all system output.

The WWT-D2 was operational at the Naval Sea Systems Command (NAVSEA) test facility in Caderock, MD prior to shipment to the BCIL. There was a concern that the active biomass would not easily survive the transportation and setup period to get to the BCIL and return to operation. The Technology Provider worked diligently to feed the bacteria and restore this activity, but the level of success was likely very low. The system was set up, wastewater was pumped into the system, and effluent was discharged. The amounts of wastewater in and product water out, plus the energy consumed by the process, are shown in Table 15. The time-series data for operations on 13 June are graphed below in **Figure 150** along with the power profile.

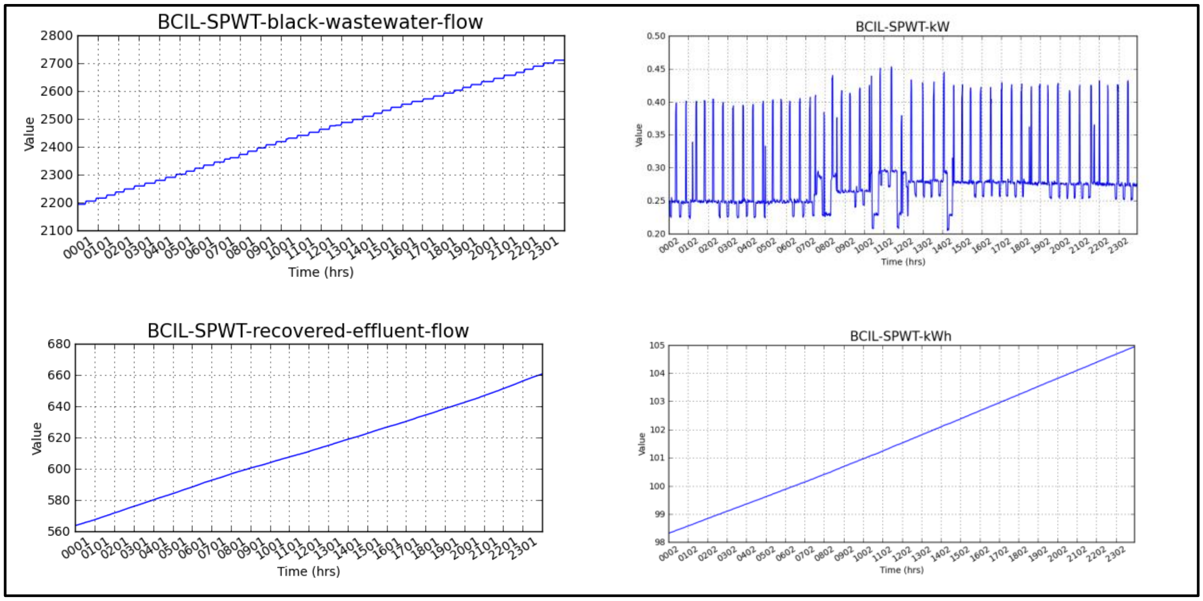


Figure 150: WWT-D2 Results for 13 June

The system operated steadily as seen in the influent and effluent graphs on the left side of the figure. The graph in the upper right quadrant is the power profile and the graph in the lower right quadrant is the energy consumed. The system appears to operate around 250-275 W, with spikes up to 400-450 W. In addition to these data, water quality samples were taken and shipped off for analysis. The results, once known, will help with understanding how well the biomass did or did not survive and the efficiency of this wastewater treatment system.

Lessons Learned: The Project Officer provides the following Lessons Learned regarding the biomass in the system.

Some of the typical issues with Cambrian wastewater treatment that were described in Section 2.8 were encountered during the demonstration of the prototype system at the June 2016 BCIL demonstration. Additional system problems (including a water re-circulation issue and a pump failure) that occurred during the demonstration may have increased the time required to get the system operating in a steady state mode. Signs of a potentially septic system were noted by the operator onsite on 7 June as well as the potential of some membrane fouling. The need to transport and rebuild an active biomass for wastewater treatment is one of the trade-offs that must be considered when deciding to move forward with the best technology solution to meet the Army's needs. With this in mind, TARDEC is exploring a variety of solutions to meet the wastewater treatment need for contingency base camp support and sustainment.

5.9 WQM-PM Results and Discussion

Information in this section was submitted by the Technology Provider and edited for format.

WQM-PM was designed for the GWR-FORO product water, which is highlighted blue in **Table 16** below. The WQM-PM tested the recycled graywater for the target disease-causing organism with limited success in its first field environment test (one failure in eight samples). The field event atmosphere had much pollen landing on the sample pad of the device that blocked the sample flow, causing failure (one in eight samples). Also the STO-D testing discovered that this system can misidentify and count pollen particles as pathogens (average false alarm noise, eight counts). The failures and the false counts can readily be addressed with engineering and software improvements. One positive is that the pathogen monitoring analyzed more difficult waters that were not intended in its mission, such as untreated graywater and treated blackwater with no significant increase in failure rate (4 failures in 19 samples). Turbidity, the water’s cloudiness, was analyzed because it could easily be determined that this would cause failures or false counts, but there is no correlation.

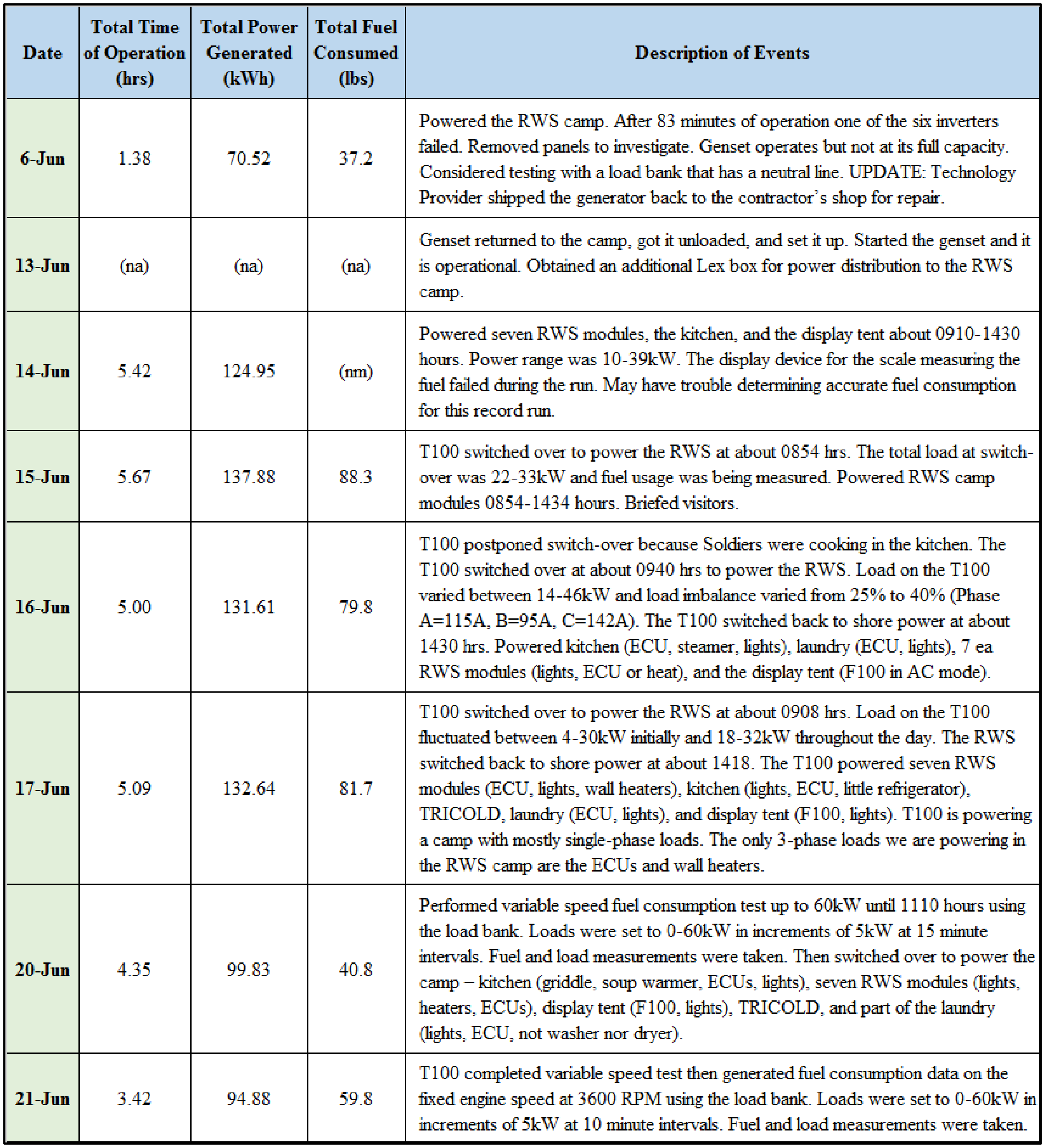
Table 16: WQM-PM Results

Sample	Sample Date	WQM-PM Count	PHC True Result	Successful Analysis? (y/n)	Turbidity NTU
GWR-FORO in	6/7/2016	0	0	y	69
GWR-FORO out	6/7/2016	n/a	0	n	0.28
GWR-FORO in	6/8/2016	3	0	y	64.6
GWR-FORO out	6/8/2016	20	0	y	0.23
WWT-D2 in	6/9/2016	n/a	0	n	885
WWT-D2 out	6/9/2016	0	0	y	7.3
WWT-D2 out	6/13/2016	2	0	y	33.3
GWR-FORO out	6/13/2016	8	0	y	0.91
WWT-D2 out	6/14/2016	20	no measure	y	8.09
GWR-FORO out	6/14/2016	9	no measure	y	0.25
GWR-FORO out	6/14/2016	9	0	y	0.25
WWT-D2 out	6/15/2016	25	0	y	
GWR-FORO in	6/15/2016	n/a	0	n	56.6
GWR-FORO out	6/15/2016	8	0	y	1.58
WWT-D2 out	6/16/2016	4	0	y	3.65
GWR-FORO in	6/16/2016	n/a	no measure	n	56.8
GWR-FORO out	6/16/2016	8	no measure	y	1.51
WWT-D2 out	6/17/2016	1	no measure	y	2.12
GWR-FORO out	6/17/2016	0	no measure	y	0.31

5.10 T100 Results and Discussion

The T100 powered the E2RWS camp and display tent in the east region of the BCIL. During the first day of record runs, 6 June, the system experienced a failure of one of its inverters. The system was shipped back to the vendor, repaired, returned, and able to resume record runs during the second week. **Table 17** shows the daily results for performance of the T100 generator during record runs from 14-17 June and a special event to collect fuel consumption data from 20-21 June.

Table 17: T100 Results



Date	Total Time of Operation (hrs)	Total Power Generated (kWh)	Total Fuel Consumed (lbs)	Description of Events
6-Jun	1.38	70.52	37.2	Powered the RWS camp. After 83 minutes of operation one of the six inverters failed. Removed panels to investigate. Genset operates but not at its full capacity. Considered testing with a load bank that has a neutral line. UPDATE: Technology Provider shipped the generator back to the contractor's shop for repair.
13-Jun	(na)	(na)	(na)	Genset returned to the camp, got it unloaded, and set it up. Started the genset and it is operational. Obtained an additional Lex box for power distribution to the RWS camp.
14-Jun	5.42	124.95	(nm)	Powered seven RWS modules, the kitchen, and the display tent about 0910-1430 hours. Power range was 10-39kW. The display device for the scale measuring the fuel failed during the run. May have trouble determining accurate fuel consumption for this record run.
15-Jun	5.67	137.88	88.3	T100 switched over to power the RWS at about 0854 hrs. The total load at switch-over was 22-33kW and fuel usage was being measured. Powered RWS camp modules 0854-1434 hours. Briefed visitors.
16-Jun	5.00	131.61	79.8	T100 postponed switch-over because Soldiers were cooking in the kitchen. The T100 switched over at about 0940 hrs to power the RWS. Load on the T100 varied between 14-46kW and load imbalance varied from 25% to 40% (Phase A=115A, B=95A, C=142A). The T100 switched back to shore power at about 1430 hrs. Powered kitchen (ECU, steamer, lights), laundry (ECU, lights), 7 ea RWS modules (lights, ECU or heat), and the display tent (F100 in AC mode).
17-Jun	5.09	132.64	81.7	T100 switched over to power the RWS at about 0908 hrs. Load on the T100 fluctuated between 4-30kW initially and 18-32kW throughout the day. The RWS switched back to shore power at about 1418. The T100 powered seven RWS modules (ECU, lights, wall heaters), kitchen (lights, ECU, little refrigerator), TRICOLD, laundry (ECU, lights), and display tent (F100, lights). T100 is powering a camp with mostly single-phase loads. The only 3-phase loads we are powering in the RWS camp are the ECUs and wall heaters.
20-Jun	4.35	99.83	40.8	Performed variable speed fuel consumption test up to 60kW until 1110 hours using the load bank. Loads were set to 0-60kW in increments of 5kW at 15 minute intervals. Fuel and load measurements were taken. Then switched over to power the camp – kitchen (griddle, soup warmer, ECUs, lights), seven RWS modules (lights, heaters, ECUs), display tent (F100, lights), TRICOLD, and part of the laundry (lights, ECU, not washer nor dryer).
21-Jun	3.42	94.88	59.8	T100 completed variable speed test then generated fuel consumption data on the fixed engine speed at 3600 RPM using the load bank. Loads were set to 0-60kW in increments of 5kW at 10 minute intervals. Fuel and load measurements were taken.

The graphs in **Figure 151** and **Figure 152** show the power data and energy data, respectively, for operations on 17 June. This is a typical load profile for the power demand of the combined E2RWS modules and the display tent with F100 ECU powered by the T100 during record runs. Most of the cycling seen in the graph would be due to air conditioning units turning compressors ON and OFF.

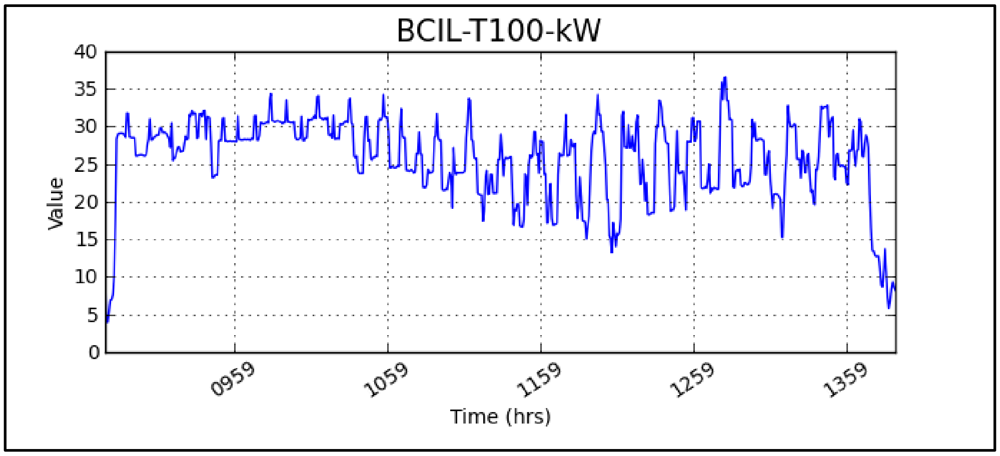


Figure 151: T100 Power Data for 17 June

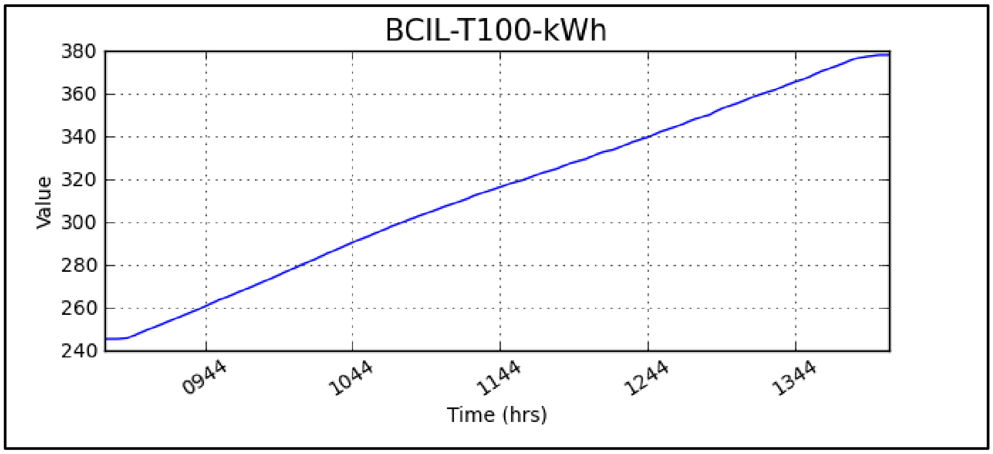


Figure 152: T100 Energy Data for 17 June

By contrast, **Figure 153** and **Figure 154** show the power and energy data, respectively, for the quick-scan fuel consumption data collection on 21 June using a load bank instead of the operational load. The first two peaks in the power graph represent the completion of the variable speed data collection started the previous day, on 20 June. The remainder of the data points show the stepwise data collection with the engine at constant speed, 3600 rpm. **Figure 155** plots the derivative of the energy consumed by the T100 on 21 June.

The raw data for both the variable speed and fixed speed quick-scan fuel consumption data collection are shown in **Table 18** and **Table 19**. These data were collected and submitted by the Technology Provider, but were not authenticated by the DAG. These data therefore are not included in the DDS, but are included here for informational purposes.

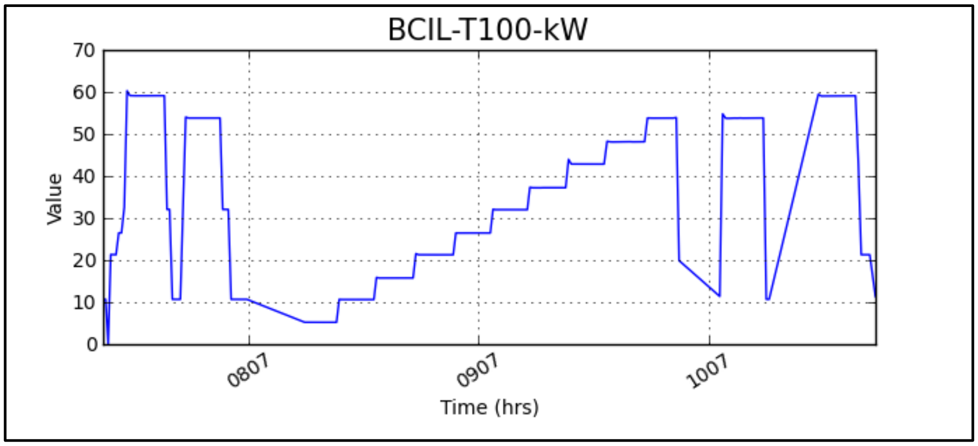


Figure 153: T100 Power Data During Fuel Consumption Data Collection

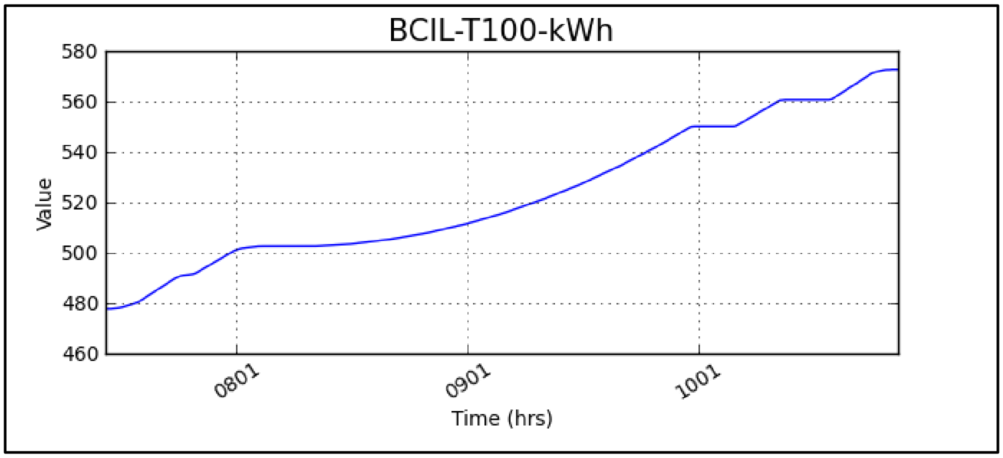


Figure 154: T100 Energy Data During Fuel Consumption Data Collection

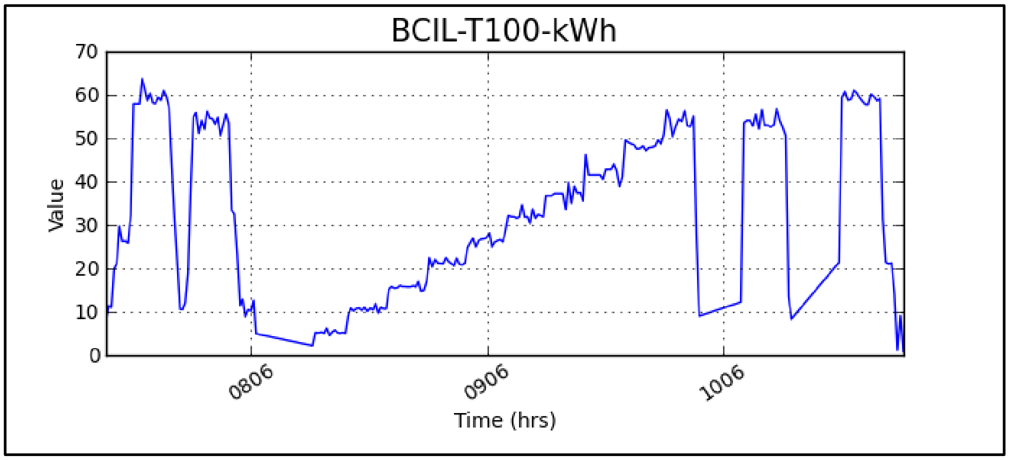


Figure 155: Derivative of T100 Energy Data

Table 18: T100 Variable Speed Power and Fuel Data

T-100 Quick-Scan Fuel Consumption Measurements: Variable Speed

Load Bank Switches (kW)	Shark Meter (kW)	Engine Speed (RPM)	TPS (Volts)	Beginning Fuel (lbs)	Ending Fuel (lbs)	Delta Fuel (lbs)	Delta Fuel (gallons)	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Interval (hh:mm:ss)	Interval (hrs)	Fuel Consumption (gal/hr)
0	0	1,875	1.49	-1.7	-3.8	2.10	0.302	8:16:20	8:39:20	0:23:00	0.3833	0.789
5	5.22	1,800	1.49	-3.8	-5.8	2.00	0.288	8:39:20	8:55:30	0:16:10	0.2694	1.069
10	10.63	1,900	1.62	-5.8	-8.3	2.50	0.360	8:55:30	9:10:00	0:14:30	0.2417	1.490
15	15.75	2,000	1.75	-8.3	-11.5	3.20	0.461	9:10:00	9:25:00	0:15:00	0.2500	1.844
20	21.26	2,100	1.80	-11.5	-15.3	3.80	0.547	9:25:00	9:40:00	0:15:00	0.2500	2.189
25	26.44	2,175	1.90	-15.3	-19.6	4.30	0.619	9:40:00	9:55:00	0:15:00	0.2500	2.477
30	31.98	2,250	1.98	-19.6	-24.4	4.80	0.691	9:55:00	10:10:00	0:15:00	0.2500	2.765
35	37.18	2,325	2.03	-24.4	-29.9	5.50	0.792	10:10:00	10:25:00	0:15:00	0.2500	3.169
40	42.81	2,475	2.14	-29.9	-35.9	6.00	0.864	10:25:00	10:40:00	0:15:00	0.2500	3.457
45	48.09	2,575	2.25	-35.9	-42.5	6.60	0.951	10:40:00	10:55:00	0:15:00	0.2500	3.802
50	53.74	2,725	2.35	-9.3	-14.5	5.20	0.749	7:50:00	8:00:00	0:10:00	0.1667	4.494
55	59.05	2,775	2.44	-2.6	-8.2	5.60	0.807	7:35:00	7:45:00	0:10:00	0.1667	4.839

Submitted by Spectrum Research Corporation.

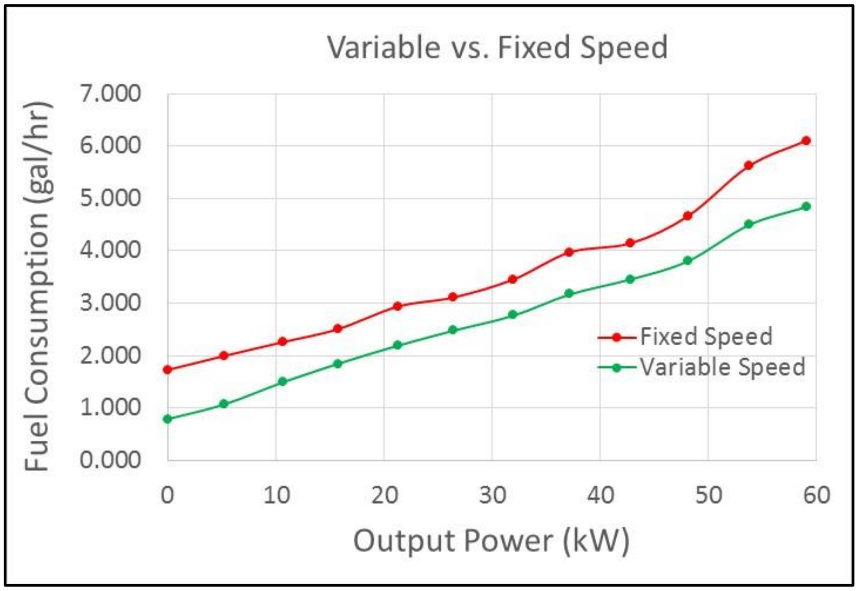
Table 19: T100 Fixed Speed Power and Fuel Data

T-100 Quick-Scan Fuel Consumption Measurements: Fixed Speed

Load Bank Switches (kW)	Shark Meter (kW)	Engine Speed (RPM)	TPS (Volts)	Beginning Fuel (lbs)	Ending Fuel (lbs)	Delta Fuel (lbs)	Delta Fuel (gallons)	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Interval (hh:mm:ss)	Interval (hrs)	Fuel Consumption (gal/hr)
0	0	3600	2.67	-16.3	-18.3	2.00	0.288	8:11:00	8:21:00	0:10:00	0.1667	1.728
5	5.22	3600	2.72	-18.3	-20.3	2.00	0.288	8:21:00	8:29:40	0:08:40	0.1444	1.994
10	10.63	3600	2.75	-20.3	-23.0	2.70	0.389	8:29:40	8:40:00	0:10:20	0.1722	2.258
15	15.74	3600	2.79	-23.0	-25.9	2.90	0.418	8:40:00	8:50:00	0:10:00	0.1667	2.506
20	21.28	3600	2.84	-25.9	-29.3	3.40	0.490	8:50:00	9:00:00	0:10:00	0.1667	2.938
25	26.43	3600	2.84	-29.3	-32.9	3.60	0.519	9:00:00	9:10:00	0:10:00	0.1667	3.111
30	31.98	3600	2.87	-32.9	-36.9	4.00	0.576	9:10:00	9:20:00	0:10:00	0.1667	3.457
35	37.20	3600	2.89	-36.9	-41.5	4.60	0.663	9:20:00	9:30:00	0:10:00	0.1667	3.975
40	42.84	3600	2.89	-41.5	-46.3	4.80	0.691	9:30:00	9:40:00	0:10:00	0.1667	4.148
45	48.12	3600	2.92	-46.3	-51.7	5.40	0.778	9:40:00	9:50:00	0:10:00	0.1667	4.667
50	53.72	3600	2.93	-57.3	-63.8	6.50	0.936	10:10:15	10:20:15	0:10:00	0.1667	5.617
55	59.05	3600	2.93	-65.5	-72.8	7.30	1.051	10:35:00	10:45:20	0:10:20	0.1722	6.105

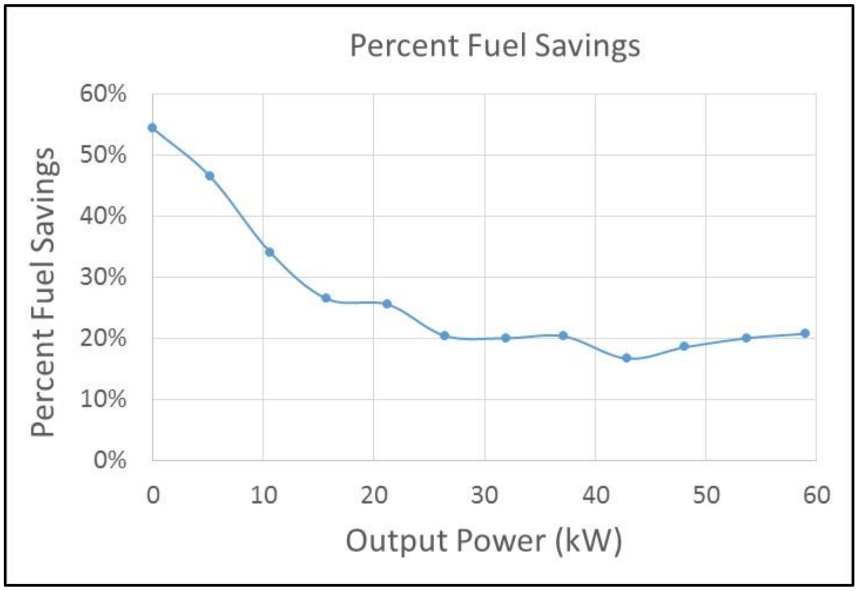
Submitted by Spectrum Research Corporation.

The data show there is indeed a fuel savings from operation in variable speed. **Figure 156** shows the fuel consumption rate as a function of power for each mode. **Figure 157** shows the percentage of fuel savings in the variable mode as a function of power, averaging about 20% fuel savings at operational loads.



Submitted by Spectrum Research Corporation

Figure 156: T100 Fuel Consumption Rate Variable vs. Fixed Speed



Submitted by Spectrum Research Corporation

Figure 157: T100 Percent Fuel Savings Variable vs. Fixed Speed

Lessons Learned: The Technology Provider submitted the following Lessons Learned.

Operational environments can be very different from those found in a laboratory. As one example: in preparation for meeting the SLB-STO-D entrance requirements, the T100 was tested at both the contractor’s facility and at Aberdeen Proving Ground using commercial load banks.

The T100 provided stable performance during these prequalification tests, yet while operating under the realistic loads found in the BCIL east camp, a small-signal engine speed instability was observed. This was undoubtedly caused by some combination of small-signal load fluctuations, single-phase unbalanced loads, rapid load cycling (thermostats), and high inrush currents. Fortunately, this issue was quickly resolved through a firmware modification. For future development efforts, the vendor plans to upgrade its in-house testing capabilities to better replicate realistic loads in a controlled laboratory setting.

Military power sources must be designed and tested to the point of failure so that it is known where those limits exist. During the second day of pilot record runs, one of the T100 inverter legs was loaded far in excess of the 100 kW system rating. As a result, one of the inverter modules sustained arc damage, which in all likelihood precipitated from a radiofrequency corona discharge. Possible root causes include parasitic inductive voltage spikes on the DC bus, or external arcing on the load side, perhaps caused by a loose power connection.

While the T100 will be upgraded to guard against these and other possible root causes, the T100 subsystems must be packaged into an even more modular format so that they can be quickly repaired in the field.

5.11 SPSWH Results and Discussion

The SPSWH was employed to preheat water entering the AWH-400 for the South Camp shower system. The hypothesis was that the AWH-400 would use less fuel if the incoming water was preheated. This demonstration was not able to definitively show a significant fuel savings by preheating water with the SPSWH, but the system did perform and generate hot water on a daily basis.

The daily results are shown in **Table 20**. Each dataset is for the 90-min script unless otherwise indicated.

“Average input water temperature” is the temperature of the water coming out of the source bladder and entering the three-way switch en route to either the SPSWH or the AWH-400. The temperature varies based on climatic conditions.

“Amount of water heated” is the amount of the water routed to the SPSWH during the script or routed directly to the AWH-400. This value exceeds 70 gal for the 90 min during the bypass script (*AWH-400 only*) but is routinely lower during the *SPSWH inline* script.

“Average SPSWH output water temperature” shows the temperature of the water coming out of the SPSWH and entering the AWH-400. The difference between this temperature and the input water temperature is a reflection of the performance of the SPSWH under the current conditions.

“Average AWH-400 output water temperature” is the temperature of the water exiting the AWH-400 and entering the shower for both scripts. These values are relatively constant. In the case of the *AWH-400 only* script, the data reflect the heating of the water from the average input water temperature to the AWH-400 output water temperature. In the case of the *SPSWH inline* script, this reflects the heating of the water from the average SPSWH output water temperature to the AWH-400 output water temperature.

Table 20: SPSWH Results

Date	Design	Description of Events	Avg Input Water Temp (F)	Amt of Water Heated (gal)	Avg SPSWH Output Water Temp (F)	Avg AWH400 Output Water Temp (F)	Fuel Consumed by AWH400 (lbs)	Comment on Fuel Usage
6-Jun	SPSWH inline	Starting temperature of the TSD was 73.4°F at 0740 hours. The water temp was the same. The morning was partly sunny and the afternoon had full sun. Delivered hot water at 105°F continuously to shower for 90 minutes, 1210-1340 hours. System battery charged maintained at 100%.	71.84	50.30	106.12	129.37	13.9	Not filled in the morning, so this fuel usage represents holding water temperature over several days plus today's script.
7-Jun	AWH400 only	Initiated operation at 0800, however cloudy conditions forced us to shut down by 0900 hours. Ran hot water in the showers for 90 minutes, 1207-1337 hours as a baseline test for the AWH400 without the SPSWH heating any water.	73.54	76.50		131.15	18.7	This value includes overnight usage plus fuel consumed during the script.
8-Jun	SPSWH inline	Started up at 0730. Fully operational with sun in the morning and cloudy after noon. Hot water delivered to shower at 0.6 gpm, 105°F, for two hours continuous flow. Delivered to a single 1.5 gpm showerhead. **Data collection failed so data shown here are for the first 75 minutes of the script.**	74.20	43.60	106.69	131.07	0.4	This value represents fuel consumed during the script.
9-Jun	AWH400 only	Started up at 0730 with cloudy skies. Cleaned pollen off the mirrors. Sun started to break through clouds at 1000 hrs. Achieved TSD temperature of 135°C, which falls well under the target heating threshold, yet did produce 112°F water temperature at the outlet.	67.95	73.30		132.31	2.9	Added 25.4 pounds in the morning representing Soldier use of the showers after hours. The value to the left represents fuel consumed during the script
10-Jun	AWH400 only	System operated 0730-1200 hours. Shut down system 1200-1300 hours by aiming mirrors away from the sun. Resumed operation after lunch. Repeated 90-minute record run on the AWH400 operation.	68.55	73.00		130.66	1.9	Added 20.9 pounds in the morning representing Soldier use of the showers after hours. The value to the left represents fuel consumed during the script.
13-Jun	SPSWH inline	Started up SPSWH system at 0730 hours. Operated in mostly sunny conditions in morning and mostly cloudy in the afternoon. Completed record run with SPSWH delivering about 105°F water to shower.	65.80	55.00	96.61	130.21	0.0	73.9 lbs added in morning representing weekend usage of the water heater. No fuel added after script since there was no discernible difference on the dipstick.
14-Jun	none	NO Water available* Full sun with low humidity provided strong solar insolation with the TSD reaching a maximum temperature of 384°C. However, the thermocouple in the TSD faulted at 1415 hrs this afternoon.					0.0	28.3 lbs added in the morning representing fuel used overnight. No fuel added after script since there was no discernible difference on the dipstick.
15-Jun	SPSWH inline	Repaired thermocouple with alternate type J thermocouple and system started up in full sun by 0800 hours. Delivered hot water to showers and demo sink simultaneously. Maintained outlet water temperature at about 115°F. Briefed visitors.	72.91	46.50	124.43	124.67	0.0	No fuel added after script since there was no discernible difference on the dipstick.
16-Jun	SPSWH inline	Ran scripts. Initiated operation at 0730 hrs under hazy, partly sunny conditions. Sun slowly became full by 1145, producing a rapid increase in TSD and outlet water temperatures. Began record run of SPSWH at 1215 hours.	75.00	51.00	105.30	128.30	2.4	12.2 lbs in morning; 5.5 lbs added before script. Value to the left represents fuel consumed during script.
17-Jun	AWH400 only	Intiated breaking down the SPSWH. Conducted a run for the AWH400. Pump lost prime when power was accidently cut to the grid.	73.02	71.80		129.57	0.0	19.2 lbs added in the morning representing fuel used overnight. No fuel added after script since there was no discernible difference on the dipstick.

Data from 13 June show the potential impact of weather on the system. The output temperature for the SPSWH was the lowest, about 96 °F during the script on this day. This can be explained by looking at the solar conditions. In **Figure 158**, the pink line is the solar radiation. The data show that there were sunny conditions at the start of the script at 1200 h (**Figure 159**). However, over the course of the next 90 min there is much less solar radiation. A corresponding dip in the input water temperature is seen in **Figure 160**. The SPSWH must overcome a lower input water temperature and there is less solar radiation to heat the water.

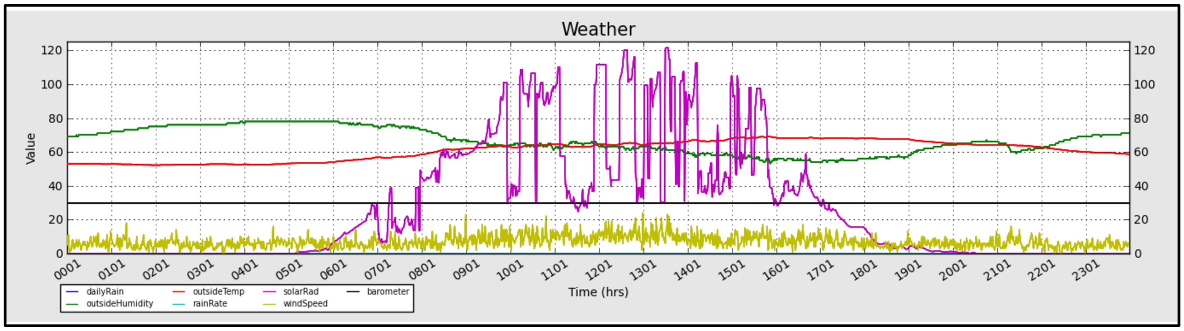


Figure 158: Weather Data 13 June

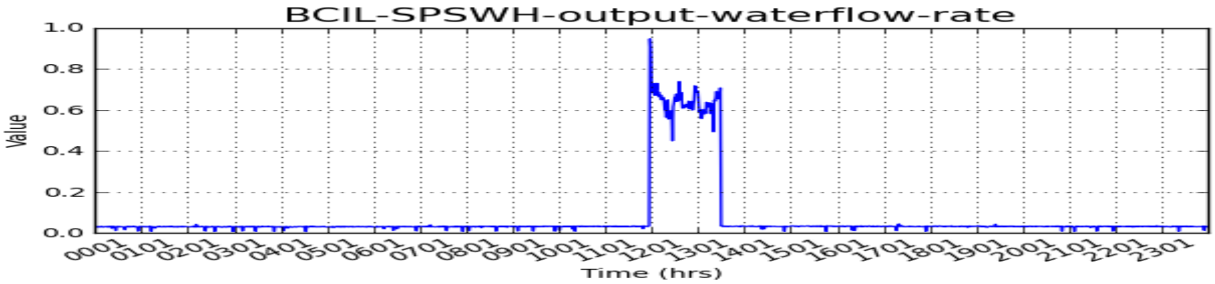


Figure 159: SPSWH Output Flow

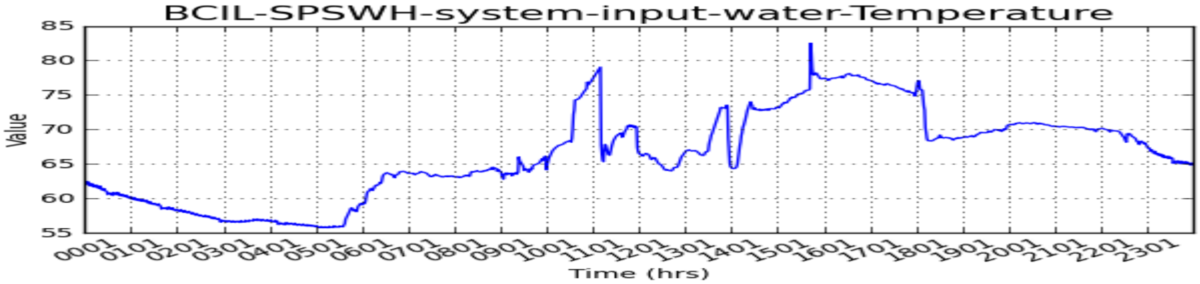


Figure 160: Input Water Temperature

The fuel data in **Table 20** generally show the fuel consumed by the AWH-400 during conduct of the 90-min scripts. As it turned out, the scripts were too short to definitively show the fuel savings based on preheating the water with the SPSWH. The technique to measure the level of the fuel in the external fuel barrel was not very precise. A couple of pounds of diesel is less than half a gallon, and that small amount is difficult to distinguish in a barrel.

Lessons Learned:

Assembly of the system required materiel handling equipment to lift the thermal storage device, which was quite heavy. During this operation, a bolt was sheared when too much tension was applied. The shorter bolt should have been used. In the future, the different bolts will be more clearly indicated.

During cloudy conditions the system could not automatically track the sun. When the sun reappeared, the solar radiation was focused somewhere other than the center of the dish. In one instance this caused some insulation to burn. During the demonstration the system had to be manned continuously, and then manually adjusted as required, to prevent further damage.

The demonstration showed there was temperature loss in the water hose between the SPSWH and the water's ultimate destination. The setup could not deliver the heated water as quickly as desired. The water line (100 ft) that connected the SPSWH to the AWH-400 water heater caused cooler water in the line to enter the AWH-400, which triggered the AWH-400 to start heating the water coming in the line. This impacted the fuel saving ability of the SPSWH because it turned on the AWH-400 prematurely.

In an operational setting of demand for hot water, such as multiple showers, the SPSWH cannot draw thermal energy from its thermal storage device fast enough to maintain the required output temperature of 130 °F. Also, the SPSWH cannot operate at the 70 psi pressure provided by the fresh water pump, which resulted in decreased pressure at the shower head. These are interoperability issues.

5.12 EIO-C Results and Discussion

The EIO-C grid powered the South Camp during the demonstration. The daily schedule of operations with notes for six days of record runs are shown in **Table 21**.

Table 21: EIO-C Operations

Date	Start Time	Stop Time	Load	Comments
9-Jun	12:40	14:40	South Camp	Trained Soldiers on EIO. Gained insights and feedback on how to improve the grid and application. Participated in focus group meetings. Exposed Soldiers to future power solutions. Powered grid 1240-1440 hours (late due to participation in training and focus group).
10-Jun	10:00	14:30	South Camp	Soldiers helped power up the South Camp (Shelters 1-8, 19, 20, and 22, Latrines 17-18). Soldiers commented that the procedure is very intuitive. Performed grid e-stop test.
13-Jun	10:00	14:15	South Camp	Successfully ran grid. Soldiers started the grid and performed operations on the EIO application.
15-Jun	8:00	15:00	South Camp	Powered grid as inverter/generator grid and then all-generator grid. Demonstrated successful grid resilience. Worked with Soldiers on the EIO application. Briefed visitors.
16-Jun	9:00	14:45	South Camp, plus washer and dryer	Ran the South Camp grid from 0900 to 1445 hours without failure. From 1340 to 1430 hours the grid was able to power the camp with the washer and dryer.
17-Jun	8:00	12:45	South Camp, plus washer and dryer	Powered all load on context diagram. Broke down grid & started prep for shipping.

The Technology Provider collected data on fuel and inverter usage and submitted the following results and discussion.

Actual fuel usage for the demonstration is shown in **Table 22**.

Table 22: EIO-C Fuel Usage

	Fuel Consumed by Each Generator (gal)					
Generator	**9-Jun**	**10-Jun**	**13-Jun**	**15-Jun**	**16-Jun**	**17-Jun**
60kW HX71645	3.07	7.69	8.04	15.8	18.68	0.04
30kW HX38940	0	0.52	0	4.23	0.26	6.76
30kW HX38941	0	0.1	0	1.07	0.03	7.07
Daily Totals	3.07	8.31	8.04	21.10	18.97	13.87

Based on calculations of the fuel usage compared to an assumed baseline, the EIO-C grid performed extremely well. To assess potential fuel savings of the EIO-C grid, the following assumptions were made about a possible baseline:

- Tents 1, 2, and 3 are powered by a single 60 kW TQG with an average load of 22.86 kW (one ECU on COOL, two on VENT, and 2.62 kW of internal convenience load) for the entire day.
- Tents 4, 5, and 6 are also powered by a single 60 kW TQG with the same average load of 22.86 kW.
- Tents 7 and 8 and the kitchen tent are also powered by a single 60 kW TQG with the same average load of 22.86 kW.
- The two showers are powered by a single 60 kW generator with an assumed load of 47.5 kW.
- The two latrines are powered by a single 60 kW generator with an assumed load of 23.06 kW.
- The Laundry is powered by a single 60 kW generator with a load of 34.34 kW.

Fuel consumption calculations are shown in **Table 23**. In the calculation the assumed baseline was "operational" for the same runtime hours as the record runs.

Table 23: Predicted Fuel Consumption for Assumed Baseline

			9-Jun		10-Jun		13-Jun		15-Jun		16-Jun		17-Jun	
Loads	Estimated Load (kW)	Fuel (gal/hr)	Hours	Gallons	Hours	Gallons	Hours	Gallons	Hours	Gallons	Hours	Gallons	Hours	Gallons
Tents 1, 2 &3	22.86	2.27	2.00	4.54	4.50	10.22	4.25	9.65	7.00	15.90	5.75	13.06	4.75	10.79
Tents 4, 5 &6	22.86	2.27	2.00	4.54	4.50	10.22	4.25	9.65	7.00	15.90	5.75	13.06	4.75	10.79
Tents 7, 8 &kitchen	22.86	2.27	2.00	4.54	4.50	10.22	4.25	9.65	7.00	15.90	5.75	13.06	4.75	10.79
2 Showers	47.50	3.89	2.00	7.78	4.50	17.50	4.25	16.52	7.00	27.22	5.75	22.36	4.75	18.47
2 Latrines	23.06	2.28	2.00	4.57	4.50	10.27	4.25	9.70	7.00	15.98	5.75	13.13	4.75	10.84
Laundry (only 16&17 June)	34.34	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	3.00	4.75	14.24
Totals				25.97		58.42		55.18		90.88		77.65		75.91

The predicted fuel savings for the record runs are shown in **Table 24**. Fewer generators were used in the grid than in the assumed baseline and the amount of fuel consumed was significantly smaller versus the baseline.

Table 24: EIO-C Predicted Fuel Savings

Fuel Consumption and Predicted Savings (gal)			
	Calculated Actual	Predicted Baseline	Savings
9-Jun	3.07	25.97	22.90
10-Jun	8.31	58.42	50.11
13-Jun	8.04	55.18	47.14
15-Jun	21.10	90.88	69.78
16-Jun	18.97	77.65	58.68
17-Jun	13.87	75.91	62.04

Other benefits of having the energy storage/inverter system on the grid include runtime savings of generators and increased generator efficiency. Runtime savings occurs when the ability of the energy storage system to provide power eliminates the need for the grid to turn on an additional generator. At the BCIL demonstration, the grid algorithm would turn ON a new generator when the current generator reached 80% of its generation capacity for a minimum of 15 s and turn OFF a generator when operating at only 39% or less of capacity. Due to a less demanding load at the BCIL, a minimal runtime savings was actually realized (**Table 25**). On 16 and 17 June the inverter was a functioning part of the grid and there was the potential for small savings on these two days. In the future, this is a parameter that has potential to be optimized, allowing for a much larger savings in generator runtime.

Table 25: Generator Runtime Savings

Date	Runtime Savings (minutes)
9-Jun	0.00
10-Jun	0.00
13-Jun	0.00
15-Jun	0.00
16-Jun	0.22
17-Jun	0.17

In situations when the energy storage system is charging, there is potential for generators to be running at a more efficient point on their fuel curves, allowing more usable power per gallon. These numbers can be seen in **Table 26**, and encompass all of the points that the battery system charging kept the running generators at a load above 70% of their generation capacity. Similar to the runtime savings, this was also not a factor in the grid control algorithm, but with further development it can be optimized for greater efficiency.

Table 26: Battery Charging Time

Date	Battery Charging Time (minutes)	% of Daily Runtime
9-Jun	0.00	0.00%
10-Jun	1.27	0.47%
13-Jun	0.20	0.08%
15-Jun	8.67	2.06%
16-Jun	52.67	15.27%
17-Jun	49.13	17.24%

Another interesting situation considered in post-demonstration data analysis was if the 60 kW generator on the grid had been replaced with two 30 kW generators, for a total of four 30 kW generators on a hypothetical grid. This would have been more optimal in some cases, but not in others, and was largely a function of what the load on the 60 kW happened to be. Having two 30 kW generators instead of a 60 kW would result in greater runtime savings for most days (**Table 27**), but would not have a significant effect on fuel consumption (**Table 28** and **Table 29**) or increased generator efficiency during battery charging times (**Table 30**) based on the variety of loads experienced during record runs.

Table 27: Hypothetical Runtime Savings

Date	Hypothetical Runtime Savings (minutes)	Actual	Change in Minutes Saved
9-Jun	0.00	0.00	0.00
10-Jun	0.00	0.00	0.00
15-Jun	1.80	0.00	1.80
16-Jun	0.22	0.22	0.00
17-Jun	0.17	0.17	0.00

Table 28: Hypothetical Fuel Consumption

	Fuel Consumed by Each Generator (hypothetical grid with 4 ea 30 kW TQGs)					
Generator	**9-Jun**	**10-Jun**	**13-Jun**	**15-Jun**	**16-Jun**	**17-Jun**
Hypothetical 30kW A	2.51	6.59	6.94	9.72	10.95	0.1
Hypothetical 30 kW B	0	0	0.27	7.86	10.03	0
30kW HX38940	0	0.52	0	4.23	0.12	6.76
30kW HX38941	0	0.1	0	1.07	0.03	7.07
Daily Totals	2.51	7.21	7.21	22.88	21.13	13.93

Table 29: Hypothetical Fuel Savings

Date	Calculated Hypothetical	Calculated Actual	Savings
9-Jun	2.51	3.07	0.56
10-Jun	7.21	8.31	1.1
13-Jun	7.21	8.04	0.83
15-Jun	22.88	21.1	-1.78
16-Jun	21.13	18.97	-2.16
17-Jun	13.93	13.87	-0.06

Table 30: Hypothetical Battery Charging Times

Date	Hypothetical Battery Charging Time (minutes)	Actual	Change in Minutes at Increased Efficiency
9-Jun	0.80	0.00	0.80
10-Jun	2.92	1.27	1.65
13-Jun	16.48	0.20	16.28
15-Jun	0.70	8.67	-7.97
16-Jun	79.12	52.67	26.45
17-Jun	49.13	49.13	0.00

Lessons Learned: Overall, the grid contributed to significant fuel savings. The inverter/battery system resulted in small reductions in generator runtime and increases in generator efficiency, but more importantly, showed that these parameters have the potential to be optimized with a more developed grid control algorithm and should result in greater improvements in the future. In terms of the grid including inverter compared to no inverter, CERDEC is still working on those numbers but hope to have them soon to fully show the benefits of its addition to the EIO grid.

5.13 Soldier Feedback and Findings

See ANNEX D for reports from the Soldier focus groups.

5.14 Leadership Day

On 15 June, the SLB-STO-D program held a Leadership Day with the objectives of:

Figure 161: Informational Briefings

- Informing stakeholders on the status of the SLB-STO-D (**Figure 161**)
- Emphasizing participating technologies at the SLB-STO-D Demonstration #2 at the BCIL (**Figure 162**)
- Highlighting Demonstration #2 at the BCIL as the culminating event for five technology demonstrations and to underscore the importance for the systems engineering and integrated technology demonstrations to continue past FY17.

Figure 162: Tour of Participating Technologies

The event started with the presentation of an overview of the SLB-STO-D Technology Provider organizations. The SLB-STO-D lead followed by briefing the program overview and accomplishments to date, as well as the *Soldier Quality of Life* tool update. Also, an overview of the technology thrust area in energy/fuel and water demand reduction, solid waste reduction, and basing simulation and planning tools was presented. AMSAA gave an overview of the operational energy support to the SLB-STO-D. To conclude the Leadership Day, the stakeholders toured the 15 technologies being demonstrated at the BCIL, followed by discussion of the path forward and final remarks.

The event was attended by over 100 of SLB-STO-D's stakeholders from different services and ranks. Participating high ranking stakeholders included Mr. Jyuji Hewitt, Executive Deputy to the Commanding General of the U.S. Army Research, Development and Engineering Command (**Figure 163**). Mr. Hewitt opened the event by underscoring the success of the SLB-STO-D's efforts, and stated that "It takes a team of teams. It's really all focused on not only our Soldiers, but our joint force." Also, Ms. Katherine Hammack, ASA IEE (**Figure 164**), recognized SLB-STO-D's membership and emphasized the importance of collaboration.

Figure 163: Mr. Jyuji Hewitt, RDECOM

Figure 164: Honorable Katherine Hammack, ASA (IEE)

6. CONCLUSIONS

This BCIL demonstration met the objectives of the CLT's strategic guidance for conduct of demonstrations with one exception. Objective 2 for NMS was not included in this demonstration.

Objective 1: Collect empirical data on candidate technologies and baseline systems that can be used to calibrate modeling, simulation, and analysis, and support trade-offs and engineering decisions (main effort).

- ✓ This objective was met for all technologies in accordance with the DSM. The data have been delivered to the Lead Systems Engineer.

Objective 3: Collect data on QoL at the camp.

- ✓ This objective was met by including Soldiers in training and focus groups. Maintaining a QoL is an inherent requirement of the SLB-STO-D challenge.

Objective 4: Show how SLB-STO-D meets Contingency Basing and Operational Energy (OE) gaps.

- ✓ This objective was met by demonstrating technologies that will save fuel and reduce the amount of water required and reduce the amount of waste backhauled from contingency base camps. Data collected from demonstration will help inform related Capability Development Documents and Capability Based Assessments.

Objective 5: Showcase any "Wow Factors," i.e., the materiel and non-materiel game changers.

- ✓ This objective was met by inviting key leadership to the event to observe the candidate technologies in the field. Also included in the event were certain technologies that did not participate in data collection, but were included in the Leadership Day presentations.

Objective 6: Present modeling and simulation methods and results as part of the demonstration through visual and physical displays, such as posters and computer representations of models.

- ✓ Although not documented in this report, this objective was met during the activities of Leadership Day. The MSAT tools, current findings, and approach were presented to the key leaders in attendance and posters with many of these details were featured in the display tent during demonstration.

Comments/Observations:

CIMT: This system is a first-generation prototype. It successfully demonstrated the capability to produce and bag ice. While a final production unit should require only minimal human interaction, this unit required vigilant supervision to keep making ice continuously. The important feature was shipping this system out of the lab and getting it into the field and operational under realistic conditions. The vendor learned much about minor issues in the mechanical operation (bagger, conveyor, etc.) as well as improvements required in the software (harvesting, defrosting, etc.).

WDR: The hypothesis driving the data collection for the WDR revolved around the question of whether the use of low-flow showerheads increases the shower duration times, thus reducing the water savings impact of the showerheads. This hypothesis was not as straightforward as originally thought, as there are numerous operational variables that could drive length of showers other than the rate or quality of the water flow. Schedule pressure, leadership, enemy situation, unit standard operational procedures, seasonal time of year, water resupply expectations, etc. could have various and perhaps significant impacts on shower water usage. Low-flow versus standard showerheads are just a piece of the bigger picture for water conservation.

SLiM: The system was monitored to ascertain the performance of the electrical system (i.e., PV panel array, batteries, and generator backup). Charging rates, system overload capacity, and system startup lag times were determined and documented.

MILHUT: The evaporative cooler is likely not a suitable solution under the conditions experienced at this demonstration. The air conditioner was effective for cooling, but unlike an ECU, there was no return duct to move and recirculate air through the shelter.

NPC: During the demonstration, more than 37,000 current-voltage curves were obtained from the PVs. In addition, there was an indication that the PV with nanoparticles showed an improvement over the control PV, at off normal angles of incidence. Because of the large volume of data collected, and the potentially publishable results of improved low-angle power harvesting (which the researcher is seeking to reproduce in small-scale experiments at NSRDEC if funding can be secured), this data and analysis will be reported in a separate report

GWR-FORO: This system operated as intended. The only issues the Technology Provider had to deal with were a failure of the control module and some adjustments to the chlorine injector. A replacement control module was immediately shipped, received, and installed the next day.

V2G/V2V: This system successfully powered the North Camp of the BCIL during the demonstration. As the project moves forward to further develop the V2G/V2V technology, TARDEC has identified several areas for improvement. First is weight and size. This is a prototype system, making sure the system worked and management of time were most critical, so acceptance on size and weight was relaxed. With improved packaging, the TVGM and Energy Storage Unit (ESU) weight and size will come down by two-thirds and one-half, respectively. Eliminating GFD issues as well as decreasing system boot-up time will increase system robustness.

WWT-D2: The Cambrian wastewater treatment system incorporates a biological-based component in the treatment train that requires an active biomass to treat the wastewater. Typically biological-based systems can be difficult to start up rapidly and reliably. It can take a number of days to a number of weeks to get the biomass up and running at an optimal rate (i.e., it takes time for the bugs to grow). The introduction of wastewater with high organic carbon content will also increase the reaction rate. If the microorganisms reproduce too quickly, the oxygen in the water can be depleted, causing the system biomass to become anaerobic and go septic, which could require the need to rebuild or reseed the system to keep the treatment at the desired rate. Some of these typical issues were encountered during the demonstration. TARDEC is exploring a variety of solutions to meet the wastewater treatment need for contingency base camp support and sustainment.

WQM-PM: The WQM-PM system operated with limited success during the first field exercise of the first generation prototype. The STO-D event was valuable in determining unexpected failure modes for airborne debris. This prototype has potential to perform its intended mission after engineering refinement based on this STO-D experience.

T100: The T100 successfully powered the Rigid Wall Shelter base camp on the east side of the BCIL during the demonstration. The differences between laboratory testing (i.e., using load banks) and an operational environment (i.e., actual resistive and reactive electrical loads) were evident and prompted firmware modifications to fix minor engine speed instability. An unexpected inverter leg failure occurred due to overloading and was fixed at the contractor’s facility in order to continue participation in the demonstration. Consequently, the T100 will be upgraded to preclude the aforementioned incidents and be packaged in a modular format to ease maintenance and repairs in the field.

SPSWH: The SPSWH system successfully heated water during the demonstration. However, during cloudy conditions the system could not automatically track the sun, and the system would not track properly when the sun reappeared. This situation demanded constant manual adjustments and needs to be addressed in future design improvements. Heat losses in the hot water hose between the SPSWH and the AWH-400 also need to be addressed, as it caused the AWH-400 to reheat the water and had an impact on fuel savings. Other interoperability issues uncovered related to the ability to keep up with the demand for hot water and compatibility with the operating pressures of the BCIL’s existing fresh water pump.

EIO-C: Overall, the grid contributed to significant fuel savings. The inverter/battery system resulted in small reductions in generator runtime and increases in generator efficiency, but more importantly, showed that these parameters have the potential to be optimized with a more developed grid control algorithm and should result in greater improvements in the future.

This document reports research undertaken at the
U.S. Army Natick Soldier Research, Development and
Engineering Center, Natick, MA, and has been
assigned No. NATICK/TR- 17/025 in a
series of reports approved for publication.

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LIST OF ACRONYMS

AAR	After Action Review
AC	Alternating Current
AMSAA	Army Materiel Systems Analysis Agency/Activity
ARL	Army Research Laboratory
ASA IEE	Assistant Secretary of the Army for Installations, Energy and the Environment
AWH-400	Army Water Heater 400
BAH	Booz Allen Hamilton, Inc.
BCIL	Base Camp Integration Laboratory
CASCOM	Combined Arms Support Command
CBITEC	Contingency Basing Integration and Technology Evaluation Center
CCB	Configuration Control Board
CERDEC	Communications-Electronics Research, Development and Engineering Center
CERL	Construction Engineering Research Laboratory
CIMT	Containerized Ice Making Technology
CLT	Core Leadership Team
CM	Configuration Management
COP	Combat Outpost
COTS	Commercial-off-the-Shelf
CRT	Consumer Research Team
DAG	Data Authentication Group
DAMP	Demonstration and Assessment Master Plan
DC	Direct Current
DDS	Deliverable Dataset
DESERT	Desert Environment Sustainable Efficient Refrigeration Technology
DFAC	Dining Facility
DIR	Demonstration Incident Report
DIT	Data Investigation Ticket
DMMS	Deployable Metering and Monitoring System
DN	Nominal Diameter
DNP	Distributed Network Protocol
DOC	Demonstration Operations Center
DRD	Data Review Dashboard
DRR	Demonstration Readiness Review
DSM	Data Source Matrix
E2RWS	Energy-Efficient Rigid Wall Shelter
ECU	Environmental Control Unit
EDVT	Experimentation, Demonstration, and Validation Team
EIO-C	Energy Informed Operations - Central
ERDC	Engineer Research and Development Center
ESU	Energy Storage Unit

ETK-FF	Expeditionary TRICON Kitchen System Appliance Integration, Fuel-Fired
FOB	Forward Operating Base
FPE	Force Provider Expeditionary
FY	Fiscal Year
GDIT	General Dynamics Information Technology
GFD	Ground Fault Detection
GHT	Garden Hose Type
GWR	Graywater Reuse
GWR-FORO	Graywater Reuse – Forward Osmosis/Reverse Osmosis
HESCO	Hercules Engineering Solutions Consortium
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HPT	Hybrid Power Trailer
HVAC	Heating, Ventilation, and Air Conditioning
ICE	Innovative Cooling Equipment
IEC	Integrated Electronic Control
IECU	Improved Environmental Control Unit
IPD	Intelligent Power Distribution
IPERC	Intelligent Power Energy Research Corporation
JIFF	Joint Inter-Service Field Feeding (Burner)
JLTV	Joint Light Tactical Vehicle
JP-8	Jet Propulsion fuel, type 8
LCD	Liquid crystal display
LED	Light Emitting Diode
LINER	Expedient Shelters with Non-woven Composite Insulation Liner
MACK	Modular Appliances for Configurable Kitchens
MANGEN	1kWe JP-8 fueled, Man-Portable Generator Set
MBSE	Model-Based System Engineering
MDCA	Manual Data Collection Application
MILHUT	Minimized Logistics Habitat Unit
MIT-LL	Massachusetts Institute of Technology-Lincoln Laboratories
MOS	Military Occupational Specialty
MRAP	Mine Resistant Ambush Protected (vehicle)
MSAT	Modeling, Simulation, and Analysis Team
MSCoE	Maneuver Support Center of Excellence
NAS	Network Attached Storage
NASA	National Aeronautics and Space Administration
NAVSEA	Naval Sea Systems Command
NCD	New Core Database
NCOIC	Non-Commissioned Officer In Charge
NI	National Instrument
NMS	Non-Materiel Solutions
NPC	Nanoparticle-Polymer Composite for Soldier Power and Energy
NPN	Negative-Positive-Negative
NPT	National Pipe Taper

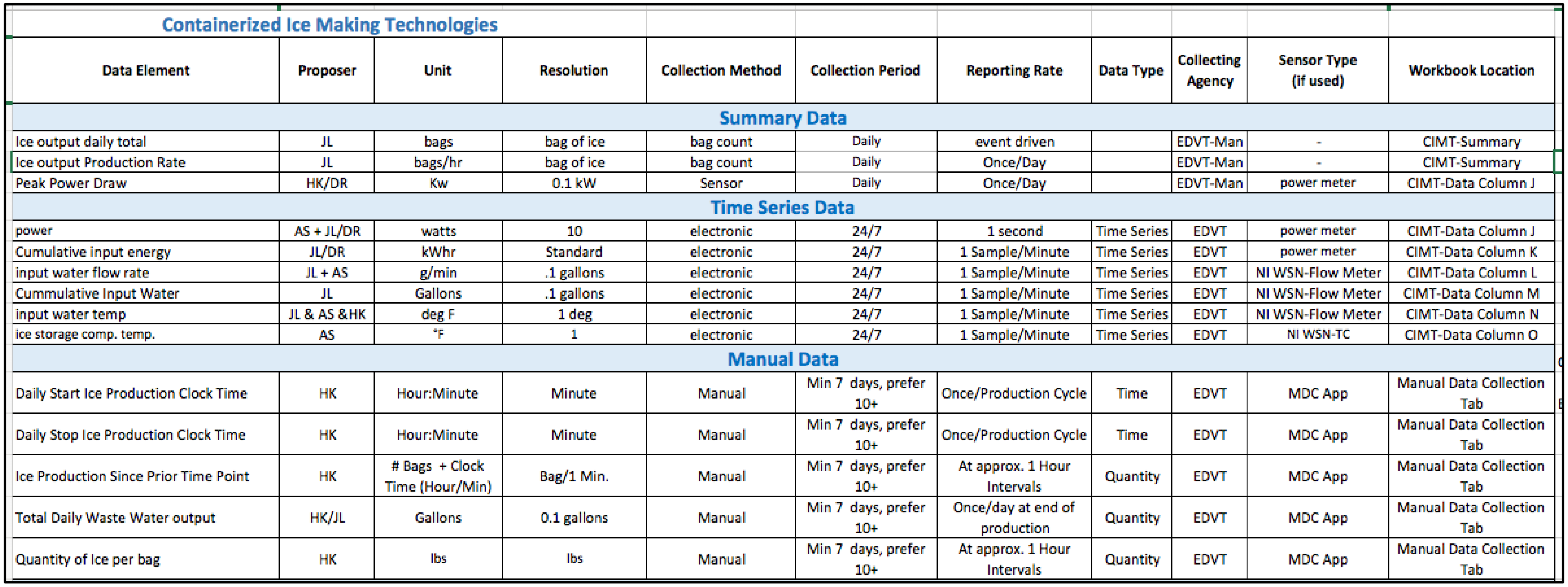
NSRDEC	Natick Soldier Research, Development and Engineering Center
O&S	Operations & Support
OACIS	Onsite Automatic Chiller for Individual Sustainment
OBVP	Onboard Vehicle Power
OE	Operational Energy
ORISE	Oak Ridge Institute for Science and Education
OTC	U. S. Army Operational Test Command
PDISE	Power Distribution and Illumination System, Electrical
PdM FSS	Product Manager Force Sustainment Systems
PdM PAWS	Product Manager Petroleum & Water Systems
PM E2S2	Program Manager Expeditionary Energy and Sustainment Systems
PMIPT	Program Management Integrated Process Team
PNP	Positive-Negative-Positive
POC	Point of Contact
PoRs	Programs of Record
PP	Polypropylene
PSHADE	PowerShade
PV	Photovoltaic
PVDF	Polyvinylidene Fluoride
QM	Quartermaster
QoL	Quality of Life
QoL (O)	Operational Quality of Life
RDECOM	Research, Development and Engineering Command
RDS	Rapidly Deployable Lightweight Austere Weather Shelter System
REDUCE	Renewable Energy for Distributed Under-supplied Command Environments
RIT	Requirements Integration Team
RJ-11	Registered Jack Function 11
RJ-45	Registered Jack Function 45
S&T	Science and Technology
SEIT	Systems Engineering and Integration Team
SIP-Hut	Structural Insulated Panel Hut
SIP-Hut 3.0	Structural Insulated Panel Huts version 3.0
SIP-Hut 4.0	Structural Insulated Panel Huts version 4.0
SLB-STO-D	Sustainability and Logistics-Basing Science and Technology Objective - Demonstration
SLiM	Self-Sustaining Living Module
SME	Subject Matter Expert
SOC	State of Charge
SOP	Standard Operating Procedure
SPSS	Solar-Powered Shelter System
SPST	Single Pole-Single Throw (switch)
SPSWH	Self-Powered Solar Water Heater
SRHS	Shelter Radiant Heating System
SS	Stainless Steel

SV	System View
T100	HMMWV-Towable Load Following 100kW Power Unit
TARDEC	Tank and Automotive Research, Development and Engineering Center
TE	Thermoelectrics
TECD	Technology-Enabled Capability Demonstration
TEMPER	Tent, Extendable, Modular, Personnel
TMIT	Technology Maturation and Integration Team
TOPM	Test Operating Procedure and Methodology
TQG	Tactical Quiet Generator
TRADOC	Training and Doctrine Command
TRICON	Triple Container
TRL	Technology Readiness Level
TV2GM	Tactical Vehicle-to-Grid Module
USAPHC	U.S. Army Public Health Command
V2G/V2V	Tactical Vehicle-to-Grid/Vehicle-to-Vehicle Demo System
WATERMON	Real Time Inline Diagnostic Technology for Water Monitoring
WDR	Exploration of Water Demand Reduction Technologies for Forward Operating Base Organizational Equipment
WFA	Modular Force Water Generation Storage & Analysis
WQM-PM	Water Quality Monitoring – Pathogen Monitor
WSN	Wireless Sensor Network
WWT-Bio	Wastewater Treatment-Biological
WWT-D2	Self-Powered Wastewater Treatment for Forward Operating Bases – Cambrian Innovation

ANNEX A – DATA SOURCE MATRIX

A.1 CIMT Data Source Matrix

Table A-1: CIMT Data Source Matrix

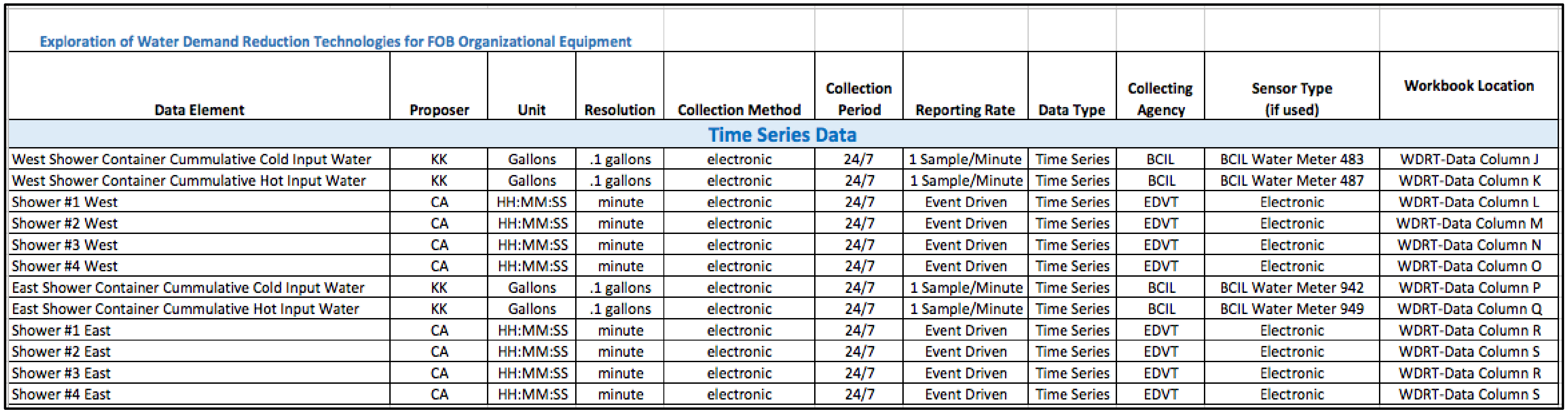


Containerized Ice Making Technologies

Data Element	Proposer	Unit	Resolution	Collection Method	Collection Period	Reporting Rate	Data Type	Collecting Agency	Sensor Type (if used)	Workbook Location
Summary Data										
Ice output daily total	JL	bags	bag of ice	bag count	Daily	event driven		EDVT-Man	-	CIMT-Summary
Ice output Production Rate	JL	bags/hr	bag of ice	bag count	Daily	Once/Day		EDVT-Man	-	CIMT-Summary
Peak Power Draw	HK/DR	Kw	0.1 kW	Sensor	Daily	Once/Day		EDVT-Man	power meter	CIMT-Data Column J
Time Series Data										
power	AS + JL/DR	watts	10	electronic	24/7	1 second	Time Series	EDVT	power meter	CIMT-Data Column J
Cumulative input energy	JL/DR	kWhr	Standard	electronic	24/7	1 Sample/Minute	Time Series	EDVT	power meter	CIMT-Data Column K
input water flow rate	JL + AS	g/min	.1 gallons	electronic	24/7	1 Sample/Minute	Time Series	EDVT	NI WSN-Flow Meter	CIMT-Data Column L
Cummulative Input Water	JL	Gallons	.1 gallons	electronic	24/7	1 Sample/Minute	Time Series	EDVT	NI WSN-Flow Meter	CIMT-Data Column M
input water temp	JL & AS &HK	deg F	1 deg	electronic	24/7	1 Sample/Minute	Time Series	EDVT	NI WSN-Flow Meter	CIMT-Data Column N
ice storage comp. temp.	AS	°F	1	electronic	24/7	1 Sample/Minute	Time Series	EDVT	NI WSN-TC	CIMT-Data Column O
Manual Data										
Daily Start Ice Production Clock Time	HK	Hour:Minute	Minute	Manual	Min 7 days, prefer 10+	Once/Production Cycle	Time	EDVT	MDC App	Manual Data Collection Tab
Daily Stop Ice Production Clock Time	HK	Hour:Minute	Minute	Manual	Min 7 days, prefer 10+	Once/Production Cycle	Time	EDVT	MDC App	Manual Data Collection Tab
Ice Production Since Prior Time Point	HK	# Bags + Clock Time (Hour/Min)	Bag/1 Min.	Manual	Min 7 days, prefer 10+	At approx. 1 Hour Intervals	Quantity	EDVT	MDC App	Manual Data Collection Tab
Total Daily Waste Water output	HK/JL	Gallons	0.1 gallons	Manual	Min 7 days, prefer 10+	Once/day at end of production	Quantity	EDVT	MDC App	Manual Data Collection Tab
Quantity of Ice per bag	HK	lbs	lbs	Manual	Min 7 days, prefer 10+	At approx. 1 Hour Intervals	Quantity	EDVT	MDC App	Manual Data Collection Tab

A.2 WDR Data Source Matrix

Table A-2: WDR Data Source Matrix



Exploration of Water Demand Reduction Technologies for FOB Organizational Equipment

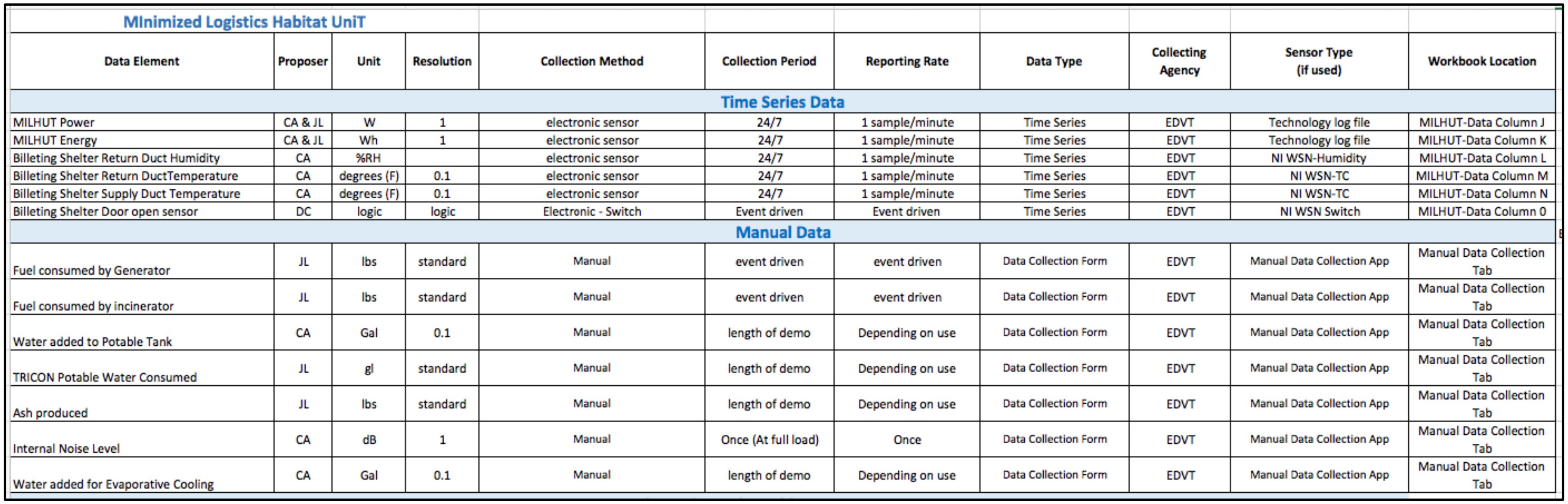
Data Element	Proposer	Unit	Resolution	Collection Method	Collection Period	Reporting Rate	Data Type	Collecting Agency	Sensor Type (if used)	Workbook Location
Time Series Data										
West Shower Container Cummulative Cold Input Water	KK	Gallons	.1 gallons	electronic	24/7	1 Sample/Minute	Time Series	BCIL	BCIL Water Meter 483	WDRT-Data Column J
West Shower Container Cummulative Hot Input Water	KK	Gallons	.1 gallons	electronic	24/7	1 Sample/Minute	Time Series	BCIL	BCIL Water Meter 487	WDRT-Data Column K
Shower #1 West	CA	HH:MM:SS	minute	electronic	24/7	Event Driven	Time Series	EDVT	Electronic	WDRT-Data Column L
Shower #2 West	CA	HH:MM:SS	minute	electronic	24/7	Event Driven	Time Series	EDVT	Electronic	WDRT-Data Column M
Shower #3 West	CA	HH:MM:SS	minute	electronic	24/7	Event Driven	Time Series	EDVT	Electronic	WDRT-Data Column N
Shower #4 West	CA	HH:MM:SS	minute	electronic	24/7	Event Driven	Time Series	EDVT	Electronic	WDRT-Data Column O
East Shower Container Cummulative Cold Input Water	KK	Gallons	.1 gallons	electronic	24/7	1 Sample/Minute	Time Series	BCIL	BCIL Water Meter 942	WDRT-Data Column P
East Shower Container Cummulative Hot Input Water	KK	Gallons	.1 gallons	electronic	24/7	1 Sample/Minute	Time Series	BCIL	BCIL Water Meter 949	WDRT-Data Column Q
Shower #1 East	CA	HH:MM:SS	minute	electronic	24/7	Event Driven	Time Series	EDVT	Electronic	WDRT-Data Column R
Shower #2 East	CA	HH:MM:SS	minute	electronic	24/7	Event Driven	Time Series	EDVT	Electronic	WDRT-Data Column S
Shower #3 East	CA	HH:MM:SS	minute	electronic	24/7	Event Driven	Time Series	EDVT	Electronic	WDRT-Data Column R
Shower #4 East	CA	HH:MM:SS	minute	electronic	24/7	Event Driven	Time Series	EDVT	Electronic	WDRT-Data Column S

A.3 SLiM Data Source Matrix

There are no data elements to be collected by the EDVT for the SLiM. The Technology Provider will collect data independently during this event.

A.4 MILHUT Data Source Matrix

Table A-3: MILHUT Data Source Matrix



MInimized Logistics Habitat UniT

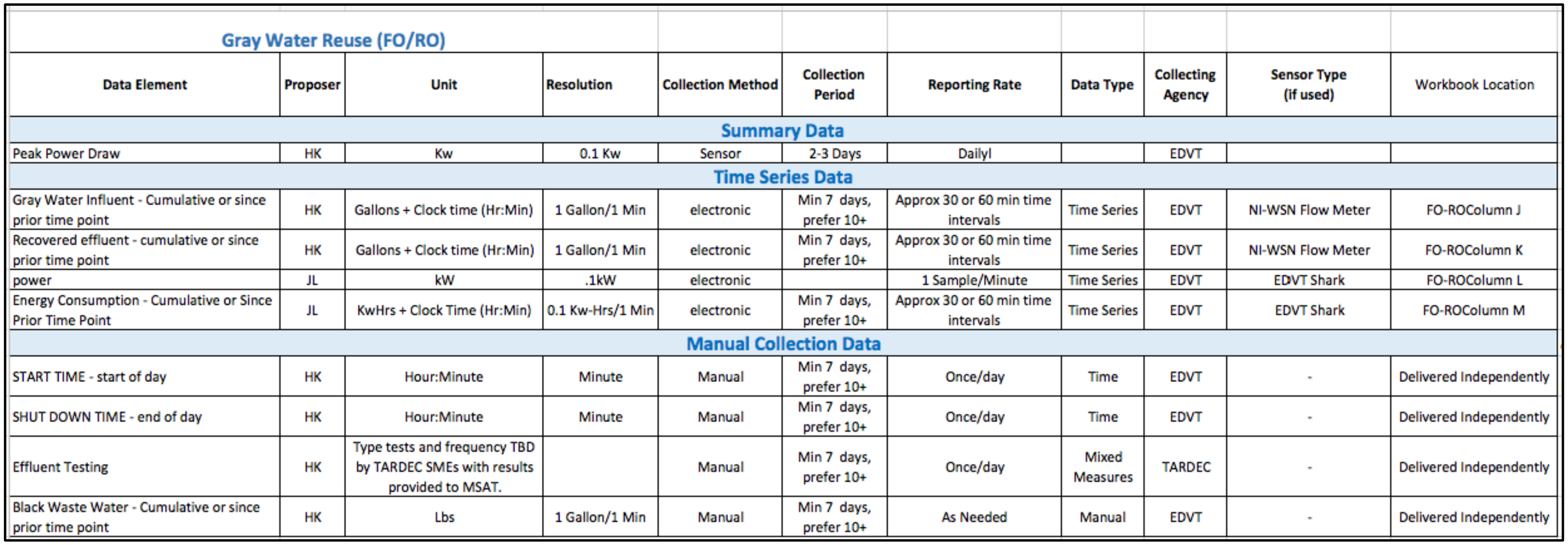
Data Element	Proposer	Unit	Resolution	Collection Method	Collection Period	Reporting Rate	Data Type	Collecting Agency	Sensor Type (if used)	Workbook Location
Time Series Data										
MILHUT Power	CA & JL	W	1	electronic sensor	24/7	1 sample/minute	Time Series	EDVT	Technology log file	MILHUT-Data Column J
MILHUT Energy	CA & JL	Wh	1	electronic sensor	24/7	1 sample/minute	Time Series	EDVT	Technology log file	MILHUT-Data Column K
Billeting Shelter Return Duct Humidity	CA	%RH		electronic sensor	24/7	1 sample/minute	Time Series	EDVT	NI WSN-Humidity	MILHUT-Data Column L
Billeting Shelter Return DuctTemperature	CA	degrees (F)	0.1	electronic sensor	24/7	1 sample/minute	Time Series	EDVT	NI WSN-TC	MILHUT-Data Column M
Billeting Shelter Supply Duct Temperature	CA	degrees (F)	0.1	electronic sensor	24/7	1 sample/minute	Time Series	EDVT	NI WSN-TC	MILHUT-Data Column N
Billeting Shelter Door open sensor	DC	logic	logic	Electronic - Switch	Event driven	Event driven	Time Series	EDVT	NI WSN Switch	MILHUT-Data Column 0
Manual Data										
Fuel consumed by Generator	JL	lbs	standard	Manual	event driven	event driven	Data Collection Form	EDVT	Manual Data Collection App	Manual Data Collection Tab
Fuel consumed by incinerator	JL	lbs	standard	Manual	event driven	event driven	Data Collection Form	EDVT	Manual Data Collection App	Manual Data Collection Tab
Water added to Potable Tank	CA	Gal	0.1	Manual	length of demo	Depending on use	Data Collection Form	EDVT	Manual Data Collection App	Manual Data Collection Tab
TRICON Potable Water Consumed	JL	gl	standard	Manual	length of demo	Depending on use	Data Collection Form	EDVT	Manual Data Collection App	Manual Data Collection Tab
Ash produced	JL	lbs	standard	Manual	length of demo	Depending on use	Data Collection Form	EDVT	Manual Data Collection App	Manual Data Collection Tab
Internal Noise Level	CA	dB	1	Manual	Once (At full load)	Once	Data Collection Form	EDVT	Manual Data Collection App	Manual Data Collection Tab
Water added for Evaporative Cooling	CA	Gal	0.1	Manual	length of demo	Depending on use	Data Collection Form	EDVT	Manual Data Collection App	Manual Data Collection Tab

A.5 NPC Data Source Matrix

There were no data elements collected by EDVT for NPC. The Technology Provider collected data independently during this event.

A.6 GWR-FORO Data Source Matrix

Table A-4: GWR-FORO Data Source Matrix

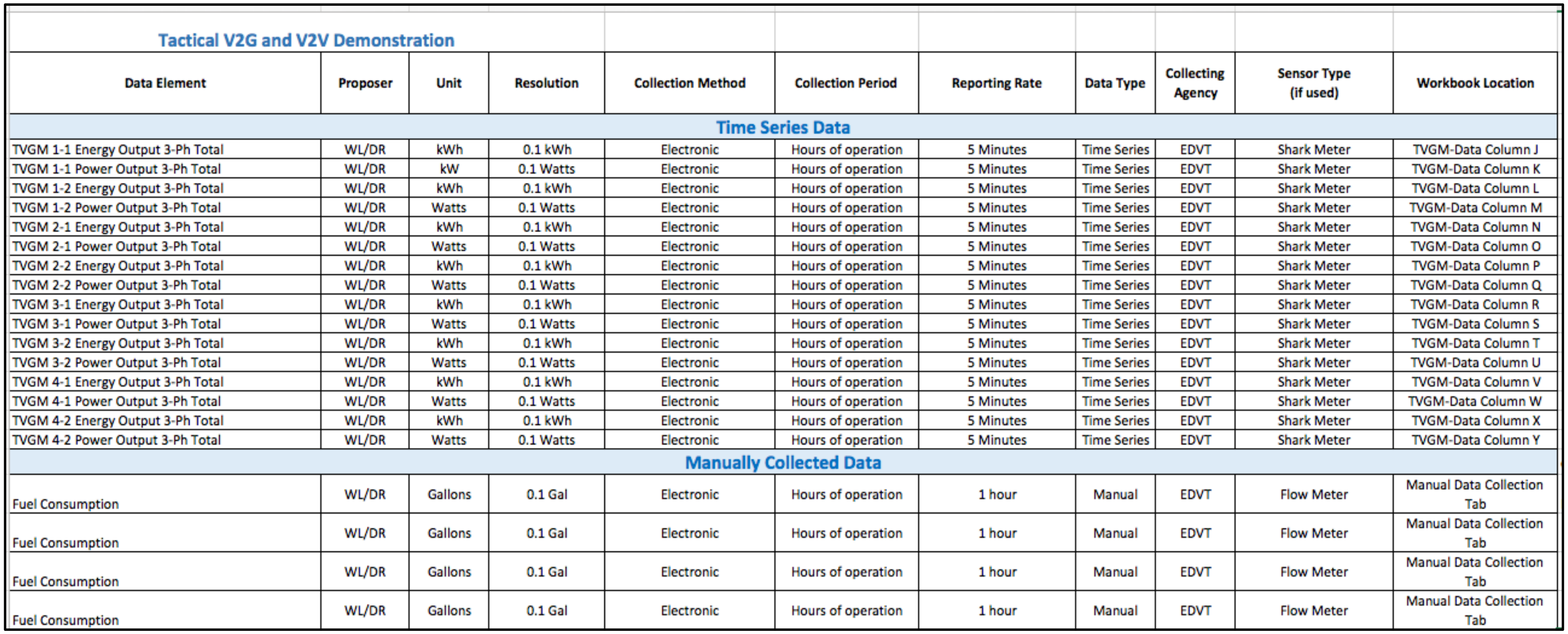


Gray Water Reuse (FO/RO)

Data Element	Proposer	Unit	Resolution	Collection Method	Collection Period	Reporting Rate	Data Type	Collecting Agency	Sensor Type (if used)	Workbook Location
Summary Data										
Peak Power Draw	HK	Kw	0.1 Kw	Sensor	2-3 Days	Dailyl		EDVT		
Time Series Data										
Gray Water Influent - Cumulative or since prior time point	HK	Gallons + Clock time (Hr:Min)	1 Gallon/1 Min	electronic	Min 7 days, prefer 10+	Approx 30 or 60 min time intervals	Time Series	EDVT	NI-WSN Flow Meter	FO-ROColumn J
Recovered effluent - cumulative or since prior time point	HK	Gallons + Clock time (Hr:Min)	1 Gallon/1 Min	electronic	Min 7 days, prefer 10+	Approx 30 or 60 min time intervals	Time Series	EDVT	NI-WSN Flow Meter	FO-ROColumn K
power	JL	kW	.1kW	electronic		1 Sample/Minute	Time Series	EDVT	EDVT Shark	FO-ROColumn L
Energy Consumption - Cumulative or Since Prior Time Point	JL	KwHrs + Clock Time (Hr:Min)	0.1 Kw-Hrs/1 Min	electronic	Min 7 days, prefer 10+	Approx 30 or 60 min time intervals	Time Series	EDVT	EDVT Shark	FO-ROColumn M
Manual Collection Data										
START TIME - start of day	HK	Hour:Minute	Minute	Manual	Min 7 days, prefer 10+	Once/day	Time	EDVT	-	Delivered Independently
SHUT DOWN TIME - end of day	HK	Hour:Minute	Minute	Manual	Min 7 days, prefer 10+	Once/day	Time	EDVT	-	Delivered Independently
Effluent Testing	HK	Type tests and frequency TBD by TARDEC SMEs with results provided to MSAT.		Manual	Min 7 days, prefer 10+	Once/day	Mixed Measures	TARDEC	-	Delivered Independently
Black Waste Water - Cumulative or since prior time point	HK	Lbs	1 Gallon/1 Min	Manual	Min 7 days, prefer 10+	As Needed	Manual	EDVT	-	Delivered Independently

A.7 V2G/V2V Data Source Matrix

Table A-5: V2G/V2V Data Source Matrix

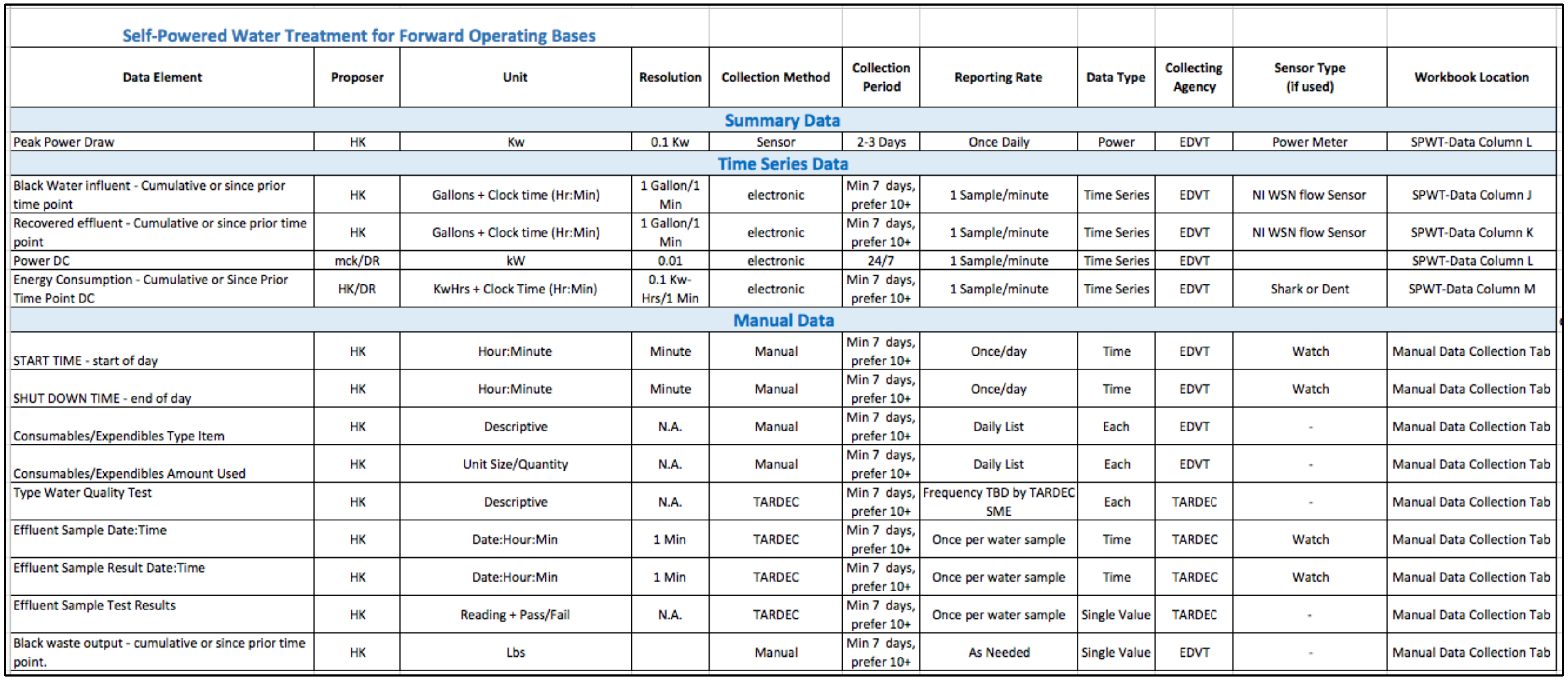


Tactical V2G and V2V Demonstration

Data Element	Proposer	Unit	Resolution	Collection Method	Collection Period	Reporting Rate	Data Type	Collecting Agency	Sensor Type (if used)	Workbook Location
Time Series Data										
TVGM 1-1 Energy Output 3-Ph Total	WL/DR	kWh	0.1 kWh	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column J
TVGM 1-1 Power Output 3-Ph Total	WL/DR	kW	0.1 Watts	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column K
TVGM 1-2 Energy Output 3-Ph Total	WL/DR	kWh	0.1 kWh	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column L
TVGM 1-2 Power Output 3-Ph Total	WL/DR	Watts	0.1 Watts	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column M
TVGM 2-1 Energy Output 3-Ph Total	WL/DR	kWh	0.1 kWh	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column N
TVGM 2-1 Power Output 3-Ph Total	WL/DR	Watts	0.1 Watts	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column O
TVGM 2-2 Energy Output 3-Ph Total	WL/DR	kWh	0.1 kWh	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column P
TVGM 2-2 Power Output 3-Ph Total	WL/DR	Watts	0.1 Watts	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column Q
TVGM 3-1 Energy Output 3-Ph Total	WL/DR	kWh	0.1 kWh	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column R
TVGM 3-1 Power Output 3-Ph Total	WL/DR	Watts	0.1 Watts	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column S
TVGM 3-2 Energy Output 3-Ph Total	WL/DR	kWh	0.1 kWh	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column T
TVGM 3-2 Power Output 3-Ph Total	WL/DR	Watts	0.1 Watts	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column U
TVGM 4-1 Energy Output 3-Ph Total	WL/DR	kWh	0.1 kWh	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column V
TVGM 4-1 Power Output 3-Ph Total	WL/DR	Watts	0.1 Watts	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column W
TVGM 4-2 Energy Output 3-Ph Total	WL/DR	kWh	0.1 kWh	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column X
TVGM 4-2 Power Output 3-Ph Total	WL/DR	Watts	0.1 Watts	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	TVGM-Data Column Y
Manually Collected Data										
Fuel Consumption	WL/DR	Gallons	0.1 Gal	Electronic	Hours of operation	1 hour	Manual	EDVT	Flow Meter	Manual Data Collection Tab
Fuel Consumption	WL/DR	Gallons	0.1 Gal	Electronic	Hours of operation	1 hour	Manual	EDVT	Flow Meter	Manual Data Collection Tab
Fuel Consumption	WL/DR	Gallons	0.1 Gal	Electronic	Hours of operation	1 hour	Manual	EDVT	Flow Meter	Manual Data Collection Tab
Fuel Consumption	WL/DR	Gallons	0.1 Gal	Electronic	Hours of operation	1 hour	Manual	EDVT	Flow Meter	Manual Data Collection Tab

A.8 WWT-D2 Data Source Matrix

Table A-6: WWT-D2 Data Source Matrix



Self-Powered Water Treatment for Forward Operating Bases

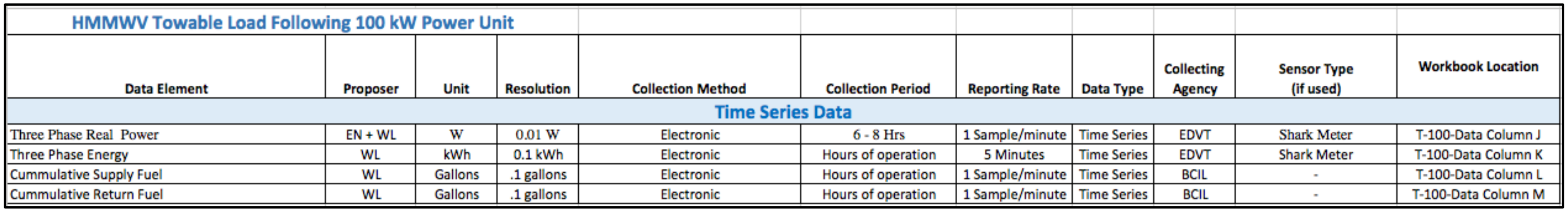
Data Element	Proposer	Unit	Resolution	Collection Method	Collection Period	Reporting Rate	Data Type	Collecting Agency	Sensor Type (if used)	Workbook Location
Summary Data										
Peak Power Draw	HK	Kw	0.1 Kw	Sensor	2-3 Days	Once Daily	Power	EDVT	Power Meter	SPWT-Data Column L
Time Series Data										
Black Water influent - Cumulative or since prior time point	HK	Gallons + Clock time (Hr:Min)	1 Gallon/1 Min	electronic	Min 7 days, prefer 10+	1 Sample/minute	Time Series	EDVT	NI WSN flow Sensor	SPWT-Data Column J
Recovered effluent - Cumulative or since prior time point	HK	Gallons + Clock time (Hr:Min)	1 Gallon/1 Min	electronic	Min 7 days, prefer 10+	1 Sample/minute	Time Series	EDVT	NI WSN flow Sensor	SPWT-Data Column K
Power DC	mck/DR	kW	0.01	electronic	24/7	1 Sample/minute	Time Series	EDVT		SPWT-Data Column L
Energy Consumption - Cumulative or Since Prior Time Point DC	HK/DR	KwHrs + Clock Time (Hr:Min)	0.1 Kw-Hrs/1 Min	electronic	Min 7 days, prefer 10+	1 Sample/minute	Time Series	EDVT	Shark or Dent	SPWT-Data Column M
Manual Data										
START TIME - start of day	HK	Hour:Minute	Minute	Manual	Min 7 days, prefer 10+	Once/day	Time	EDVT	Watch	Manual Data Collection Tab
SHUT DOWN TIME - end of day	HK	Hour:Minute	Minute	Manual	Min 7 days, prefer 10+	Once/day	Time	EDVT	Watch	Manual Data Collection Tab
Consumables/Expendibles Type Item	HK	Descriptive	N.A.	Manual	Min 7 days, prefer 10+	Daily List	Each	EDVT	-	Manual Data Collection Tab
Consumables/Expendibles Amount Used	HK	Unit Size/Quantity	N.A.	Manual	Min 7 days, prefer 10+	Daily List	Each	EDVT	-	Manual Data Collection Tab
Type Water Quality Test	HK	Descriptive	N.A.	TARDEC	Min 7 days, prefer 10+	Frequency TBD by TARDEC SME	Each	TARDEC	-	Manual Data Collection Tab
Effluent Sample Date:Time	HK	Date:Hour:Min	1 Min	TARDEC	Min 7 days, prefer 10+	Once per water sample	Time	TARDEC	Watch	Manual Data Collection Tab
Effluent Sample Result Date:Time	HK	Date:Hour:Min	1 Min	TARDEC	Min 7 days, prefer 10+	Once per water sample	Time	TARDEC	Watch	Manual Data Collection Tab
Effluent Sample Test Results	HK	Reading + Pass/Fail	N.A.	TARDEC	Min 7 days, prefer 10+	Once per water sample	Single Value	TARDEC	-	Manual Data Collection Tab
Black waste output - cumulative or since prior time point.	HK	Lbs		Manual	Min 7 days, prefer 10+	As Needed	Single Value	EDVT	-	Manual Data Collection Tab

A.9 WQM-PM Data Source Matrix

There were no data elements to be collected by the EDVT for the WQM-PM. The Technology Provider collected data independently during this event.

A.10 T100 Data Source Matrix

Table A-7: T100 Data Source Matrix

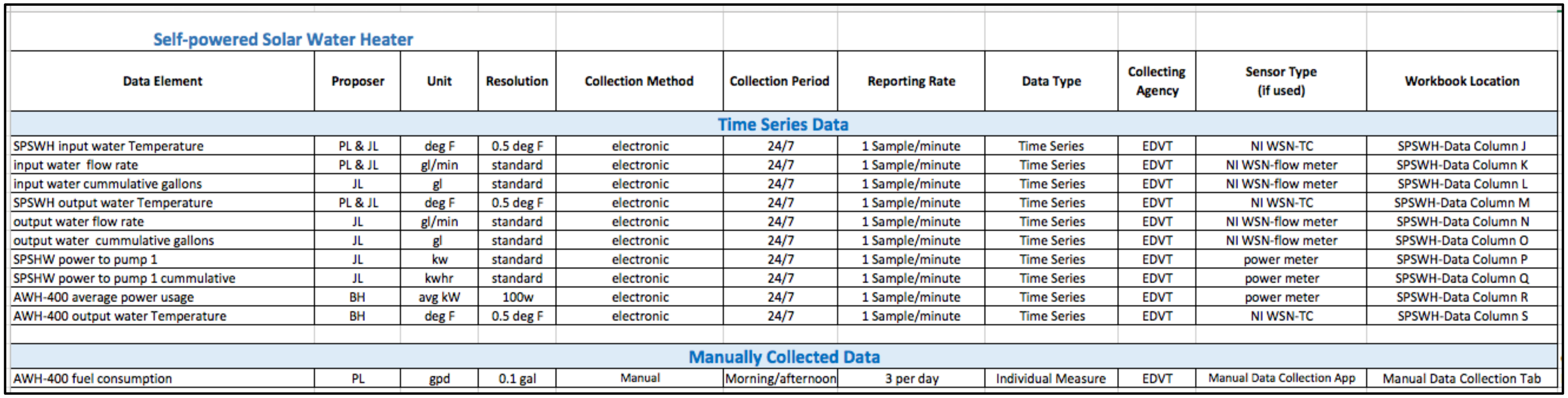


HMMWV Towable Load Following 100 kW Power Unit

Data Element	Proposer	Unit	Resolution	Collection Method	Collection Period	Reporting Rate	Data Type	Collecting Agency	Sensor Type (if used)	Workbook Location
Time Series Data										
Three Phase Real Power	EN + WL	W	0.01 W	Electronic	6 - 8 Hrs	1 Sample/minute	Time Series	EDVT	Shark Meter	T-100-Data Column J
Three Phase Energy	WL	kWh	0.1 kWh	Electronic	Hours of operation	5 Minutes	Time Series	EDVT	Shark Meter	T-100-Data Column K
Cummulative Supply Fuel	WL	Gallons	.1 gallons	Electronic	Hours of operation	1 Sample/minute	Time Series	BCIL	-	T-100-Data Column L
Cummulative Return Fuel	WL	Gallons	.1 gallons	Electronic	Hours of operation	1 Sample/minute	Time Series	BCIL	-	T-100-Data Column M

A.11 SPSWH Data Source Matrix

Table A-8: SPSWH Data Source Matrix

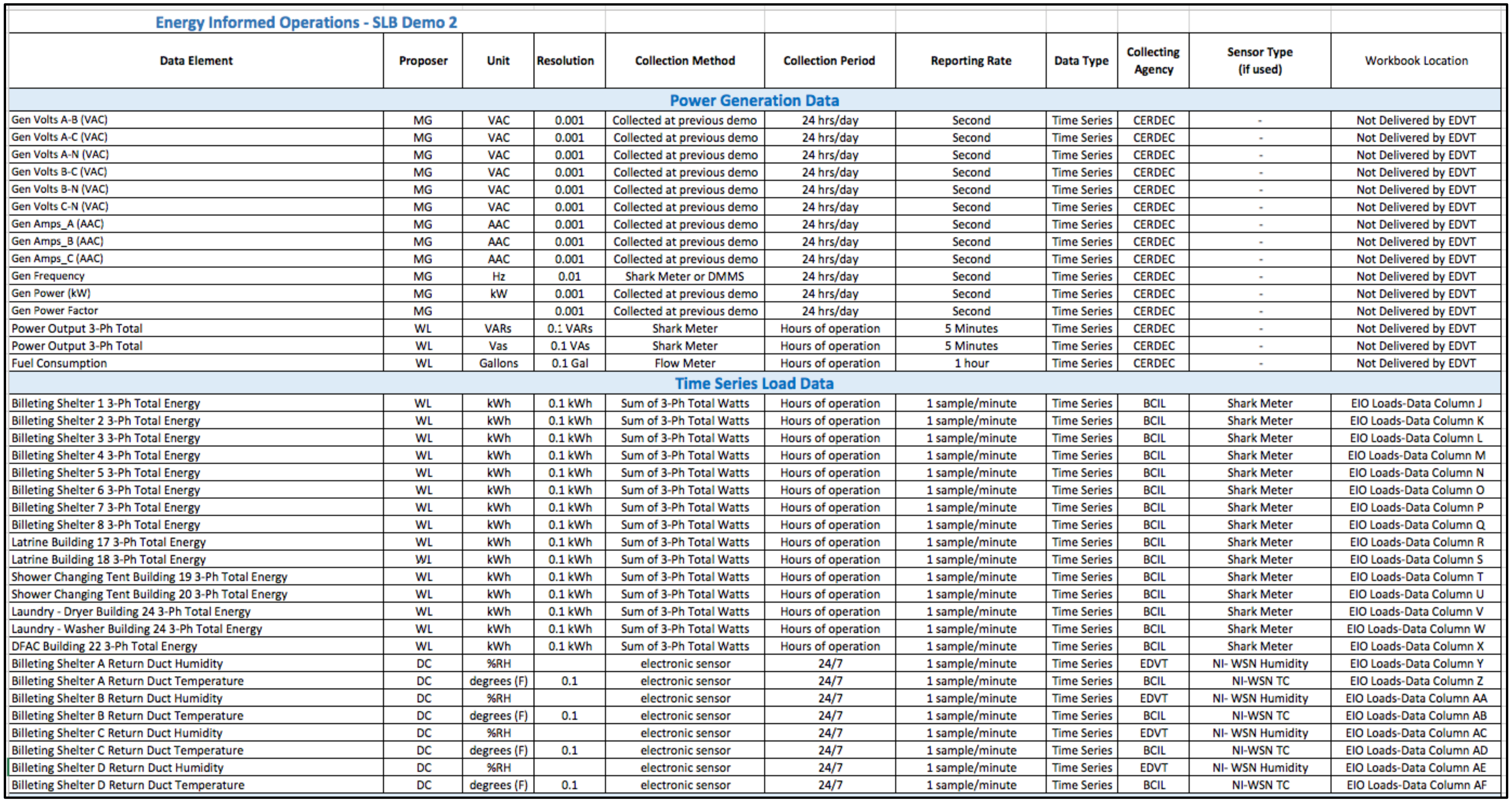


Self-powered Solar Water Heater

Data Element	Proposer	Unit	Resolution	Collection Method	Collection Period	Reporting Rate	Data Type	Collecting Agency	Sensor Type (if used)	Workbook Location
Time Series Data										
SPSWH input water Temperature	PL & JL	deg F	0.5 deg F	electronic	24/7	1 Sample/minute	Time Series	EDVT	NI WSN-TC	SPSWH-Data Column J
input water flow rate	PL & JL	gl/min	standard	electronic	24/7	1 Sample/minute	Time Series	EDVT	NI WSN-flow meter	SPSWH-Data Column K
input water cummulative gallons	JL	gl	standard	electronic	24/7	1 Sample/minute	Time Series	EDVT	NI WSN-flow meter	SPSWH-Data Column L
SPSWH output water Temperature	PL & JL	deg F	0.5 deg F	electronic	24/7	1 Sample/minute	Time Series	EDVT	NI WSN-TC	SPSWH-Data Column M
output water flow rate	JL	gl/min	standard	electronic	24/7	1 Sample/minute	Time Series	EDVT	NI WSN-flow meter	SPSWH-Data Column N
output water cummulative gallons	JL	gl	standard	electronic	24/7	1 Sample/minute	Time Series	EDVT	NI WSN-flow meter	SPSWH-Data Column O
SPSHW power to pump 1	JL	kw	standard	electronic	24/7	1 Sample/minute	Time Series	EDVT	power meter	SPSWH-Data Column P
SPSHW power to pump 1 cummulative	JL	kwhr	standard	electronic	24/7	1 Sample/minute	Time Series	EDVT	power meter	SPSWH-Data Column Q
AWH-400 average power usage	BH	avg kW	100w	electronic	24/7	1 Sample/minute	Time Series	EDVT	power meter	SPSWH-Data Column R
AWH-400 output water Temperature	BH	deg F	0.5 deg F	electronic	24/7	1 Sample/minute	Time Series	EDVT	NI WSN-TC	SPSWH-Data Column S
Manually Collected Data										
AWH-400 fuel consumption	PL	gpd	0.1 gal	Manual	Morning/afternoon	3 per day	Individual Measure	EDVT	Manual Data Collection App	Manual Data Collection Tab

A.12 EIO-C Data Source Matrix

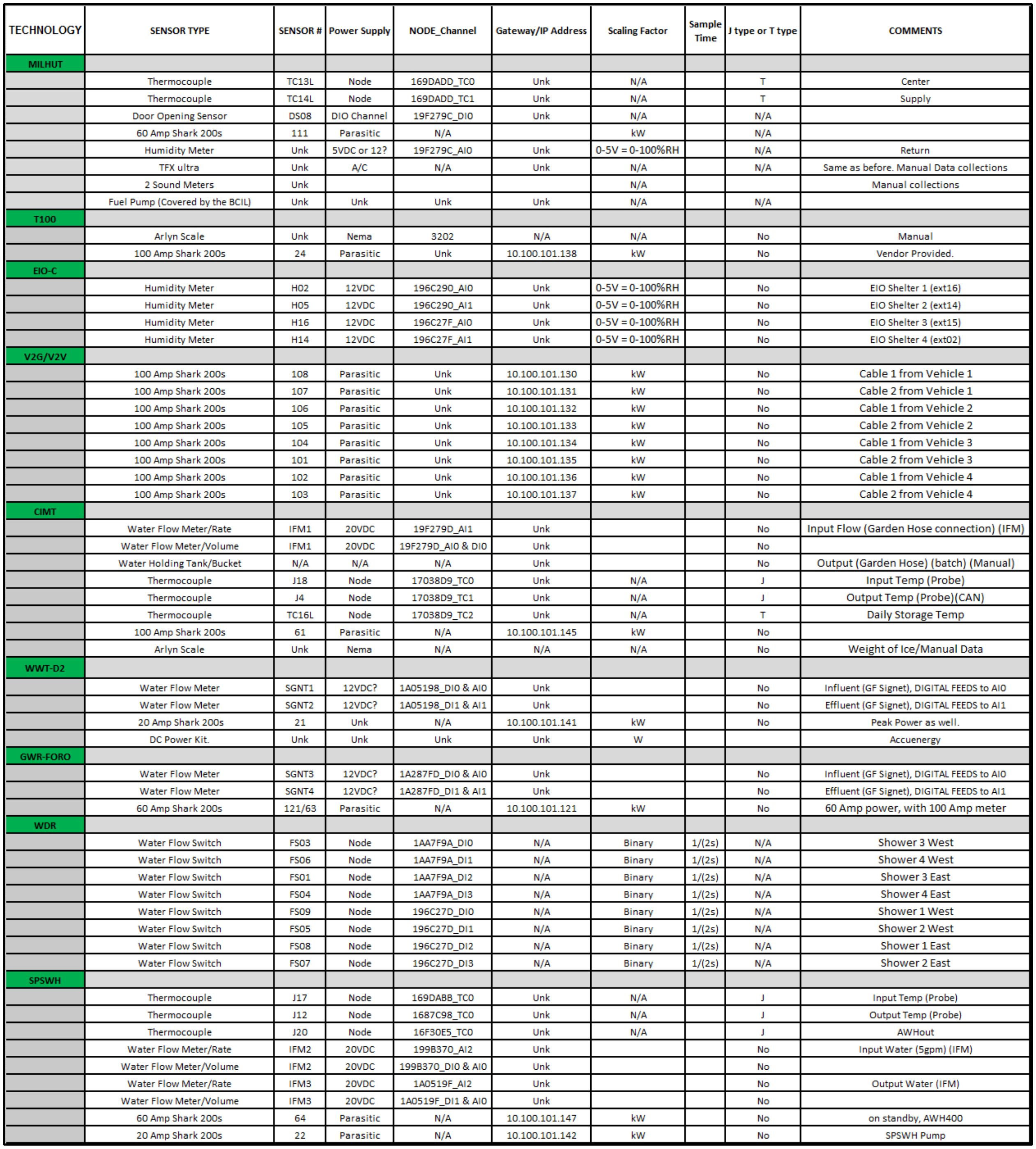
Table A-9: EIO-C Data Source Matrix



Energy Informed Operations - SLB Demo 2

Data Element	Proposer	Unit	Resolution	Collection Method	Collection Period	Reporting Rate	Data Type	Collecting Agency	Sensor Type (if used)	Workbook Location
Power Generation Data										
Gen Volts A-B (VAC)	MG	VAC	0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Volts A-C (VAC)	MG	VAC	0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Volts A-N (VAC)	MG	VAC	0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Volts B-C (VAC)	MG	VAC	0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Volts B-N (VAC)	MG	VAC	0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Volts C-N (VAC)	MG	VAC	0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Amps_A (AAC)	MG	AAC	0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Amps_B (AAC)	MG	AAC	0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Amps_C (AAC)	MG	AAC	0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Frequency	MG	Hz	0.01	Shark Meter or DMMS	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Power (kW)	MG	kW	0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Gen Power Factor	MG		0.001	Collected at previous demo	24 hrs/day	Second	Time Series	CERDEC	-	Not Delivered by EDVT
Power Output 3-Ph Total	WL	VARs	0.1 VARs	Shark Meter	Hours of operation	5 Minutes	Time Series	CERDEC	-	Not Delivered by EDVT
Power Output 3-Ph Total	WL	Vas	0.1 VAs	Shark Meter	Hours of operation	5 Minutes	Time Series	CERDEC	-	Not Delivered by EDVT
Fuel Consumption	WL	Gallons	0.1 Gal	Flow Meter	Hours of operation	1 hour	Time Series	CERDEC	-	Not Delivered by EDVT
Time Series Load Data										
Billeting Shelter 1 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column J
Billeting Shelter 2 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column K
Billeting Shelter 3 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column L
Billeting Shelter 4 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column M
Billeting Shelter 5 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column N
Billeting Shelter 6 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column O
Billeting Shelter 7 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column P
Billeting Shelter 8 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column Q
Latrine Building 17 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column R
Latrine Building 18 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column S
Shower Changing Tent Building 19 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column T
Shower Changing Tent Building 20 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column U
Laundry - Dryer Building 24 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column V
Laundry - Washer Building 24 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column W
DFAC Building 22 3-Ph Total Energy	WL	kWh	0.1 kWh	Sum of 3-Ph Total Watts	Hours of operation	1 sample/minute	Time Series	BCIL	Shark Meter	EIO Loads-Data Column X
Billeting Shelter A Return Duct Humidity	DC	%RH		electronic sensor	24/7	1 sample/minute	Time Series	EDVT	NI- WSN Humidity	EIO Loads-Data Column Y
Billeting Shelter A Return Duct Temperature	DC	degrees (F)	0.1	electronic sensor	24/7	1 sample/minute	Time Series	BCIL	NI-WSN TC	EIO Loads-Data Column Z
Billeting Shelter B Return Duct Humidity	DC	%RH		electronic sensor	24/7	1 sample/minute	Time Series	EDVT	NI- WSN Humidity	EIO Loads-Data Column AA
Billeting Shelter B Return Duct Temperature	DC	degrees (F)	0.1	electronic sensor	24/7	1 sample/minute	Time Series	BCIL	NI-WSN TC	EIO Loads-Data Column AB
Billeting Shelter C Return Duct Humidity	DC	%RH		electronic sensor	24/7	1 sample/minute	Time Series	EDVT	NI- WSN Humidity	EIO Loads-Data Column AC
Billeting Shelter C Return Duct Temperature	DC	degrees (F)	0.1	electronic sensor	24/7	1 sample/minute	Time Series	BCIL	NI-WSN TC	EIO Loads-Data Column AD
Billeting Shelter D Return Duct Humidity	DC	%RH		electronic sensor	24/7	1 sample/minute	Time Series	EDVT	NI- WSN Humidity	EIO Loads-Data Column AE
Billeting Shelter D Return Duct Temperature	DC	degrees (F)	0.1	electronic sensor	24/7	1 sample/minute	Time Series	BCIL	NI-WSN TC	EIO Loads-Data Column AF

ANNEX B – SENSOR TRACKING MATRIX



TECHNOLOGY	SENSOR TYPE	SENSOR #	Power Supply	NODE_Channel	Gateway/IP Address	Scaling Factor	Sample Time	J type or T type	COMMENTS
MILHUT									
	Thermocouple	TC13L	Node	169DADD_TC0	Unk	N/A		T	Center
	Thermocouple	TC14L	Node	169DADD_TC1	Unk	N/A		T	Supply
	Door Opening Sensor	DS08	DIO Channel	19F279C_DI0	Unk	N/A		N/A	
	60 Amp Shark 200s	111	Parasitic	N/A		kW		N/A	
	Humidity Meter	Unk	5VDC or 12?	19F279C_AI0	Unk	0-5V = 0-100%RH		N/A	Return
	TFX ultra	Unk	A/C	N/A	Unk	N/A		N/A	Same as before. Manual Data collections
	2 Sound Meters	Unk				N/A			Manual collections
	Fuel Pump (Covered by the BCIL)	Unk	Unk	Unk	Unk	N/A		N/A	
T100									
	Arlyn Scale	Unk	Nema	3202	N/A	N/A		No	Manual
	100 Amp Shark 200s	24	Parasitic	Unk	10.100.101.138	kW		No	Vendor Provided.
EIO-C									
	Humidity Meter	H02	12VDC	196C290_AI0	Unk	0-5V = 0-100%RH		No	EIO Shelter 1 (ext16)
	Humidity Meter	H05	12VDC	196C290_AI1	Unk	0-5V = 0-100%RH		No	EIO Shelter 2 (ext14)
	Humidity Meter	H16	12VDC	196C27F_AI0	Unk	0-5V = 0-100%RH		No	EIO Shelter 3 (ext15)
	Humidity Meter	H14	12VDC	196C27F_AI1	Unk	0-5V = 0-100%RH		No	EIO Shelter 4 (ext02)
V2G/V2V									
	100 Amp Shark 200s	108	Parasitic	Unk	10.100.101.130	kW		No	Cable 1 from Vehicle 1
	100 Amp Shark 200s	107	Parasitic	Unk	10.100.101.131	kW		No	Cable 2 from Vehicle 1
	100 Amp Shark 200s	106	Parasitic	Unk	10.100.101.132	kW		No	Cable 1 from Vehicle 2
	100 Amp Shark 200s	105	Parasitic	Unk	10.100.101.133	kW		No	Cable 2 from Vehicle 2
	100 Amp Shark 200s	104	Parasitic	Unk	10.100.101.134	kW		No	Cable 1 from Vehicle 3
	100 Amp Shark 200s	101	Parasitic	Unk	10.100.101.135	kW		No	Cable 2 from Vehicle 3
	100 Amp Shark 200s	102	Parasitic	Unk	10.100.101.136	kW		No	Cable 1 from Vehicle 4
	100 Amp Shark 200s	103	Parasitic	Unk	10.100.101.137	kW		No	Cable 2 from Vehicle 4
CIMT									
	Water Flow Meter/Rate	IFM1	20VDC	19F279D_AI1	Unk			No	Input Flow (Garden Hose connection) (IFM)
	Water Flow Meter/Volume	IFM1	20VDC	19F279D_AI0 & DI0	Unk			No	
	Water Holding Tank/Bucket	N/A	N/A	N/A	Unk			No	Output (Garden Hose) (batch) (Manual)
	Thermocouple	J18	Node	17038D9_TC0	Unk	N/A		J	Input Temp (Probe)
	Thermocouple	J4	Node	17038D9_TC1	Unk	N/A		J	Output Temp (Probe)(CAN)
	Thermocouple	TC16L	Node	17038D9_TC2	Unk	N/A		T	Daily Storage Temp
	100 Amp Shark 200s	61	Parasitic	N/A	10.100.101.145	kW		No	
	Arlyn Scale	Unk	Nema	N/A	N/A	N/A		No	Weight of Ice/Manual Data
WWT-D2									
	Water Flow Meter	SGNT1	12VDC?	1A05198_DI0 & AI0	Unk			No	Influent (GF Signet), DIGITAL FEEDS to AI0
	Water Flow Meter	SGNT2	12VDC?	1A05198_DI1 & AI1	Unk			No	Effluent (GF Signet), DIGITAL FEEDS to AI1
	20 Amp Shark 200s	21	Unk	N/A	10.100.101.141	kW		No	Peak Power as well.
	DC Power Kit.	Unk	Unk	Unk	Unk	W			Accuenergy
GWR-FORO									
	Water Flow Meter	SGNT3	12VDC?	1A287FD_DI0 & AI0	Unk			No	Influent (GF Signet), DIGITAL FEEDS to AI0
	Water Flow Meter	SGNT4	12VDC?	1A287FD_DI1 & AI1	Unk			No	Effluent (GF Signet), DIGITAL FEEDS to AI1
	60 Amp Shark 200s	121/63	Parasitic	N/A	10.100.101.121	kW		No	60 Amp power, with 100 Amp meter
WDR									
	Water Flow Switch	FS03	Node	1AA7F9A_DI0	N/A	Binary	1/(2s)	N/A	Shower 3 West
	Water Flow Switch	FS06	Node	1AA7F9A_DI1	N/A	Binary	1/(2s)	N/A	Shower 4 West
	Water Flow Switch	FS01	Node	1AA7F9A_DI2	N/A	Binary	1/(2s)	N/A	Shower 3 East
	Water Flow Switch	FS04	Node	1AA7F9A_DI3	N/A	Binary	1/(2s)	N/A	Shower 4 East
	Water Flow Switch	FS09	Node	196C27D_DI0	N/A	Binary	1/(2s)	N/A	Shower 1 West
	Water Flow Switch	FS05	Node	196C27D_DI1	N/A	Binary	1/(2s)	N/A	Shower 2 West
	Water Flow Switch	FS08	Node	196C27D_DI2	N/A	Binary	1/(2s)	N/A	Shower 1 East
	Water Flow Switch	FS07	Node	196C27D_DI3	N/A	Binary	1/(2s)	N/A	Shower 2 East
SPSWH									
	Thermocouple	J17	Node	169DABB_TC0	Unk	N/A		J	Input Temp (Probe)
	Thermocouple	J12	Node	1687C98_TC0	Unk	N/A		J	Output Temp (Probe)
	Thermocouple	J20	Node	16F30E5_TC0	Unk	N/A		J	AWHout
	Water Flow Meter/Rate	IFM2	20VDC	199B370_AI2	Unk			No	Input Water (5gpm) (IFM)
	Water Flow Meter/Volume	IFM2	20VDC	199B370_DI0 & AI0	Unk			No	
	Water Flow Meter/Rate	IFM3	20VDC	1A0519F_AI2	Unk			No	Output Water (IFM)
	Water Flow Meter/Volume	IFM3	20VDC	1A0519F_DI1 & AI0	Unk			No	
	60 Amp Shark 200s	64	Parasitic	N/A	10.100.101.147	kW		No	on standby, AWH400
	20 Amp Shark 200s	22	Parasitic	N/A	10.100.101.142	kW		No	SPSWH Pump

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ANNEX C – DATA CATALOG

Collection Date	Data Set	Technology CIMT
Monday, June 06, 2016	DS-001	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160606_1-2_D.xlsx
Tuesday, June 07, 2016	DS-002	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160607_1-1_D.xlsx
Wednesday, June 08, 2016	DS-003	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160608_1-1_D.xlsx
Thursday, June 09, 2016	DS-004	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160609_1-1_D.xlsx
Friday, June 10, 2016	DS-005	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160610_1-1_D.xlsx
Saturday, June 11, 2016	DS-006	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160611_1-1_D.xlsx
Sunday, June 12, 2016	DS-007	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160612_1-1_D.xlsx
Monday, June 13, 2016	DS-008	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160613_1-1_D.xlsx
Tuesday, June 14, 2016	DS-009	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160614_1-1_D.xlsx
Wednesday, June 15, 2016	DS-010	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160615_1-1_D.xlsx
Thursday, June 16, 2016	DS-011	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160616_1-1_D.xlsx
Friday, June 17, 2016	DS-012	EDVT_DDS_EE-0690-CIMT_BCIL-Demo2-20160617_1-1_D.xlsx
Number of Data Sets	12	
		EIO
Monday, June 06, 2016	DS-001	EDVT_DDS_EE-0363-EIO_BCIL-Demo2-20160606_1-1_D.xlsx
Tuesday, June 07, 2016	DS-002	EDVT_DDS_EE-0363-EIO_BCIL-Demo2-20160607_1-1_D.xlsx
Wednesday, June 08, 2016	DS-003	EDVT_DDS_EE-0363-EIO_BCIL-Demo2-20160608_1-1_D.xlsx
Thursday, June 09, 2016	DS-004	EDVT_DDS_EE-0363-EIO_BCIL-Demo2-20160609_1-1_D.xlsx
Friday, June 10, 2016	DS-005	EDVT_DDS_EE-0363-EIO_BCIL-Demo2-20160610_1-1_D.xlsx
Saturday, June 11, 2016	DS-006	
Sunday, June 12, 2016	DS-007	
Monday, June 13, 2016	DS-008	EDVT_DDS_EE-0363-EIO_BCIL-Demo2-20160613_1-1_D.xlsx
Tuesday, June 14, 2016	DS-009	EDVT_DDS_EE-0363-EIO_BCIL-Demo2-20160614_1-1_D.xlsx
Wednesday, June 15, 2016	DS-010	EDVT_DDS_EE-0363-EIO_BCIL-Demo2-20160615_1-1_D.xlsx
Thursday, June 16, 2016	DS-011	EDVT_DDS_EE-0363-EIO_BCIL-Demo2-20160616_1-1_D.xlsx
Friday, June 17, 2016	DS-012	EDVT_DDS_EE-0363-EIO_BCIL-Demo2-20160617_1-1_D.xlsx
Number of Data Sets	10	
		FORO
Monday, June 06, 2016	DS-001	EDVT_DDS_EE-0862-FORO_BCIL-Demo2-20160606_1-1_D.xlsx
Tuesday, June 07, 2016	DS-002	EDVT_DDS_EE-0862-FORO_BCIL-Demo2-20160607_1-1_D.xlsx
Wednesday, June 08, 2016	DS-003	EDVT_DDS_EE-0862-FORO_BCIL-Demo2-20160608_1-1_D.xlsx
Thursday, June 09, 2016	DS-004	EDVT_DDS_EE-0862-FORO_BCIL-Demo2-20160609_1-1_D.xlsx
Friday, June 10, 2016	DS-005	EDVT_DDS_EE-0862-FORO_BCIL-Demo2-20160610_1-1_D.xlsx
Saturday, June 11, 2016	DS-006	
Sunday, June 12, 2016	DS-007	
Monday, June 13, 2016	DS-008	EDVT_DDS_EE-0862-FORO_BCIL-Demo2-20160613_1-1_D.xlsx
Tuesday, June 14, 2016	DS-009	EDVT_DDS_EE-0862-FORO_BCIL-Demo2-20160614_1-1_D.xlsx
Wednesday, June 15, 2016	DS-010	EDVT_DDS_EE-0862-FORO_BCIL-Demo2-20160615_1-1_D.xlsx
Thursday, June 16, 2016	DS-011	EDVT_DDS_EE-0862-FORO_BCIL-Demo2-20160616_1-1_D.xlsx
Friday, June 17, 2016	DS-012	EDVT_DDS_EE-0862-FORO_BCIL-Demo2-20160617_1-1_D.xlsx
Number of Data Sets	10	
		MILHUT
Monday, June 06, 2016	DS-001	EDVT_DDS_EE-1173-MILHUT_BCIL-Demo2-20160606_1-1_D.xlsx
Tuesday, June 07, 2016	DS-002	EDVT_DDS_EE-1173-MILHUT_BCIL-Demo2-20160607_1-1_D.xlsx
Wednesday, June 08, 2016	DS-003	EDVT_DDS_EE-1173-MILHUT_BCIL-Demo2-20160608_1-1_D.xlsx
Thursday, June 09, 2016	DS-004	EDVT_DDS_EE-1173-MILHUT_BCIL-Demo2-20160609_1-1_D.xlsx
Friday, June 10, 2016	DS-005	EDVT_DDS_EE-1173-MILHUT_BCIL-Demo2-20160610_1-1_D.xlsx
Saturday, June 11, 2016	DS-006	
Sunday, June 12, 2016	DS-007	
Monday, June 13, 2016	DS-008	EDVT_DDS_EE-1173-MILHUT_BCIL-Demo2-20160613_1-1_D.xlsx
Tuesday, June 14, 2016	DS-009	EDVT_DDS_EE-1173-MILHUT_BCIL-Demo2-20160614_1-1_D.xlsx
Wednesday, June 15, 2016	DS-010	EDVT_DDS_EE-1173-MILHUT_BCIL-Demo2-20160615_1-1_D.xlsx
Thursday, June 16, 2016	DS-011	EDVT_DDS_EE-1173-MILHUT_BCIL-Demo2-20160616_1-1_D.xlsx
Friday, June 17, 2016	DS-012	EDVT_DDS_EE-1173-MILHUT_BCIL-Demo2-20160617_1-1_D.xlsx
Number of Data Sets	10	
		SPSWH
Monday, June 06, 2016	DS-001	EDVT_DDS_EE-0300-SPSWH_BCIL-Demo2-20160606_1-3_D.xlsx
Tuesday, June 07, 2016	DS-002	EDVT_DDS_EE-0300-SPSWH_BCIL-Demo2-20160607_1-2_D.xlsx
Wednesday, June 08, 2016	DS-003	EDVT_DDS_EE-0300-SPSWH_BCIL-Demo2-20160608_1-2_D.xlsx
Thursday, June 09, 2016	DS-004	EDVT_DDS_EE-0300-SPSWH_BCIL-Demo2-20160609_1-2_D.xlsx
Friday, June 10, 2016	DS-005	EDVT_DDS_EE-0300-SPSWH_BCIL-Demo2-20160610_1-2_D.xlsx
Saturday, June 11, 2016	DS-006	
Sunday, June 12, 2016	DS-007	
Monday, June 13, 2016	DS-008	EDVT_DDS_EE-0300-SPSWH_BCIL-Demo2-20160613_1-2_D.xlsx
Tuesday, June 14, 2016	DS-009	EDVT_DDS_EE-0300-SPSWH_BCIL-Demo2-20160614_1-2_D.xlsx
Wednesday, June 15, 2016	DS-010	EDVT_DDS_EE-0300-SPSWH_BCIL-Demo2-20160615_1-1_D.xlsx
Thursday, June 16, 2016	DS-011	EDVT_DDS_EE-0300-SPSWH_BCIL-Demo2-20160616_1-1_D.xlsx
Friday, June 17, 2016	DS-012	EDVT_DDS_EE-0300-SPSWH_BCIL-Demo2-20160617_1-1_D.xlsx
Number of Data Sets	10	

Collection Date	Data Set	Technology CIMT
		SPWT
Monday, June 06, 2016	DS-001	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160606_1-1_D.xlsx
Tuesday, June 07, 2016	DS-002	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160607_1-1_D.xlsx
Wednesday, June 08, 2016	DS-003	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160608_1-1_D.xlsx
Thursday, June 09, 2016	DS-004	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160609_1-1_D.xlsx
Friday, June 10, 2016	DS-005	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160610_1-1_D.xlsx
Saturday, June 11, 2016	DS-006	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160611_1-1_D.xlsx
Sunday, June 12, 2016	DS-007	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160612_1-1_D.xlsx
Monday, June 13, 2016	DS-008	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160613_1-1_D.xlsx
Tuesday, June 14, 2016	DS-009	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160614_1-1_D.xlsx
Wednesday, June 15, 2016	DS-010	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160615_1-1_D.xlsx
Thursday, June 16, 2016	DS-011	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160616_1-1_D.xlsx
Friday, June 17, 2016	DS-012	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160617_1-1_D.xlsx
Saturday, June 18, 2016	DS-013	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160618_1-1_D.xlsx
Sunday, June 19, 2016	DS-014	EDVT_DDS_EE-0982-SPWT_BCIL-Demo2-20160619_1-1_D.xlsx
Number of Data Sets	14	
		T100
Friday, June 03, 2016	DS-P03	EDVT_DDS_EE-0030-T100_BCIL-Demo2-20160603_1-1_D.xlsx
Monday, June 06, 2016	DS-001	EDVT_DDS_EE-0030-T100_BCIL-Demo2-20160606_1-1_D.xlsx
Tuesday, June 07, 2016	DS-002	
Wednesday, June 08, 2016	DS-003	
Thursday, June 09, 2016	DS-004	
Friday, June 10, 2016	DS-005	
Saturday, June 11, 2016	DS-006	
Sunday, June 12, 2016	DS-007	
Monday, June 13, 2016	DS-008	
Tuesday, June 14, 2016	DS-009	EDVT_DDS_EE-0030-T100_BCIL-Demo2-20160614_1-1_D.xlsx
Wednesday, June 15, 2016	DS-010	EDVT_DDS_EE-0030-T100_BCIL-Demo2-20160615_1-1_D.xlsx
Thursday, June 16, 2016	DS-011	EDVT_DDS_EE-0030-T100_BCIL-Demo2-20160616_1-1_D.xlsx
Friday, June 17, 2016	DS-012	EDVT_DDS_EE-0030-T100_BCIL-Demo2-20160617_1-1_D.xlsx
Saturday, June 18, 2016	DS-013	
Sunday, June 19, 2016	DS-014	
Monday, June 20, 2016	DS-015	EDVT_DDS_EE-0030-T100_BCIL-Demo2-20160620_1-1_D.xlsx
Tuesday, June 21, 2016	DS-016	EDVT_DDS_EE-0030-T100_BCIL-Demo2-20160621_1-1_D.xlsx
Number of Data Sets	8	
		TVGM
Monday, June 06, 2016	DS-001	EDVT_DDS_EE-0462-TVGM_BCIL-Demo2-20160606_1-1_D.xlsx
Tuesday, June 07, 2016	DS-002	
Wednesday, June 08, 2016	DS-003	EDVT_DDS_EE-0462-TVGM_BCIL-Demo2-20160608_1-1_D.xlsx
Thursday, June 09, 2016	DS-004	EDVT_DDS_EE-0462-TVGM_BCIL-Demo2-20160609_1-1_D.xlsx
Friday, June 10, 2016	DS-005	EDVT_DDS_EE-0462-TVGM_BCIL-Demo2-20160610_1-1_D.xlsx
Saturday, June 11, 2016	DS-006	
Sunday, June 12, 2016	DS-007	
Monday, June 13, 2016	DS-008	EDVT_DDS_EE-0462-TVGM_BCIL-Demo2-20160613_1-1_D.xlsx
Tuesday, June 14, 2016	DS-009	EDVT_DDS_EE-0462-TVGM_BCIL-Demo2-20160614_1-1_D.xlsx
Wednesday, June 15, 2016	DS-010	EDVT_DDS_EE-0462-TVGM_BCIL-Demo2-20160615_1-1_D.xlsx
Thursday, June 16, 2016	DS-011	EDVT_DDS_EE-0462-TVGM_BCIL-Demo2-20160616_1-1_D.xlsx
Friday, June 17, 2016	DS-012	EDVT_DDS_EE-0462-TVGM_BCIL-Demo2-20160617_1-1_D.xlsx
Number of Data Sets	9	
		WDRT
Monday, June 06, 2016	DS-001	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160606_1-2_D.xlsx
Tuesday, June 07, 2016	DS-002	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160607_1-1_D.xlsx
Wednesday, June 08, 2016	DS-003	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160608_1-1_D.xlsx
Thursday, June 09, 2016	DS-004	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160609_1-1_D.xlsx
Friday, June 10, 2016	DS-005	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160610_1-1_D.xlsx
Saturday, June 11, 2016	DS-006	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160611_1-1_D.xlsx
Sunday, June 12, 2016	DS-007	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160612_1-1_D.xlsx
Monday, June 13, 2016	DS-008	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160613_1-1_D.xlsx
Tuesday, June 14, 2016	DS-009	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160614_1-1_D.xlsx
Wednesday, June 15, 2016	DS-010	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160615_1-1_D.xlsx
Thursday, June 16, 2016	DS-011	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160616_1-1_D.xlsx
Friday, June 17, 2016	DS-012	EDVT_DDS_EE-1160-WDRT_BCIL-Demo2-20160617_1-1_D.xlsx
Number of Data Sets	12	
Total data sets	95	

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ANNEX D – FOCUS GROUP REPORT

(Reprint of original)

Sustainability and Logistics Basing – Science and Technology Objective – Demonstration (SLB-STO-D) Technologies Focus Group Report

Base Camp Integration Lab (BCIL) – Fort Devens, MA
6-9 June 2016

Prepared By:
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Warfighter Directorate

U. S. Army Natick Soldier Research, Development, and Engineering Center
General Greene Avenue, Natick, MA 01760
September 2016

Executive Summary

General Comments:

- PVC and rubber hosing should be replaced with reinforced nylon to improve durability of systems.
- Add a “self-leveling system” to all TRICONs with magnetic bubble levels.
- Whenever possible, technologies should have universal parts so they are compatible with other equipment.

I. Gray Water Reuse – Forward Osmosis/Reverse Osmosis (FO/RO)

- Best suited for a base camp with 150+ personnel that would be established for 30+ days.
- Basic operation/maintenance can be performed by any Soldier; however, monthly maintenance checks require a specific MOS.
- No concerns about water quality, durability, or safety.
- Likes:
    - i. Small/compact (fits into TRICON and weighs less than 10,000 lbs.)
    - ii. Ease of use.
- Suggestions for Improvement:
    - i. Simplify technical manual and add pictures on FO/RO doors.
    - ii. Integrate instructions and troubleshooting into GUI.

II. Waste Water Treatment (WWT)

- Best suited for a base camp with 50+ personnel that would be established for at least 3 months.
- Requires training and a specific MOS to handle chemicals and supervise.
- No concerns about odor or durability.
- Soldiers would use water in latrines, but would not feel comfortable drinking it.
- Likes:
    - i. 85% black waste reduction is “fantastic.”
    - ii. Can use less potable water in latrines.
- Suggestions for Improvement:
    - i. Add a pull-out tray or separate system into two TRICONs to improve ease of access to components.
    - ii. Add a containment system for potential waste leakages.
    - iii. Add an onboard heater and insulate lines to prevent waste from freezing.
    - iv. Add a bigger vent to reduce condensation.
    - v. Lower the GUI.
    - vi. Add solar panels.

III. Water Quality Monitoring (WQM)

- Best suited for a base camp with at least 150 personnel; however, larger camps (300-500+) will have specialized Soldiers to monitor water sanitation.
- Potential difficulties using in the field – losing supplies, pollen, sanitation, keeping antibodies out of heat and light.
- Requires more training relative to other systems.

- No concerns about test result accuracy or safety.
- Likes:
    1. Good ROI – does not require sending samples to a lab.
- Suggestions for Improvement:
    1. Make simpler and more user friendly – instructions should be “dummy proof.”
    2. Make system handheld and automated.
    3. Make it self-contained so it does not require Wi-Fi or Bluetooth.

IV. Self-Powered Solar Water Heater (SPSWH)

- Best suited for a base camp that would be established for at least 3-4 weeks.
- Need 1-2 systems to support a platoon. Three systems for 150 personnel.
- No concerns about durability.
- Likes:
    1. Requires only four Soldiers to set up and can be set up in 3-4 hours.
    2. Automatically tracks sun and resets at sunset.
    3. Can be stored in a TRICON to transport easily.
    4. Individual mirrors can be replaced.

V. Containerized Ice-Making Technologies (CIMT)

- Best suited for a base camp with at least 150 personnel.
- Does not require a specific MOS to operate because it is automated and simple to use.
- Concerns about sanitation in ice storage area.
- Likes:
    1. Convenient – bags ice automatically and generates 3600 lbs. per day.
- Suggestions for Improvement:
    1. Make sling-loadable.
    2. Add RO filtration.
    3. Use 20 lb. bags instead of 10 lb. bags.
    4. Use reusable or biodegradable bags to reduce waste.

VI. HMMWV-Towable Load Following 100kW Power Unit (T100)

- Best suited for a base camp with at least 40 personnel.
- Soldiers “love” this generator.
- Does not require a specific MOS or significant training to operate.
- Likes:
    1. Ease of use.
    2. Variable speeds.
- Suggestions for Improvement:
    1. Replace aluminum frame with steel to improve durability.
    2. Make system fit inside of a TRICON so it can be airdropped.
    3. Must have 240/416V.
    4. Use JP-8 instead of diesel.
    5. Anchor down pins on T100 doors so they don’t fall off.
    6.

VII. Nanoparticle-Polymer Composite for Soldier and Energy (NPC)

- Project engineers should focus on the weight, size, and durability of this technology.
- Goal weight – 3 lbs.
- Concerns about durability – panel durability/delamination and water damage to ports.
- Likes:
    i. Can be packed into a rucksack.
    ii. Fast to employ and fold.
    iii. Could potentially reduce the number of batteries Soldiers are required to carry.
- Suggestions for Improvement:
    i. Reduce size by ¼ to better fit in rucksacks.
    ii. Add silicon plug to ports to prevent water damage.
    iii. Add more battery plug-ins.

VIII. Energy Informed Operations (EIO)

- Best suited for a base camp with at least 50 personnel (as long as it will grow to company size) that would be established for at least 3-6 months.
- Does not require a specific MOS for basic operation or maintenance (need a specific MOS for more significant maintenance).
- Concerns about durability – heat/moisture damage to electronics.
- Likes:
    i. Components can be added/removed for bigger/smaller base camps.
    ii. Footprint and modularity.
    iii. Can run itself and distribute power based on priority.
    iv. Fuel efficient and conserves resources.
    v. GUI - can use mobile tablet to monitor system.
- Suggestions for Improvement:
    i. Add a manual override.
    ii. Add fan in electronics box to prevent overheating.
    iii. Balance weight of the battery TRICON for sling-loading.
    iv. Add solar panels.

IX. Onboard Vehicle Power – Tactical V2G V2V (OBVP)

- Best suited for a base camp that would be established for less than one month.
- Both groups voiced concerns about how practical this system would be in a field environment; however, they could envision it being used for Special Forces, establishing bases or field hospitals, airport seizures, or for natural disaster and emergency relief.
- Requires training and a specific MOS to operate and maintain.
- No safety concerns.
- Likes:
    i. Can use OBVP batteries to operate quietly at night.
    ii. Troubleshooting.
- Suggestions for Improvement:
    i. Make smaller and sling-loadable.
    ii. Add solar panels.

X. MInimized Logistics Habitat UniT (MILHUT)

- Soldiers could envision this technology being used during initial entry before a Force Provider system would replace it.
- Two systems required per platoon.
- Positive feedback from all Soldiers about shower, latrine, and kitchenette.
- No concerns about gender separation in the hygiene module.
- Suggestions for Improvement:
    i. Adjust from 7 to 10 showers a day so showers can be scheduled by squad.
    ii. Add LED lights to indicate whether males or females are occupying the module.
    iii. Add quick heat cycle to dryer.

XI. Sustainable Technologies for Ration Packaging Systems

MRE Boxes

- All Soldiers agreed the new corrugated box is harder to open compared to the current fiberboard box.
- Soldiers reuse MRE boxes for trash and ammo.
- Recycling boxes in the field is not currently an important consideration.
- Soldiers from the 82nd Airborne preferred the corrugated boxes due to their lighter weight (if they can be made easier to open). Soldiers from the 542nd did not have a preference for either of the MRE boxes or MRE bags.
- Likes:
    i. Corrugated box is more lightweight and has better structural integrity.
- Suggestions for Improvement:
    i. Make corrugated box easier to open (use less glue).

MRE Bags

- A majority of Soldiers said the new MRE bags were easier to open; however, the Soldiers said they cannot always be reused in the same way as the current MRE bags.
- Soldiers currently reuse MRE bags for trash, medical emergencies (chest wounds), and chewing tobacco.
- Likes:
    i. New MRE bags are smaller – can fit more in rucksack and in uniform pockets.

Introduction

Sustainability and Logistics Basing – Science and Technology Objective – Demonstrations (SLB-STO-D) requested support from the Consumer Research Team (CRT) to conduct focus groups on 11 technologies included as part of the demonstration held at the Base Camp Integration Laboratory (BCIL) at Fort Devens, MA from May-June 2016. The focus groups were conducted on 6-9 June 2016. The goal of these focus groups was to collect qualitative feedback from two sample populations of Soldiers (intended end users and intended maintainers) who were given overviews and training on the 11 technologies. Conducting separate focus groups for the technologies with both intended end users and intended maintainers was imperative for identifying the similarities and differences of opinion between the groups.

Method and Participants

Soldiers met with psychologists from the CRT to discuss their opinions on 11 technologies they received overviews on during the demonstration:

SLB-STO-D Technologies – Demonstration 2	
I.	Gray Water Reuse – Forward Osmosis/Reverse Osmosis (FO/RO)
II.	Waste Water Treatment (WWT)
III.	Water Quality Monitoring (WQM)
IV.	Self-Powered Solar Water Heater (SPSWH)
V.	Containerized Ice-Making Technologies (CIMT)
VI.	HMWWV-Towable Load Following 100kW Power Unit (T100)
VII.	Nanoparticle-Polymer Composite for Soldier and Energy (NPC)
VIII.	Energy Informed Operations (EIO)
IX.	Onboard Vehicle Power – Tactical V2G V2V (OBVP)
X.	MInimized Logistics Habitat UniT (MILHUT)
XI.	Sustainable Technologies for Ration Packaging Systems

Focus group discussion guides were followed (see Appendices A-C), which included topics to be discussed (e.g. maintainability of the systems, best uses of the system, ideal camp size for the technology, durability problems, and recommendations for improvement). Soldiers were asked to give candid feedback in order to improve the acceptability of the systems. The focus groups were audio recorded and notes were taken by a member of the CRT. The results of these focus groups are summarized in this report.

Two groups of Soldiers participated in this demonstration's focus groups. One group was a squad of eight Infantry Soldiers from the 82nd Airborne Company at Fort Bragg, NC who represented the intended end users of the technologies. These Soldiers did not live at the BCIL during the demonstration; however, they were onsite during the week of 6 June to receive technology overviews and participate in focus groups. The other group of Soldiers was a subset of Soldiers from the 542nd Quartermaster Company who represented the intended maintainers of the technologies. This SLB-STO-D demonstration was integrated into their annual training, so Soldiers from the 542nd Quartermaster Company were housed at the BCIL for two weeks while participating in the demonstration.

82nd Airborne Division: Participants' ages ranged from 19 to 29 years, with a mean of 23.5 years. Their ranks held were PV2 (n=1), SPC (n=5), SGT (n=1), and SSG (n=1). All participants were 11B (Infantry). Years in service ranged from 1 to 8 years, with a mean of 3.38 years. Two Soldiers had deployment experience (one Soldier deployed three times to camps with less than 300 personnel, while the other Soldier deployed once to a 1000-personnel camp).

542nd Quartermaster Company: Participants' ages ranged from 19 to 28 years, with a mean of 22.73 years. Their ranks held were PV2 (n=2), PFC (n=2), SPC (n=6), and SGT (n=1). Their MOSs were Water Treatment Specialist, 92W (n=3), Power-Generation Equipment Repairer, 91D (n=3), and Shower/Laundry and Clothing Repair Specialist, 92S (n=5). Years in service ranged from 1.5 to 12 years, with a mean of 5.14 years. Two participants were female and no participants had deployment experience.

See tables below for participant details:

82nd Airborne Division Focus Group Participants (n=8)

ID#	Age	Gender	Rank	MOS	Years in Service	Months Deployed
1	20	M	SPC	11B	2	0
2	24	M	SGT	11B	6	9
3	27	M	SSG	11B	8	24
4	23	M	SPC	11B	3	0
5	19	M	PV2	11B	1	0
6	24	M	SPC	11B	2	0
7	29	M	SPC	11B	3	0
8	22	M	SPC	11B	2	0
MEAN	23.5				3.38	4.13

542nd Quartermaster Company Focus Group Participants (n=11)

ID#	Age	Gender	Rank	MOS	Years in Service	Months Deployed
1	28	M	SGT	92W	12	0
2	22	M	SPC	92W	4	0
3	21	M	SPC	91D	3	0
4	21	M	SPC	92S	4	0
5	21	M	PFC	92S	4	0
6	19	M	PV2	91D	2	0
7	21	M	PFC	92W	1.5	0
8	25	F	SPC	92S	8	0
9	22	M	PV2	92S	5	0
10	26	F	SPC	91D	9	0
11	24	M	SPC	92S	4	0
MEAN	22.73				5.14	0

Results

Water Technologies

I. Gray Water Reuse – Forward Osmosis/Reverse Osmosis (FO/RO)

Each group of Soldiers participated in separate focus groups for the Gray Water Reuse (FO/RO) system.

Figure 1: Gray Water Reuse – Forward Osmosis/Reverse Osmosis (FO/RO)

82nd Airborne Focus Group (FO/RO):

The Soldiers were first asked whether this technology was appropriate for use on a base camp and how they could envision it being used. They said it would be appropriate for any camp that is company-sized (150-personnel) or larger because it recycles water to be reused as non-potable water and therefore reduces the need for water resupply. One Soldier said it could be used when "we're coming out of GWOT [Global War on Terrorism]" because deployed units are "getting much smaller" so it is becoming more difficult to get supplies out to those units. This Soldier said "something like this will change the amount of resources you need because it's a closed loop system. If it's used for shower or laundry alone, you're going to have hardly anything lost." Another Soldier said it could be used for expeditionary forces. They were then asked how long a camp would need to be established in order for it to be worth the time investment of setting up the gray water reuse system. All Soldiers agreed that they would have to be planning to stay on a camp for greater than 30 days in order to set up and use this system, but would want to "employ it right away so that it could be established with the camp. That way the piping and hosing is done at the same time." None of the Soldiers saw any logistical problems with the system because it is sized to fit inside a TRICON, weighs less than 10,000 lbs., and "would be no different than getting a company and their gear out there."

As Infantry Soldiers, they said they would be able to operate the FO/RO system if they were given "another run down" on the system. One Soldier said "with a system like this, you're not going to worry about quality. You're just using it back in toilets. You just monitor chlorine and you don't need [a water] MOS to test chlorine." The Soldiers said they would be able to maintain the system with "daily PMCS [preventative maintenance checks and services]." And because the water is not potable, they said they could run the system as long as a medic or "water dog" took samples of the water monthly. None of the Soldiers voiced any concerns about the quality of water coming out of the system – they all said they would shower in the recycled water and would drink it if no other water was available.

The Soldiers' main durability concern was the use of PVC and rubber hoses in the system: "PVC breaks too easily, just like rubber hosing." The Soldiers suggested not using PVC and replacing the rubber hoses with reinforced nylon. They were unsure how the system would fare being air dropped, so they suggested drop testing the system.

Lastly, the Soldiers shared their likes, dislikes, and suggestions for improvement to the system. The Soldiers liked that it's user friendly, simple, "small and compact," "almost a closed loop when utilized with the waste water treatment system," and "you don't have to measure it [citric acid, anti-scale, and salt] out – you just have to throw it in there and the system draws out what it needs." One Soldier said this system "is going to save money and lives." The Soldiers suggested making the system cheaper and simplifying the technical manual with pictures, stick figures, and stickers inside the doors of the system. They also suggested integrating instructions, start-up, shut-down, and troubleshooting into the graphical user interface (GUI). In response, one Soldier expressed concerns about updating manuals if they are integrated into the GUI. Some Soldiers then suggested only having "basic level" instructions in the GUI (e.g. start-up, shut-down, and maintenance) and that "anything more would be for the monthly maintenance specialists." Another Soldier suggested having the ability to update manuals in the GUI with an SD card.

542nd Quartermaster Focus Group (FO/RO):

The Soldiers were first asked at what size camp this system could be used and how long a camp would need to be established in order for it to be worth the time investment of setting up the gray water reuse system. They said that because there is a minimum amount of gray water that needs to be in the system for it to continue running, the camp cannot be too small. Most of the Soldiers agreed that the smallest camp it could be used would be a 150-person camp and the largest would be an 800-person camp. The Soldiers did not think there was a minimum amount of time the camp would need to be established in order to use this system because Soldiers "could roll it out pretty quickly" and "setup shouldn't take long at all." The Soldiers said this system is "more beneficial" and would be used more frequently than the waste water treatment system because it outputs more water.

Both the water and power MOS participants in this group said that any Soldier could run the system because it is “one of the most user friendly pieces of equipment here.” They thought it was user friendly because the citric acid, anti-scale, and salt could be added to the system without requiring measurement. The Soldiers said the system seemed “very maintenance free” and “very simplistic” compared to systems that require precisely measuring out the chemicals. Some of the Soldiers said specialized training for this system would not be necessary because “you could read the manual and start-up procedures and be fine.” Other Soldiers said a week-long class would be beneficial for learning how to set up, run, and troubleshoot the system. All of the Soldiers agreed that basic operation of the FO/RO system would not require extensive training; however, the Soldiers also agreed that “if something major happens, it’s above us to fix it.”

When asked if the 92W (Water Treatment Specialist) MOS should be expanded to include gray water reuse and black water treatment, the Soldiers said it could be expanded for gray water reuse because the FO/RO system is simple to use and would be easy to run in addition to other 92W duties. These Soldiers said, however, that having 92W Soldiers treating black water “didn’t seem feasible” because they noticed the engineer’s difficulties working on the black water treatment system and did not think it was a simple enough system. The 92W Soldiers in the group said it’s “possible to include black water, but it’s not there yet. If it was more simplistic, but I don’t know if it can be.” The 92S (Shower/Laundry and Laundry and Clothing Repair Specialist) Soldiers said they often “tag along” with 92W Soldiers to “get familiarization,” so although they are not water treatment specialists, they said they “should be a part of that [gray water reuse] because it deals with stuff we’re using – it connects to the machines we’re using.” The 92S Soldiers said they could run this system with “no problems.”

Next, the Soldiers were asked if they had any durability concerns with the system being used in the field. None of the Soldiers indicated concerns about durability because it “comes in a self-contained container [TRICON].” They liked that the system came in a TRICON because it’s compact and provides easy access to the reverse osmosis components.

The Soldiers did not foresee any safety concerns using the system as long as Soldiers operating and maintaining the system use proper PPE (i.e. gloves, face shield, and glasses). They also said they were confident in the quality of the recycled water coming out of the system: “I would be comfortable showering in it… I’d even drink it”; “If it tested okay, I’d drink it.”

Lastly, Soldiers shared their likes and dislikes of the system. The main likes were the simplicity and ease of use of the system, the display, that the system is under low pressure, and that it has “fail safes in place.” The Soldiers thought the display on the system was at the “perfect level” and easy to read. They liked that the display “breaks down the entire flow of water” and “shows you what pumps are working and what’s not and collects data so you don’t have to take it [data] down on paper.” They also liked the RO filter system: “If one [RO filter] goes down it would just keep running. It would just bypass that one and use another one as opposed to the machine just not working”; “I like that the RO filters are just regular industrial ones. You’d have them on a yacht or something like that… they’ve worked for a long time and nothing has happened to them.” The Soldiers shared only one dislike of the system, which was related to fitting the chemical tanks. This Soldier suggested having “something universal like a quick disconnect.”

II. Waste Water Treatment (WWT)

Each group of Soldiers participated in separate focus groups for the Waste Water Treatment (WWT) system.

Figure 2: Waste Water Treatment (WWT)

82nd Airborne Focus Group (WWT):

The Soldiers were first asked whether this technology was appropriate for use on a base camp and for what size camp it would be best suited. They all thought an 85% reduction of black waste was “fantastic” and that it could be used on a base camp with at least 50 personnel. For other uses of the system, the Soldiers said it could be used on expeditionary FOBs on other continents because it “keeps our direct area of operations cleaner and doesn’t put stress on local population’s resources.”

When asked how long a camp needs to be established in order to use this system, most of the Soldiers agreed that a camp would need to be established for at least three months. The Soldiers stressed that this does not mean they would want to bring in the system after three months, but rather they would want to set up the system on day one, but only if they were planning to be there for at least three months. This is because it takes three weeks to get the system up and another three weeks for it to be fully operational.

Next, the Soldiers were asked whether they believe an MOS-specific Soldier would be necessary to run this system. Unlike the gray water reuse system, the Soldiers said that this system does need a trained MOS-specific Soldier because it “can’t go without supervision for more than three days… so it needs a resident MOS." The Soldiers thought this system could possibly be used in conjunction with other water treatment systems so that the "resident MOS" could be in charge of running and monitoring all of them.

None of the Soldiers expressed any concerns about odors from the system because "smell is going to happen regardless" and they would prefer the WWT system over other black waste systems because "all black water goes to one location instead of having Porta-Johns all over the place." They did, however, express concerns about the system's ease of use. Although they said operating the system would be easier than maintaining it, they said it was like a "temperamental child" because of the problems it encountered during the demonstration. They also said it would be difficult to maintain with the entire system housed in a single TRICON due to its confined space and lack of accessibility for repairs and maintenance. The Soldiers did not like that an experienced forklift operator would be needed to remove the "center core" for maintenance. Because of this, they said they would prefer the system be spread between two TRICONs. All of the Soldiers agreed that it would be easier to maintain and access all components of the system if it were spread between two TRICONs.

When asked about their confidence in the quality of water output from system, they said it "looked fine" and would reuse the water for flushing toilets, but would not drink it. They also said they would like the ability to use the water for laundry.

Next, the Soldiers discussed their safety concerns. They were concerned about the chemicals used in the system and said they would need an MOS-specific person to handle the chemicals. The Soldiers would like the ability to replace the 15-gallon tanks instead of having to refill them. They also suggested "ensuring there is a containment system in case of leakage" similar to "a skirt like a generator or fuel blivet."

Lastly, they provided some suggestions for improvement to the WWT system. The Soldiers said solar panels should be added to the TRICON(s) to lower the fuel requirement of the system. To improve the durability of the system, they suggested replacing the PVC and adding reinforced nylon tubing. They also suggested adding an onboard heater and insulating the lines to prevent the waste from freezing. Their other suggestions for improvement were to add a bigger vent to help with condensation, make the control box smaller, and lower the GUI. As a general suggestion for improvement to all TRICON systems, they said TRICONs need a "self-leveling jacking system where the knuckles go in, you jack it up, and there's a magnetic level. You crank it up and it levels the system. Then you take the bubble level and move onto the next one."

542nd Quartermaster Focus Group (WWT):

The Soldiers were first asked at what size camp this technology would be best suited. One Soldier thought the system could "feasibly" be used on up to an 800-person camp; however, most thought a camp with a maximum of 250 personnel would be more appropriate because of the amount of water the WWT system outputs: "it doesn't push out enough usable gray water to support anything more than that [250 personnel]. Even with what it was producing, it's almost 100 gallons short of the normal daily usage we had at Fort Bliss. Our daily usage was 450-600 gallons just for showers and laundry for 140-162 personnel. We were using about 1000 gallons a night." The Soldiers were then informed the water from the WWT system would primarily be used for flushing toilets. Based on this information, the Soldiers said "if that's the case, then 500 gallons a day is plenty" and said multiple WWT units could be used to support a larger camp. They liked that with this system, they could use less potable water for the toilets and therefore have more potable water for other purposes.

Most of the Soldiers said use of the WWT system would be “more optimal… at an isolated camp where they’re not traveling in and out much because there would be less traffic coming in to take the waste out. If it was a big camp with trucks moving in and out, I could see people just taking the waste out.”

Next, the Soldiers were asked if the system would require MOS-specific Soldiers to run it. All of the Soldiers agreed that either a 92W (Water Treatment Specialist) or 92S (Shower/Laundry and Clothing Repair Specialist) would be needed to run the WWT system; however, they explained that other Soldiers would be able to perform basic operations of the system, but “nothing too in depth.” They also said Soldiers handling the system would need training/schooling and certification “especially when the environmental people come out wanting to see that we know what we’re doing.”

For maintenance of the system, the Soldiers said it “could be comparable to the FO/RO system because the water lines are normal things we run into.” One of the focus group moderators then shared that Soldiers in the 82nd Airborne focus group said the system should be in two TRICON containers to make maintenance easier. The 542nd Soldiers did not think two containers would be better because it is “a lot more equipment” and suggested having a “pull out tray for the chemicals” instead. One Soldier said, however, that if they did have a second TRICON container, it would allow for enough space to store the onion bag.

The Soldiers then discussed any difficulties or concerns they could foresee with the system. During the demonstration, there were various problems with the system that prevented proper functioning: “it’s broken down now and there’s an air pocket. In the lab, you have the tools to fix it, but now it’s a whole other issue. It needs further development for it to be suitable for us.” The Soldiers expressed concern about the complexity of the system because “there’s a lot of information to take in.” Their safety concerns included needing to climb a ladder to reach the GUI and the health hazards related to working with black waste. The Soldiers did not have any concerns about the durability of the system: “it seems to be built pretty well and moving sludge off the membrane seems easy.”

Lastly, the Soldiers provided some suggestions for improvement to the WWT system. Their main suggestions included having color-coded quick connects on the chemical tanks, lowering the GUI/screen, and reversing the emergency light system: “when the emergency stop is on, the light is off. When it’s off, the light is red.” The Soldiers said this was confusing because typically a red light is an indicator that something is wrong. They also said the emergency stop should cut power to the entire system, not just the WWT program.

III. Water Quality Monitoring (WQM)

Each group of Soldiers participated in separate focus groups for the Water Quality Monitoring (WQM) system.

Figure 3: Water Quality Monitoring (WQM)

82nd Airborne Focus Group (WQM):

The Soldiers were first asked whether this technology was appropriate for use on a base camp and for what size camp it would be best suited. Overall, the Soldiers thought the WQM was convenient and a good idea; however, they said as Infantry Soldiers, they would not be the ones using the technology to test water quality. Most of the Soldiers agreed the minimum base camp size this technology is best suited for would be 150 personnel. For the largest base camp this technology could be used, some of the Soldiers thought 300 personnel would be the largest because “higher than that, you’re going to have water sanitation and dedicated teams of techs.” Other Soldiers thought it would be appropriate for use on a base camp with up to 600-1000 personnel.

During the demonstration, the Soldiers observed a researcher testing water with the WQM system. The Soldiers were concerned about conducting tests outside because of pollen and “stuff falling on the ground, which probably affects quality, especially if you drop something you need.” They thought a lab setting would be ideal for testing with this technology because in a field environment, they would worry about losing required supplies. In addition, the technology would need a ruggedized Pelican case to protect it if used in the field. Following the water testing, the Soldiers were able to look at the WQM display, but said "I didn't know what I was looking at" and "if there was something on there, I wouldn't know what it was." They explained that understanding the results of testing would come with specialized WQM training.

All of the Soldiers thought the WQM system would require at least 40 hours of training and certification because the procedure is not simple enough to follow without training. Most of the Soldiers said a specific MOS would not necessarily be required because they would be able to use the technology with enough practice: "I read through the procedures. I understood it but some of them I had to read twice. It's not simple, but it's understandable." Although the Soldiers said they could learn to use it, they would still prefer something simpler: "We just need something where you can scoop water in and it tells us"; "For our end, we would need something that just detects it"; "Why can't it be like a pool with strips?"

Next, the Soldiers were asked whether they believed the system provided accurate results. All of the Soldiers trusted that the results would be accurate and would feel safe showering in water tested with the WQM system. They also said they did not have any safety concerns about using the WQM system, but thought it should require the use of gloves, eye protection, and an apron.

Lastly, the Soldiers provided suggestions for improvement and discussed the WQM's return on investment. Their main suggestions were to make it more user friendly, hand-held, and automated; however, they said that regardless of automation, Soldiers would still need to be trained and certified to use the equipment. Additionally, the Soldiers had concerns about needing a cell phone to use with the WQM because they don't have access to cell phones in the field. Because of this, they said a cell phone would have to be included with the system. Some of the Soldiers then said they had been issued an iPod Touch in the field and suggested using them for the WQM system because "we could Bluetooth images to squad leaders and have the manual and references put onto it." They said the 40 hours of training "could be eliminated" if there was an app on the phone or iPod Touch that "could tell you what to do and when to do it. Like 'hey, time to put another drop in there.'" At the conclusion of this discussion, one Soldier said that the WQM should be a "self-contained system" meaning it should not require Wi-Fi or Bluetooth to function because it "needs to work on the premise that we aren't going to have signal." Because of this, he said the phone or iPod Touch would require its own database so that it did not require sending or receiving data via Wi-Fi or Bluetooth.

All of the Soldiers said the system provided a good return on investment because "if we didn't have this, we would have to send it [water samples] to a lab, which requires logistics to send it there and back. If we have this to do it in the field, we can have results in two hours."

542nd Quartermaster Focus Group (WQM):

The Soldiers were first asked whether this technology was appropriate for use on a base camp and for what size camp it would be best suited. All of the Soldiers said it would be appropriate to use on a base camp because of its speed and accuracy; however, they also said it is "complex" and "there are a lot of steps and a lot of processes," which would require 1-3 days of specialized training. Although it would require training, the Soldiers liked that it would save time because it did not require shipping samples to a lab. Some of the Soldiers said the technology could be used on any size camp, while others thought the ideal range would be 150-500 personnel. One Soldier said "I probably wouldn't go over 500 because once you get to 500 people, a water person has to take care of the drinking water, shower water, and laundry water and there are lots of tests."

The Soldiers agreed that the WQM system should primarily be utilized by a trained MOS-specific Soldier (i.e. 92S – Shower/Laundry and Clothing Repair Specialist, 92W – Water Treatment Specialist, or 68S – Preventative Medicine Specialist); however, they also said "cross-training is always good" and "it would be best if the whole unit knew how to operate and fix it just in case all the water specialty MOSs had to leave and something broke." For specialized training, the Soldiers said hands-on training is necessary and the training could be conducted during "one of our four-day drills up here." The Soldiers said the procedure "didn't look difficult," but "reading through the instructions was more advanced. They were made for someone who really knows what they're doing." These Soldiers suggested making the instructions "more private-proof," meaning they should be easier for a newer Soldier to read and understand.

Next, the Soldiers were asked whether they believed the system provided accurate results. All of the Soldiers agreed that the system "seemed like it would be pretty accurate." They also agreed that they would feel comfortable showering in water tested with the WQM system, but would not necessarily feel comfortable drinking it. The only safety concern they shared was "if bacteria is in the water and you drink it."

When asked if an automated system would be preferable to a manual kit, some of the Soldiers thought automation "is the way to go if it can be done accurately," while the other Soldiers were concerned about automation because "if it's automated, how will you catch something [errors]?" The Soldiers said if it could be automated, the tests should be done more than once to reduce potential errors.

The Soldiers then shared various concerns about durability and using the WQM system in a field environment. One of their concerns was the difficulty of keeping the light and heat sensitive antibodies protected in a field environment. Most of the Soldiers agreed that this technology would be best used indoors because of pollen and sanitation: "everything has to be really clean. I feel like if you're in bad weather conditions, it'll be hard unless you have a building that's clean and enclosed." Their other concerns were "if you messed something up down the line, you've already wasted three hours because you couldn't use the reading" and having results come in on a cell phone. They were concerned about having results on a cell phone because "what if it [the battery] drains? What if there's no charging? Or rain? Then you can't get the results anyway."

Lastly, the Soldiers provided suggestions for improvement to the WQM system. Their main suggestion for improvement was to make the instructions "dummy proof." The Soldiers said "each step should be very specific and drawn out because everyone learns differently and if you don't do it correctly, it's not going to be as accurate as it's supposed to be."

IV. Self-Powered Solar Water Heater (SPSWH)

Due to scheduling, only one focus group was conducted for the Self-Powered Solar Water Heater (SPSWH).

Figure 4: Self-Powered Solar Water Heater (SPSWH)

82nd Airborne Focus Group (SPSWH):

The Soldiers were first asked whether this technology was appropriate for use on a base camp and for what size camp it would be best suited. The Soldiers liked that "everything can be picked up by a four-man group," it can be set up in 3-4 hours, it can be easily serviced, "it follows the sun," and it can be stored in a TRICON. They also liked that it "has the capability to generate power" and can function as a generator. The Soldiers would "definitely use this system" and agreed the "capabilities are endless" with the SPSWH because there is "a lot of science behind it, but a lot of common sense too." Although they thought the system would be appropriate for use on a base camp, the Soldiers said that they would only set it up if they were going to be somewhere longer than 3-4 weeks. Another Soldier explained that "it does take up some space" and because the system looks like a satellite, "it's going to be a reference point for mortar attacks." This Soldier also said "I'd rather them hit that [SPSWH] than our TOC." The Soldiers then said 1-2 systems would heat enough water for a platoon of Soldiers and three systems could generate enough heated water for 150 personnel. They also agreed it would be practical to have one system per kitchen.

Next, the Soldiers were asked if anyone could operate the system. All of the Soldiers agreed that the system is “so simple” because it “detects sunlight and operates itself.” Although simple, they said there should still be someone who is trained on the system so they are able to show other Soldiers how to use it. The Soldiers said the engineers “thought of literally everything” and liked that the system resets itself back to facing east at sunset and that the “only maintenance is lubricating it.” They were enthusiastic about the change from four to 16 mirrors they were told would be incorporated into the next SPSWH iteration: “Because there are 16 mirrors, single mirrors could be replaced instead of taking the entire panel off. At some point, something is going to break, so you can replace any one and swap them.” Their only suggestion for improvement for the mirrors was that the four mirrors in the center could be removed because they “are not getting much sun anyway when it is pointed at the sun.”

The Soldiers then discussed logistics of transporting the system. They liked that three SPSWH systems could fit into a TRICON because a Black Hawk would be able to transport them in. The Soldiers also commented that that they would “not be surprised to see this system put on a trailer at some point” to make transport and movement even easier.

Lastly, Soldiers discussed potential challenges using the system and durability concerns. The main challenge they could foresee using this system in the field is when it “loses the sun behind clouds” because it requires someone to manually reset the system. The Soldiers were also concerned about the reliability of automatically tracking the sun because they were told by the system’s engineer that it was “having some issues with tracking and sometimes it was just a little bit off.” Overall, the Soldiers were not concerned about the system’s durability because it is waterproof and a “smart system that sets itself down in high winds [75 mph].” Their only concern was using the system in an area with lots of sand or dirt because they would need pressurized water to clean it off of the mirrors.

V. Containerized Ice-Making Technologies (CIMT)

Due to scheduling, only one focus group was conducted for the Containerized Ice-Making Technologies (CIMT).

Figure 5: Containerized Ice-Making Technologies (CIMT)

82nd Airborne Focus Group (CIMT):

The Soldiers were first asked at what size camp this technology would be best suited and how much ice is typically used on a base camp. All of the Soldiers agreed it should be used on a base camp with at least 150 personnel because it generates too much ice for a smaller base camp. The Soldiers said “one wheeled patrol could use 200 pounds of ice” minimum and that every vehicle would have a chest of ice for medical use and to keep water cold. One Soldier said the system would likely be running 24/7 when there are three patrols and Soldiers using ice in towers. They then said “having cold drinks waiting for you in a tent or hard structure is a morale boost and it’s a safety thing as well. It beats soaking a sock and hanging it off your side mirror.” The Soldiers indicated the CIMT could be employed immediately upon establishment of a base camp; however, they said “if you’re early entry, you normally don’t have potable water" so the ice would initially not be consumable and could only be used for coolers. When asked about transport of the system, the Soldiers said they would like the technology to be sling-loadable.

The Soldiers were then asked if a specialized skill-set or training would be required to use the system. All of the Soldiers said it would not require an MOS-specific Soldier to operate because it is automated and simple to use. They also said cooks would likely be responsible for the system on a 150-personnel base camp. The Soldiers did not think formal training would be necessary to use the system because of its simplicity. One Soldier suggested putting pictures and instructions on the door of the CIMT to show Soldiers how to use it.

Next, the Soldiers discussed the durability, design, and safety concerns of the CIMT. All of the Soldiers agreed that any PVC in the system should be replaced with reinforced nylon tubing to increase durability of the technology: "It's [PVC] not durable over time because it's rigid and it can become brittle over time." Some of the Soldiers expressed concerns about it being a "tight squeeze" between the TRICON container and the mechanical frame and said they would need more space because they don't always have a truck to pull it out. They also suggested adding a winch system to help remove it because it currently has only a limited number of wheels. The only safety concern the Soldiers shared was related to sanitation of the ice storage area. Due to Soldiers needing to enter the storage area to get bags of ice, they were concerned about ensuring that area was always kept clean. Relatedly, one Soldier said "if you give more space inside the refrigeration to come out, if there are gaps around it during a sand storm, it definitely needs to be protected. Otherwise, dirt and dust is going to get in there and into the machine." The Soldiers emphasized that all components of the technology need to be "as sealed as possible" to ensure no dirt or dust gets inside.

The Soldiers then discussed likes and benefits of the system. They found the system to be convenient because it generates and bags the ice itself and liked that it can generate 3600 pounds of ice per day. They said it would "alleviate strain on the DFAC or plus up the capability of the DFAC." Although the Soldiers liked the system overall, one Soldier said he was "hesitant to give it [CIMT] a thumbs up" because it requires potable water. This Soldier was conflicted because he would like the ability to use non-potable water in the CIMT; however, he was concerned about the potential use of contaminated water: "If you have well water and you don't have a person to monitor water quality… if somebody does drink or eat the ice, you affect operations because they get sick. If it's an Afghan well, it can have E. coli." Because of this, he said he would "like to see that system [CIMT] with RO filtration." Another Soldier then said "ice is made non-potable normally. It's not abnormal for it to be non-potable if it's just for ice chests. People wouldn't drink it or eat it." Some of the other Soldiers agreed that the requirement should be changed to not requiring potable water; however, it was noted that "once you hook that system up to something that's non-potable, you have to flush it before you use it again with potable."

Lastly, the Soldiers provided suggestions for improvement to the CIMT system. Their main suggestions included having the system be able to hold more bags and adding a trough or "something to pour the water into so it could be reused in the system." They also suggested using 20 pound bags instead of 10 pound bags because they "don't have to move as many bags if they're 20 pounds" and would like that two Soldiers could carry 80 pounds of ice instead of 40 pounds. They further explained that "the whole point of this is waste reduction," so they would like reusable bags (if possible) or bags that are biodegradable.

Power Technologies

VI. HMMWV-Towable Load Following 100Kw Power Unit (T100)

Due to scheduling, only one focus group was conducted for the HMMWV-Towable Load Following 100Kw Power Unit (T100).

Figure 6: HMMWV-Towable Load Following 100Kw Power Unit (T100)

82nd Airborne Focus Group (T100):

The Soldiers were first asked whether this technology was appropriate for use on a base camp and for what size camp it would be best suited. All of the Soldiers said they "love this generator" and that the T100 would be practical in a field environment; however, one Soldier said "if deploying, it needs a steel frame. It will increase the weight but it needs to be ruggedized." Another Soldier then said the T100's hitch should be removable or the system should be slightly smaller so that it can be put inside of a TRICON to be airdropped or it should be made sling-loadable. The Soldiers were then asked if this system needed to be movable after it was sling-loaded in. Most of the Soldiers were not concerned about being able to move the system once it was brought to the camp because they pre-plan where it should be placed; however, some of the Soldiers said a trailer is the "best setup" because it's "very mobile." They said there was no minimum time they would need to be on a base camp to use this system and said it could be used on any size camp supporting more than 40 personnel: "Whether we're in the field for one day or 12 hours, if we need electricity, we need this."

Next, the Soldiers were asked if anyone could operate the system and how they envisioned the system being used. They all said it could be operated by any Soldier because "it's plug and play" and the "next generation will be even easier because you will just press a button." The Soldiers also said any Infantry Soldier could perform basic maintenance of the system because "Infantry companies get 5Kw and 10Kw [generators] and we are required to know basic functions, so this will just fall on the same lines." They said access to the inside of the system was easy because "you can take both sides and the top off" and requested that this type of access not be changed. The Soldiers did not think much training would be required to run the system: "just training when it gets assigned to the unit." The Soldiers were impressed with the system's ease of use: "It pumped its own oil out – that's amazing. It practically runs itself"; "This is another common sense product – they thought of everything."

They envisioned the system being used to power "operations centers and housing" or "to establish a COP away from a major FOB." They liked that "this system takes no seats away from our trucks so we can carry more equipment. The trailer versus skid has more capabilities for where it can go." All of the Soldiers also said the system could be used to run a platoon-sized FOB with its 100Kw because it is "very efficient and very powerful" and does not require "retrofitting" of a vehicle. The Soldiers liked that the T100 "can adjust its load based on what we're losing on the base camp" and also liked the variable speeds because it saves fuel. They viewed the variable speeds as "a big plus." The Soldiers then explained that having 240/416VAC is "good because Europe uses that and it's good to have for heavy equipment" and said "having the capability [240/416VAC] is a must."

For durability of the system, the Soldiers were concerned about the aluminum on the top of the system "getting worn down quickly" or "bent up," especially if being sling-loaded. One Soldier said "it would be a one-time fly thing because of the damage it would cause. You would probably risk damaging the inside and the casing would be unserviceable. If you start bending it, it's not going to come off like it's intending to. You can't just bend it back because it snaps." To mitigate damage done to the system, the Soldiers said they would put tape on friction points and suggested replacing the aluminum with steel.

Lastly, the Soldiers provided suggestions for improvement to the T100 system. One change the Soldiers said needed to be made to the system was it should run on JP-8, not diesel, because they want to "make sure it can take common oil and fuel… Bradleys, Strykers, and Tanks all take the same fuel and oil, so we'd want it [generators] to be the same." Their other suggestions included anchoring down the pins on the system's doors so they don't fall off, making it more durable for sling-loading, and adding the ability to siphon gas out of a fuel blivet.

VII. Nanoparticle-Polymer Composite for Soldier and Energy (NPC)

Due to scheduling, only one focus group was conducted for the Nanoparticle-Polymer Composite for Soldier and Energy (NPC).

Figure 7: Nanoparticle-Polymer Composite for Soldier and Energy (NPC)

82nd Airborne Focus Group (NPC):

The Soldiers were first asked whether this technology was appropriate for use on a base camp and for what size camp it would be best suited. Most of the Soldiers agreed the NPC was best suited for use on a base camp; however, one Soldier later said “the biggest thing is understanding the mission. It’s [NPC] for going out into the field and being in the elements, not at a base camp.” Most of the Soldiers said the technology would be used more frequently on a smaller camp because there are “more resources to plug in and less resupply”; however, some of the Soldiers said the NPC could be used on bigger camps to charge 5590 lithium batteries. The Soldiers believed this system could be employed right away when deployed: “As small as this is, you could pack it out [i.e. inside a rucksack]. It could go out with us everywhere”; “If I had this, I would use it every day.” The Soldiers were then asked whether they had any concerns about carrying an expensive piece of equipment and the potential for it being stolen. None of the Soldiers were concerned because they currently carry night vision devices that cost $15-20k; however, one Soldier said he would not want to carry “the other one [the smaller, more expensive, more brittle system] around because it’s going to get damaged.”

They envisioned the NPC being used primarily before going out on missions: “The day before [a mission], we would lay it out and charge batteries while we’re doing other things.” They explained they would need one system per squad and that they would mainly charge ASIP batteries, 123 batteries, and rechargeable AA batteries. When asked if they would prefer using the technology on flat ground or hung on an upright structure, the Soldiers said it would be best if it were “up and facing the sun, but realistically, it’ll be on the flat ground.”

Next, the Soldiers discussed weight, size, and durability of the technology. Weight, size, and durability were deemed “key terms” by the Soldiers to consider when further developing this technology. For weight of the NPC, all of the Soldiers agreed it should be as light as possible and explained that “everything adds up,” so cutting down any amount of weight is beneficial to a Soldier: “4.7 pounds isn’t heavy standalone, but bags are pushing 80 pounds. We have water, ammo, barrels, radio equipment, and batteries.” Another Soldier said “9 times out of 10, you leave the heavy stuff [batteries] when you draw out of a country, so the lighter it is, the more useful it is, and the longer it stays in the inventory.” One Soldier said the goal weight for the technology should be around 3 pounds. For size of the NPC, some of the Soldiers said that the current size of the NPC is “a little too big” and suggested making it ¼ smaller because there are “only two places in the rucksack it could go, on the top or on the frame.” One Soldier said “for what we do every day, it’s a perfect size… but make it smaller for recon and where extra money is worth it.” Although the Soldiers thought the technology could be made lighter and smaller, they believed the NPC could potentially lighten their overall load by reducing the number of spare batteries they are required to carry. The Soldiers’ main durability concerns were delamination or damage to the panels, water damage to the ports, and whether it would survive impact after a jump. To prevent delamination, they suggested the engineers “keep the backing material, but work on different lamination or just make it a little bit bigger so there is more of a folding surface [between panels] so there is less wear and tear on the folds.” They also suggested adding a “silicon plug to the end” to help with waterproofing, creating a repair kit for the panels and lamination, and rigorously testing the durability of the ports (during use and when packing into a rucksack).

The Soldiers then shared their main likes and dislikes of the technology. They liked that it is easy and fast to employ and fold, “saves weight in the long run”, reduces the strain on resources, and will “save so much money because we will need less JP-8 and less batteries.” All of the Soldiers said they would “love to test this” so they’d want the technology issued to them immediately to “put it through hell” and provide feedback to the engineers after testing.

Lastly, the Soldiers provided suggestions for improvement to the NPC. One Soldier suggested making the technology “multifunctional” by making it function as a poncho as well because “then you don’t have to pack the poncho.” Relatedly, another Soldier said that “this [NPC] is a little smaller than a regular poncho, so if you increased the size to increase its durability, it wouldn’t be any loss for us.” Their other suggestions included adding more battery plug ins and more adapters on the battery or end of the cord, adding a USB port directly to the solar panels for charging phones, iPod Touches, and batteries for GPS, being able to create a microgrid with the panels, and being able to charge more batteries simultaneously.

VIII. Energy Informed Operations (EIO)

Each group of Soldiers participated in separate focus groups for the Energy Informed Operations (EIO) system.

Figure 8: Energy Informed Operations (EIO)

82nd Airborne Focus Group (EIO):

The Soldiers were first asked at what size camp this technology would be best suited, how long they would need to be on a base camp to use the EIO, and what they would power with the system. One Soldier said he would use the system on a base camp with at least 50 personnel: “Off the bat, if we know we’re moving into an area, we can use this system for 50-men and up. We’re setting ourselves up for success as we add more tents and making everyone’s job easier down the road while providing the best power source available. It’s awesome.” One Soldier then said the system should also only be used if the base camp will grow to company size. The other Soldiers said the EIO can “easily be added on to” for base camps with more personnel because smaller generators can be swapped out for larger ones and additional generators can be added. All of the Soldiers agreed the system should be set up during the initial setup of the base camp, but only if they would be on a base camp for at least three months because of the time required for setup. When asked what they would power with the system, all of the Soldiers said they would power the entire camp. The Soldiers explained that a battery and two generators connected to the EIO system “would be perfect for a FOB.”

When the Soldiers were asked about the system's footprint, one Soldier said "this is probably the best system footprint-wise since I've been in the Army and that's saying a lot." They liked that the system is "very modular" because the generators can be placed wherever there is space or it can be consolidated to a single location. Some Soldiers then expressed concerns about having the entire EIO system in a single location: "I don't like the idea of them all in the same area because of rocket attacks or mortar attacks. If they get it, it's done." Another Soldier then explained that although it might not be ideal to consolidate the system, it likely would be consolidated in a field environment.

The Soldiers were asked if anyone could operate the system and what training or certification would be required. All of the Soldiers agreed anyone could set up and operate the system, but "fixing it is a different story… anything past level 10 maintenance needs an MOS." The Soldiers said some training would be required if a Soldier had never seen the EIO or similar system, but because there are other microgrid systems in the Army, Soldiers would mainly need training on the differing components of the EIO system and GUI.

Next, the Soldiers discussed the pros and cons of a smart generator system. The pros of the smart generator system were that it can run itself, can distribute power based on priority, it's fuel efficient, conserves resources, can turn on generators when others are low on fuel, is smaller than preexisting systems, requires less generator maintenance, and lets Soldiers know when to order maintenance parts. The cons of the smart generator system were that it does not have a maintenance plan programmed into the system and does not have a manual override to be able to perform maintenance at any time. One Soldier said "nothing is worse than when you're trying to do maintenance and you want to just shut it [EIO] off and you can't. You always need the ability to do manual mode."

The engineers then asked the Soldiers about the planning wizard. The Soldiers said it is "awesome" and would be helpful for improving efficiency of a base camp. They noted that they would not be the ones using it because it would be used by a major or 1SG. The Soldiers said "this is something they might use stateside to plan because it makes their job easier" before a deployment.

The Soldiers then discussed durability and safety concerns. Their main durability concerns were heat or moisture damaging the system's electronics. They were told the electronics box has "vapor stripping" to protect it from moisture, but the electronics would not be protected if the box were open in a wet environment. Because of this, the Soldiers were unsure how the system would fare in a jungle location. To prevent overheating, the Soldiers suggested adding a "little computer fan" inside the electronics box. Their only safety concern was the system's use of acid batteries and suggested using a different type of battery. They were told by engineers that the EIO's lead acid batteries are used because they are "extremely efficient and economical." The engineers also noted, however, that there is a problem with the batteries' weight and lifetime.

Lastly, the Soldiers shared their likes and dislikes of the technology and suggestions for improvement to the EIO system. The Soldiers said the EIO shows "great ingenuity" and liked that the system is "easy to understand, convenient, and tells us fuel levels." One Soldier said he liked the ability to use a mobile tablet with the EIO because they would be able to monitor the system from their TOC and "don't have to run from the TOC to the microgrid." Other Soldiers agreed that a tablet system would be "awesome," but the tablet would need to be ruggedized. The Soldiers liked that the EIO "can take elements from anything" and emphasized that all military equipment should be developed in the same way: "That's the first thing anyone should look at when they're talking about military equipment. It needs to have universal parts so everything can play with each other"; "The nice thing about your system is you could put 5Kw generators if you retrofit them. Any system could be incorporated into yours. This is amazing." One Soldier suggested that engineers "look at running different generators for a specific duration of time to lessen the amount of maintenance and need for oil changes." The Soldiers' other suggestions for improvement included fixing the balance of the battery TRICON because it "needs to be equally balanced for sling loading" and using solar power to charge the EIO's batteries during "low points" of use. The engineers then asked what kind of data they would like to see on the GUI. Some of the Soldiers' ideas included being able to plug everything in and have the system calculate the max load, being able to tell the system how much fuel they have to see how long the system could run before requiring resupply, and being able to see how many components are connected.

542nd Quartermaster Focus Group (EIO):

The Soldiers were first asked at what size camp this technology would be best suited, how long they would need to be on a base camp to use the EIO, and what they would power with the system. All of the Soldiers agreed the system could be used on a base camp with at least 150 personnel. They also agreed that the EIO would be best suited for a base camp that would be established for at least six months and said they would want to start setting up the EIO on day one because "you'd want to be setting it up with everything else." The Soldiers said the EIO would not be suitable for short-term use because a "regular genset could do the same" and it would not be worth the time required to set up and run Ethernet cables. When asked what they would power with the system, most of the Soldiers said they would power the entire camp; however, one Soldier said he would not power dryers with this system because they would be run off of shore power.

The Soldiers were asked if anyone could operate the system and what training or certification would be required. All of the Soldiers said anyone could run the system once it's set up, but thought it might be set up more quickly by a Soldier whose MOS provides them with more power system experience. In addition, an experienced Soldier would likely benefit more from the system's analytics, but because the EIO is a "very simple system," they said anyone could be cross-trained to understand the analytics. They also agreed that any Soldier could perform "generic maintenance on the generators" because "out in the field, you wouldn't do much more than that anyway." If the Soldiers would be in the field long-term, however, one Soldier said the situation would be different because the EIO would require annual service (oil change, filter changes, etc.). Another Soldier said any Soldier could change filters and they would still not need a specific MOS for this. For training, the Soldiers thought only 1-2 days of training would be necessary for this system because "training on the generator side is simple, but the program to run it requires more in-depth training." The Soldiers then explained that the program training would need to be hands-on, as opposed to a classroom.

The Soldiers then discussed the EIO's GUI and reports. All of the Soldiers said the GUI was simple, easy to read, and intuitive. They liked the application and said it would be best used on a tablet or laptop versus a phone because it is easier to use with a larger screen. The Soldiers said this application would be especially helpful in a configuration with a lot of generators that are spread out because it allows a Soldier to track everything connected to the EIO. When asked if the GUI provided enough information, all of the Soldiers agreed that it does: "Yes, you can find everything you needed to find. They did a great job.

Whatever information they could pull up, you can get.” The Soldiers said the most useful reports from the EIO in the field would be power levels and fuel savings. The engineers then asked the Soldiers about the planning wizard. Most of the Soldiers agreed that it would be helpful because “it tells you what to do, which saves time” and makes camp setup easier.

Next, the Soldiers were asked about the benefits of a smart generator system. The Soldiers liked the idea of a smart generator system because it makes troubleshooting easier, it’s easier to monitor, and makes the camp more efficient. One Soldier said “the way this system is set up, the batteries will save on fuel consumption and having to run it out there every day. I feel like it’s more efficient with the battery. The way they distribute automatically when things start to kick on, it’ll even out the load. It’ll save the generators and figuring out the math of what’s going to pull from there.” Another Soldier said “I think it’s nice because you can see the fuel level for anything. If you see it’s running low, you can see which ones you have to worry about.”

The only safety concern the Soldiers had with the EIO system was tripping on cables, especially on Ethernet cables. The Soldiers said tripping hazards are inherent to any generator system, but because Ethernet cables are more brittle, they were concerned that tripping on one would break it. They explained, however, that if Soldiers were on a base camp long-term, the cables would be buried, so tripping hazards would not be a concern.

Lastly, the Soldiers shared their likes and dislikes of the technology and suggestions for improvement to the EIO system. The Soldiers liked that it “shows you everything on one screen,” it is compatible with older equipment, and additional components can be added and removed as needed. The Soldiers did not share any dislikes. The Soldiers’ main suggestions for improvement included incorporating alternative energy sources (e.g. solar, wind), sending automatic notifications, and making the system wireless. The Soldiers said it could help reduce fuel consumption if an alternative energy source was used to charge the EIO’s batteries, but it would be important to always have the generators as a backup. For the automatic notifications, the Soldiers said it would be “genius” if it “automatically sends notifications to fuel guys” because the notification would alert them that fuel in a particular generator is running low so they are prompted to go fill it.

IX. Onboard Vehicle Power – Tactical V2G V2V (OBVP)

Each group of Soldiers participated in separate focus groups for the Onboard Vehicle Power – Tactical V2G V2V (OBVP) system.

Figure 9: Onboard Vehicle Power – Tactical V2G V2V (OBVP)

82nd Airborne Focus Group (OBVP):

The Soldiers were first asked whether this technology was appropriate for use on a base camp and how they envision the OBVP being used. Most of the Soldiers agreed that there are alternatives to the OBVP that would be more appropriate for use on a base camp. One Soldier said he did not like the system because it is "taking vehicles away from the fight… let's say we have 12 vehicles for three platoons. They will require extra maintenance because they're running all the time. They need to be mission ready all the time." Another Soldier then said "one thing I fear is that the trucks are being retrofitted. No one would risk taking the trucks out, so technically they're out of the fight. The ESU portion of it would be dead." The Soldiers suggested using M-ATVs or RG-33s instead of MaxxPro MRAPs for the system. Some of the Soldiers suggested having a "generator truck" that is not mission capable and always on standby to use when power on the base camp is needed.

Although the Soldiers had these concerns, the Soldiers also said they "love the battery part of it for quiet operation at night. We can run the vehicles during the day and run the batteries at night." The Soldiers said they could envision the technology being used in situations less than a month long, to power airstrips for Airborne jumps and securing airports, for airport seizures, or for emergency situations when other generators break down on the base camp. Some of the Soldiers said it was “a lot of money” to use on a technology that might primarily be used for emergency situations. Other Soldiers said they could see the OBVP being used “for base establishment” when they need an immediate power source (to power a TOC and tools) or when establishing field hospitals for locals. The Soldiers could also envision this being used for natural disaster and emergency relief.

The Soldiers were then asked how quickly they would need to set up the OBVP and whether they would need training on the technology. They said it should take less than an hour to set up, with an ideal time of approximately 20 minutes for a well-trained group of Soldiers. The Soldiers agreed that some training and/or practice on the technology would “definitely” be needed. They also said this technology is “an MOS thing” and “could not see an 11B using it.” Related to maintenance of the system, the Soldiers said the OBVP “has maintenance going for it” because any Soldier can perform level 10 maintenance on the vehicles; however, one Soldier said that ultimately, “anything that adds hours on our vehicles is more [vehicle maintenance] work for us to do.”

Lastly, the Soldiers provided suggestions for improvement to the OBVP system. One Soldier suggested making the system small enough to put on a skid so that it could be sling-loaded as one group. Another Soldier said he “definitely wants to see it smaller” so that two could fit on the back of a HMMWV.

542nd Quartermaster Focus Group (OBVP):

The Soldiers were first asked whether this technology was appropriate for use on a base camp and how they envision the OBVP being used. Most of the Soldiers said the OBVP was not practical for use on a base camp, while some of the other Soldiers said “it’s a good idea, but it’s too big” and “it’s a great technology, but it’s not relevant to us.” When asked why the system is not relevant to them, the Soldiers said “it doesn’t take much to get us going, and they [engineers] said it was for us to get going.” They explained that their setup at a base camp does not take a long time because all they need is generators and a microgrid. One Soldier said “there’s no need for supplemental power [with the OBVP] for what we have to do” and “it doesn’t make sense because by the time we set up the OBVP, we are halfway done setting everything else up.” Because of this, these Soldiers did not see the benefit of the OBVP for their work setting up base camps; however, one Soldier said he could envision this system being used at a temporary base camp in conjunction with the Minimized Logistics Habitat UniT (MILHUT) shelter system or with SF who “go on short missions for 2-3 weeks and are constantly moving.” The Soldiers then said they like that “you could press a button and unhook from the generators to leave in an emergency.” When asked what they would power with the OBVP system, the Soldiers said they would power “just the important stuff initially. The stuff that needs to get set up immediately,” which they said was primarily communications.

Next, the Soldiers were asked if the system could be used or maintained by any Soldier or if it would require Soldiers with a specific MOS. All of the Soldiers agreed that general operation of the system could be done by any Soldier because “it’s pretty self-explanatory,” but the computer system would require a day of training and specific MOS Soldiers (e.g. 91D). The Soldiers said maintenance would require training and would likely need to be performed by Wheeled Vehicle Mechanics (91B) or Construction Equipment Repairers (91L). They said “you definitely need someone in the mechanics part because if a vehicle goes down, the system goes down.” The Soldiers said they liked the troubleshooting of the system because it gives you information about faults and “eliminates [manual] troubleshooting.”

The Soldiers then discussed safety concerns and durability of the OBVP system. The Soldiers did not have any safety concerns because there are “a lot of safety features built into the system so people won’t hurt themselves.” The Soldiers liked the emergency shut down, insulation around the plugs, and that Soldiers would not be able to tamper with the plugs themselves. One Soldier said he was concerned about the lift on the back of the HMWWV because of the high center of gravity and risk of falling. Another Soldier said the “HMWWV portion wasn’t practical anyway because of the fuel consumption”; however, he said it is a “decent backup” if needed. This Soldier then said they found a crack in a TVGM lid, so they “need to be made out of thicker stuff.”

Lastly, the Soldiers provided suggestions for improvement to the OBVP system. One Soldier said it is an “overall great idea,” but needs to be made out of thicker material and weigh less. Their other suggestions included incorporating solar panels to lower fuel consumption, changing the color of the “black button” to black instead of green, and switching the red and green lights to mean off and on, respectively.

Shelter Technologies

X. Minimized Logistics Habitat UniT (MILHUT)

Due to scheduling, only one focus group was conducted for the Minimized Logistics Habitat UniT (MILHUT).

Figure 10: Minimized Logistics Habitat UniT (MILHUT)

82nd Airborne Focus Group (MILHUT):

The Soldiers were first asked about their prior experiences with military shelter systems. The Soldiers said they've set up and/or lived in Conexes, Containerized Housing Units (CHUs), General Purpose (GP) tents, TEMPER tents, empty TRICONs, and B-Huts.

The Soldiers began the discussion by sharing that they think the concept is "awesome and spectacular because there is zero waste." This Soldier also liked that the MILHUT has water filtering capabilities because it makes everything safer. The Soldiers said they could envision the MILHUT being used during training exercises (e.g. Cobra Gold) or during initial entry into a location, where a Force Provider system would subsequently come in to replace it once the area was more established.

The Soldiers were then asked how they felt about using recycled water. None of the Soldiers voiced any concerns about using recycled water because "as long as we have a shower, we are good." The Soldiers said the size of the shower was adequate and liked the idea of having timed showers because it allows more Soldiers to shower by spreading out the MILHUT's water supply evenly amongst the Soldiers. They also liked the delay programmed into the shower system so a Soldier is unable to take multiple showers in a row. Although the Soldiers liked that the MILHUT could accommodate seven showers a day, they suggested adjusting this to 10 showers a day so they would be able to schedule showers by squad. They also suggested cutting down the time for the beginning rinse from 30 seconds to 20 seconds and the final rinse from 1 minute 30 seconds to 1 minute. The Soldiers said this timing, however, is dependent on the shower pressure; as long as the shower pressure is high enough, the allotted shower time could be reduced. These Soldiers noted that they "cannot speak for females" who may potentially need longer rinse times. When asked about the toilet, the Soldiers said the size was "fine" and "better than what we would typically have." However, the Soldiers emphasized that the toilets must be able to flush baby wipes.

The project engineer then asked the Soldiers how many MILHUT systems they would need for a 40-person platoon. Most of the Soldiers agreed that having two complete systems (two tent, two hygiene modules, and two power modules) would be the minimum for a platoon.

When asked about having both males and females sharing MILHUT billeting, none of the Soldiers expressed concern because "it's going to make it very easy to put up poncho walls and privacy liners with the new ventilation system. You can fit eight on each side if you have a cot and a locker." Similarly, none of the Soldiers were concerned about males and females using the same hygiene modules because they can put signs on the doors. The Soldiers said the "biggest issue" with gender separation is "self-control and individual discipline," so as long as Soldiers are respectful to each other, there would not be a problem. The Soldiers suggested adding LED lights that would be a different color based on whether a male or female is occupying the module.

Next, the Soldiers discussed components within the kitchenette portion of the hygiene module. For the dryer, the Soldiers said it was "fine" because "you can always air dry." However, one Soldier said "you are going to catch guys trying to microwave their socks [to dry them]." Another Soldier then suggested adding a quick heat cycle to the dryer so they would not need to "use body heat to dry it [clothes]." The Soldiers then said the dryer needs to be durable enough to withstand sand. When asked about the ice maker, most of the Soldiers said they would rather use the ice maker's water for showers because showers are a "morale boost and provide health and welfare." Most of the Soldiers said they would use a microwave to make ramen noodles or snacks; however, when the Soldiers were asked about the hot water tap, most agreed that the hot water tap is "better than a microwave" because they would still be able to make ramen or macaroni and cheese. For the cook top, the Soldiers said they "would use it if we had to," but did not think it was a necessity. The Soldiers said the refrigerator would "definitely get used" to store Rip It and other energy drinks.

Related to maintenance of the MILHUT, the Soldiers were concerned whether it was designed for any Soldier to be able to perform maintenance or if it would require a Soldier with a specific MOS. The project engineer said that most of the MILHUT's components are commercial off-the-shelf (COTS) items that have been hardened by the TRICON containers. He also said the MILHUT's manual would provide instructions on how to extend its service life. The engineer noted that the MILHUT is designed to be used for a shorter amount of time and is not intended to operate as a permanent base camp, so extensive maintenance by Soldiers would not typically be required. Next, the Soldiers said the MILHUT should ship with spare filters and/or filters that can be rinsed and reused.

The Soldiers then discussed the generators and power module. The Soldiers said the generator was not loud, but “if you can make it quieter, do it.” They suggested adding a removable Plexiglass panel in the power module for better accessibility to the AC and other parts where lint might need to be removed.

Lastly, the Soldiers provided some additional suggestions for improvement to the MILHUT. Some of the suggestions included adding a bubble level to the TRICONs to aid in leveling of the modules and minimizing the footprint of the MILHUT and solar farm. The Soldiers said the footprint of the system “takes too much space” and suggested finding a place to hang the solar panels at a 45 degree angle instead of having them laid out flat on the ground.

Other Technologies

XI. Sustainable Technologies for Ration Packaging Systems (Ration Packaging)

At the start of each focus group, Soldiers were paired off and given two boxes filled with MREs (the current fiberboard box and the test corrugated box). They were not given any information about the differences between the boxes or differences between the MRE packaging. This allowed the researchers to determine whether the Soldiers were able to recognize any of the modifications on their own.

Figure 11: Sustainable Technologies for Ration Packaging Systems

82nd Airborne Focus Group (Ration Packaging):

The Soldiers first compared the current MRE box to a new corrugated MRE box. They were asked to share any differences they noticed between the boxes. The Soldiers' initial observations were that the new box may be more water resistant than the current MRE box, the new box is corrugated, and the new box is harder to open. All of the Soldiers agreed the new box was harder to open and said it was harder because it's thicker, has more glue, and they were unable to get their fingers underneath the box's flaps to pull the box open. The Soldiers also noticed that the new MRE box may be able to fit more MREs than the current box and said a dozen MREs per box is "perfect per box" and "perfect for patrol" because they would need three boxes per platoon. One Soldier then said he thought the new corrugated boxes would be harder to stack than the current boxes. Once the Soldiers were told about the weight difference of the boxes, most of the Soldiers agreed that the new box should be used due to its lighter weight, provided it can be made easier to open.

The Soldiers then discussed ways in which they reuse the current MRE boxes. Most of the Soldiers said they are primarily reused for trash or ammo boxes. One Soldier said he stacked some boxes and used them as a “foot locker” and to store socks. All of the Soldiers agreed that reusing the new corrugated box would “probably last longer” than the current MRE box because it has “better structural integrity.”

Next, the Soldiers compared the current MRE bags to a new MRE bag. A majority of the Soldiers said the new MRE bag was easier to open, while two Soldiers said the current MRE bags were easier to open. When opening the bags, some Soldiers used their hands, some used their teeth, and some used knives. One Soldier said he would typically be able to open an MRE bag with his teeth, but was unable to open the new bag with his teeth. The Soldiers who thought the new bag was easier to open said it was because the clear packaging is “not as slick as the brown.” One Soldier then said the “best combination” would be the current MRE bag made clear because with a clear bag, “you can see what you’re getting.” Another Soldier said he would be concerned about opening the new MRE bag if it were wet and was also concerned about the new packaging getting brittle in cold or hot temperatures. Next, the Soldiers remarked that the new MRE bags are smaller, which they liked because they could fit more in their rucksacks. Some of the other Soldiers said that although it’s nice the bags are smaller, “it’s not going to make that big of a difference because we will field strip it.” One Soldier then said a benefit of the current MRE bag is they can reuse it once they field strip the MRE. They said once field stripped, they could fit 3-4 meals into a single MRE bag.

The Soldiers then discussed additional ways in which they reuse the current MRE bags. All of the Soldiers said they reused it at some point, mainly for trash or for medical emergencies (e.g. chest wounds). Due to the way the new MRE bags are sealed around the sides, some of the Soldiers peeled them open such that the top and both sides were opened. Because of this, they said the new MRE bag could not be reused in the same way because once opened, it cannot hold trash or other items unless only the top is torn. One Soldier who preferred the current MRE bags suggested vacuum sealing the current bags in the same way as the new bags are.

The Soldiers were then asked about whether they currently recycle MRE boxes. All of the Soldiers said they do not recycle the boxes and “don’t care if it’s recyclable” because when they are in the field, they “don’t deal with that end of it” and “if you live in the barracks, you throw everything in the same trash and no one cares.” The Soldiers then said “if you want me to recycle, it has to be as convenient as the garbage.” One Soldier then said at “Lewis, you can actually get credit [for recycling] and you can get fined if you have recycling in the trash.” Another Soldier said he “barely recycled in Germany and you’re supposed to.”

Lastly, the Soldiers provided their suggestions for improvement to the MRE packaging. These suggestions included using the new MRE boxes with the current MRE bags and perforating the new box liner to make the box easier to open. One Soldier said “if we access it [new box] from the bottom, it’s hard to rip it out from underneath. If it’s perforated, it’ll be easier to get free.” Another Soldier said “don’t get rid of the liner because I’d use it as a sleeping mat or as knee pad inserts.” Their other suggestions were to make the box easier to open by using less glue and labeling the side of the box that is glued or adding a "point-of-entry" label so a Soldier knows which side is easier to open.

542nd Quartermaster Focus Group (Ration Packaging):

The Soldiers first compared the current MRE box to a new corrugated MRE box. They were asked to share any differences they noticed between the boxes. The Soldiers' initial observations were that the current fiberboard MRE box was heavier than the new corrugated box and the current box was more convenient and easier to open because it had less glue. When asked how the boxes would hold up to water, the Soldiers said it did not matter because the MREs inside "would be fine."

The Soldiers were then asked if they reuse the current MRE boxes. They said they primarily reuse the boxes for trash and ammo. The Soldiers then said both the current and new boxes could be reused for trash and ammo; however, the current fiberboard box would be better because the new corrugated box gets "ripped open" since it is more difficult to open.

Next, the Soldiers compared the current MRE bags to the new MRE bags. Many of the Soldiers used knives to open both the current and new bags. Some of the Soldiers said the current bag "is a pain," while others had difficulty opening the new MRE bags. All of the Soldiers noticed that the new MRE bags are smaller than the current, which they liked because it "saves on space" and they fit better in their uniform pockets. The Soldiers said it was "very much so a positive" that the new MRE bags fit more easily in their pockets because it makes them more easily accessible and is "easier than carrying a big brown bag in your pocket." All of the Soldiers said they do not field strip their MREs.

The Soldiers were then asked how they reuse the current MRE bags. They said they primarily use them for trash or for chewing tobacco. One Soldier also said "in a survival situation, you could collect water [with the MRE bag]." Overall, however, the Soldiers were not concerned about the reusability of the MRE bags.

When asked which boxes or MRE bags they prefer, none of the Soldiers had a preference because "as long as we're eating, we don't care." They were also not concerned about ease of opening because "everyone has a knife."

Lastly, the Soldiers were asked whether they recycle or burn the current MRE boxes. They said during a field exercise, they throw them away with other trash; however, they said while at the BCIL, they are thrown into the cardboard trash. The Soldiers said the importance of recycling in the field is "extremely low." The Soldiers said they typically do not burn their MRE boxes, but did not know the current fiberboard boxes contain wet strength additives that could potentially be harmful when burned.

Appendix A – Water and Power Discussion Guides

Discussion Guides for SLB-STO-D Technology Demo

6-9 June 2016

Location: Base Camp Integration Lab (BCIL) – Fort Devens, MA

Participants: 542nd Quartermaster Company, 82nd Airborne Division

Introduction: We are research and engineering psychologists from the Natick Soldier Research, Development, and Engineering Center (NSRDEC) located in Natick, MA. We have experience in conducting focus groups and creating questionnaires to collect feedback on clothing and equipment.

We are interested in hearing your feedback on the technologies included at this demonstration.

Brief background questionnaire: age, rank, MOS, and years in service, deployment experience

WATER TECHNOLOGIES: WQM, WWT, FO/RO (SPSWH, CIMT)

- Is this technology appropriate for use on a base camp?
    - What size camp is this system most appropriate for? (50, 300, 1000…)
    - Is there a particular length of time that a camp would have be in existence for it to make sense to set up this technology?
- Does a base camp need a water treatment team?
- Who should operate the water technologies on a base camp?
    - 92W? Non-MOS-specific Soldiers?
- What type of training would a Soldier need to operate or maintain the system?
    - Certification? License?
- How do you envision this technology being used?
- ROI
    - Footprint
    - Logistics
    - Manpower required to support this technology
    - Is this technology “worth it?”

Water Quality Monitoring (WQM) – No safety release – demonstration only

- Could this system be operated by a non-MOS-specific Soldier? Or would it require a 92W to operate?
    - If a non-MOS-specific Soldier could operate it, would they need specialized training and some type of certification or license?

- Was the procedure easy to follow?

    - How could the procedure be improved to make the WQM easier to use?
- Did the WQM seem physically easy to use/handle?
    - System controls?
    - If no, how could this be improved?
- Confidence in the accuracy of results?
    - How could confidence in accuracy be improved/increased?
- Were the results displayed clearly?
    - How would you improve the display of results?
- Do you foresee any durability problems with the WQM technology?
    - If yes, what could be done to improve the durability?
- Would you feel more comfortable showering or drinking bulk potable water if there was continuous versus periodic monitoring of the water quality?
- Would you rather monitor water quality with simple kits that require work on each water sample or with automated equipment that requires more skill/training to troubleshoot?
    - Why?
    - Is one better/worse in a field environment?
    - Would you need specific MOSs to test the water quality or to troubleshoot the system?
- Any safety concerns?
- Likes/dislikes
- Suggestions for improvement

Waste Water Treatment (WWT) and Gray Water Reuse (FO/RO) – Has safety releases

- Should the 92W MOS be expanded to include gray water reuse and black water treatment?
- Could this system be operated by a non-MOS-specific Soldier? Or would it require a 92W to operate?
    - If a non-MOS-specific Soldier could operate it, would they need specialized training and some type of certification or license?
- Any difficulties setting up or starting up the system?
    - System controls?
    - How could set-up or start-up be improved?
- Any difficulties operating the system?
- What maintenance did you perform on the system?
    - Any difficulties with maintenance?
    - Would you need specific MOSs to perform maintenance? 92W?
- Do you foresee any durability problems with the WWT or FO/RO technology?
    - If yes, what could be done to improve the durability?
- Confidence in the quality of water coming out of WWT or FO/RO?
- Would you feel comfortable showering in purified shower/laundry water?
    - Would you shower in purified wastewater if it was treated by a black water treatment system and then a gray water treatment system?
- Would you drink purified shower/laundry water?
- Any safety concerns?
- Likes/dislikes

- Suggestions for improvement

Self-Powered Solar Water Heater (SPSWH) – No safety release – demonstration only

- Is this technology appropriate for use on a base camp?
    - Current configuration – three systems can be stowed, transported, and deployed on a single TRICON (8'x8'x6.5')
    - Practical in a field environment?
    - How do you envision this technology being used?
    - What size camp is this system most appropriate for? (50, 300, 1000…)
    - Is there a particular length of time that a camp would have be in existence for it to make sense to set up this technology?
- Who could operate this technology? Need specific MOS?
- Need any specific training or certification/license to operate or maintain the system?
- How many gallons of hot water do you require per day?
    - For food service, sanitation, shower, other purposes?
    - This system is sized to heat ~250 gallons of water/day
        - Is that adequate?
    - One system could support kitchen/sanitation center
        - Is that adequate/practical?
    - Three systems could support the showers
        - Is that adequate/practical?
- Benefits of solar water heating?
- Do you foresee any challenges using the solar water heating system?
    - System controls?
    - Maintenance?
    - Durability?

- ROI
    - Footprint
    - Logistics
    - Manpower required to support this technology
    - Is this technology "worth it?"
- Any safety concerns? Sanitation?
- Likes/dislikes
- Suggestions for improvement

Containerized Ice-Making Technology (CIMT) – Has safety release, but mostly hands-off

- Is this technology appropriate for use on a base camp?
    - Practical in a field environment?
    - How do you envision this technology being used?

    - What size camp is this system most appropriate for? (50, 300, 1000…)

    - Is there a particular length of time that a camp would have be in existence for it to make sense to set up this technology?
- Who could operate this technology? Need specific MOS?
- Need any specific training or certification/license to operate or maintain the system?
- ROI
    - Footprint
    - Logistics
    - Manpower required to support this technology
    - Is this technology "worth it?"
- How is ice used in the field?
    - How much ice is needed per day?
- Benefits of CIMT?
- Any difficulties using the technology?
    - Stacking bags of ice
- Can you foresee any sanitary problems with the ice/ice-maker in a field environment?
    - If yes, how could that be mitigated?
- Any other safety concerns?
- Likes/dislikes
- Suggestions for improvement

POWER TECHNOLOGIES: T100, NPC, OBVP, EIO, QMEG

HMMWV Towable Load Following 100kW Power Unit (T100)

- Is this technology appropriate for use on a base camp?
    - Practical in a field environment?
    - How do you envision this technology being used?
    - What size camp is this system most appropriate for? (50, 300, 1000…)
    - Is there a particular length of time that a camp would have be in existence for it to make sense to set up this technology?
- Which fuel is readily available? JP-8 or DF-2? (This system runs on DF-2)
    - Foresee any concerns with running on DF-2?
- Could this system be operated by a non-MOS-specific Soldier? Or would it require a power MOS to operate?
- Would this system require power MOSs for maintenance?
- Need any specific training or certification/license to operate or maintain the system?
- Was the procedure for starting the generator easy to follow?
    - If no, how could the procedure be improved?
- Ease of:
    - Opening the doors
    - Removing and reattaching the doors
    - Opening the roof of the generator
    - Gaining access to the generator compartments (engine, battery, fuel pumps, etc.)
    - Maintenance
- What would you power with this technology?

    - Does power level and weight matter a lot for these uses?
    - Would you need 240/416 V_{AC}? If so, who would need it?
- How often would you use this generator set?
- ROI
    - Footprint
    - Logistics
    - Manpower required to support this technology
    - Is this technology “worth it?”
- Best way to house this system?
    - On a trailer, skid-mounted, or inside a TRICON?
        - Does it matter?
- Generator noise concerns?
- Any safety concerns?
- Likes/dislikes
- Suggestions for improvement

Nanoparticle-polymer Composite for Soldier Power (NPC)

- Is this technology appropriate for use on a base camp?
    - Practical in a field environment?
    - How do you envision this technology being used?
    - What size camp is this system most appropriate for? (50, 300, 1000…)
    - Is there a particular length of time that a camp would have be in existence for it to make sense to set up this technology?
- Could this system be operated by a non-MOS-specific Soldier? Or would it require a power MOS to operate?
- Would this system require power MOSs for maintenance?
- Need any specific training or certification/license to operate or maintain the system?
- Would you use flexible solar panels in the field?
    - If yes, prefer to use them on flat ground or attached to a structure?
- What would you power with the power generated from the solar panels?
- Ease of setting up solar panels
    - Unfolding
    - Attaching cables and electrical equipment (batteries, fans, lights) to panels
- ROI
    - Footprint
    - Logistics
    - Manpower required to support this technology
    - Is this technology “worth it?”
- Any safety concerns?
- Likes/dislikes
- Suggestions for improvement

Tactical V2G and V2V Demonstration (OBVP)

- Is this technology appropriate for use on a base camp?
  - Practical in a field environment?
  - How do you envision this technology being used?
  - What size camp is this system most appropriate for? (50, 300, 1000…)
  - Is there a particular length of time that a camp would have be in existence for it to make sense to set up this technology?
- Could this system be operated by a non-MOS-specific Soldier? Or would it require a power MOS to operate?
- Would this system require power MOSs for maintenance?
- Need any specific training or certification/license to operate or maintain the system?
- What would you power with this technology?
- How often would you use this technology?
- Ease of system controls
- GUI
  - Easy to read/understand?
  - Intuitive?
  - Everything included?
  - Need training?
- How long did it take to set up the system?
  - Is this an acceptable amount of time?
- Ease of startup, operation, and shutdown
- Ease of maintaining/troubleshooting the system
- ROI
  - Footprint
  - Logistics
  - Manpower required to support this technology
  - Is this technology “worth it?”
- Any safety concerns?
- Likes/dislikes
- Suggestions for improvement

Energy Informed Operations (EIO)

- Is this technology appropriate for use on a base camp?
  - Practical in a field environment?
  - How do you envision this technology being used?
  - What size camp is this system most appropriate for? (50, 300, 1000…)
  - Is there a particular length of time that a camp would have be in existence for it to make sense to set up this technology?
- Could this system be operated by a non-MOS-specific Soldier? Or would it require a power MOS to operate?
- Would this system require power MOSs for maintenance?
- Need any specific training or certification/license to operate or maintain the system?
- What would you power with this technology?

- How often would you use this technology?
- Ease of:
    - Turning on microgrid
    - Performing grid analytics
        - Need power MOS for this? Or could a non-MOS-specific Soldier do it?
    - Generating reports of various microgrid perspectives (e.g. fuel savings, power levels, etc.)

        - What reports are most useful in the field?
        - Any other reports you'd like to see available in the system?
    - Maintenance/troubleshooting
- GUI/microgrid application
    - Could the application be used on mobile phones or other devices?
        - What devices would be used in the field?
    - Easy to read/understand?
    - Easily accessible?
    - Intuitive?
    - Everything included?
    - Need training?
- Benefits of smart generators and smart ECUs
    - Any cons?
- ROI
    - Footprint
    - Logistics
    - Manpower required to support this technology
    - Is this technology "worth it?"
- Any safety concerns?
- Likes/dislikes
- Suggestions for improvement

Quiet, Multi-Fuel MCC Engine and Generator (QMEG)

- Is this technology appropriate for use on a base camp?
    - Practical in a field environment?
    - How do you envision this technology being used?
    - What size camp is this system most appropriate for? (50, 300, 1000…)
    - Is there a particular length of time that a camp would have be in existence for it to make sense to set up this technology?
- Could this system be operated by a non-MOS-specific Soldier? Or would it require a power MOS to operate?
- Would this system require power MOSs for maintenance?
- Need any specific training or certification/license to operate or maintain the system?
- What would you power with this technology?
    - 120 V_{AC} vs. 28 V_{DC}

- How often would you use this technology?
- Ease of:
  - Moving generator
  - Start-up
  - Fueling
  - Switching from 120 V_{AC} to 28 V_{DC}?
- Benefits of being able to switch from 120 V_{AC} to 28 V_{DC}?
- Was the control panel easy to understand?
  - Intuitive?
  - Everything included?
- ROI
  - Footprint
  - Logistics
  - Manpower required to support this technology
  - Is this technology “worth it?”
- Any safety concerns?
- Likes/dislikes
- Suggestions for improvement

Appendix B – MILHUT Discussion Guide

MILHUT Discussion Guide
6-10 June 2016

Location: Base Camp Integration Lab (BCIL) – Fort Devens, MA

Participants: 542nd Quartermaster Company, 82nd Airborne Division

Introduction: We are research and engineering psychologists from the Natick Soldier Research, Development, and Engineering Center (NSRDEC) located in Natick, MA. We have experience in conducting focus groups and creating questionnaires to collect feedback on clothing and equipment.

Brief background questionnaire: age, rank, MOS, and years in service, deployment experience

Past Experience:

- What tents or shelter systems have you used before? (Force Provider, Base Ex, TEMPER frame shelter, GP medium, etc.)
    - Did you set up these shelters or live in them?

Functional Areas:

- Hygiene TRICON (bathroom on one side, kitchen/washer on the other):
    - No segregation by gender – would this be a problem?
    - Temperature in TRICON (no HVAC)
    - Shower
        - Width of shower stall
        - Height of shower head
        - Shower controller – timed
        - Temperature in shower unit
            - Comfort?
        - Water pressure/temperature
    - Latrine (can't use per Safety Release)
        - Width of latrine stall
        - Toilet (smaller, cannot lean back)
            - Is height/width okay?
            - Cleanliness of bowl
            - Flushing – solid and liquid options
            - Vacuum assist
        - Temperature in latrine
            - Comfort?
        - Did you use the sink?
            - Water pressure

            - Hot/cold water taps (next to each other)
                - Any issues?
    - Laundry
        - Laundry capacity
        - Spin dry (no heat dry)
            - Did they use it?
            - Did they have to air dry their clothes?
                - Use clothes lines inside billeting?
                - Could they air dry in a different environment (dusty, cold, wet etc.)?
    - Kitchenette
        - Appliances (microwave, range - 2 burners, fridge, ice maker)
            - Temperature of fridge – cold enough?
                - What did you store in the fridge?
            - Did you use the microwave/range?
                - What did you use them for?
            - How do you envision this being utilized in theater?
        - LCD screen in kitchen
            - Easy to read and understand?
            - Adjust behavior in any way?
            - Additional information?
        - Did you use the sink?
            - How does the potable water taste? (cannot drink)
            - Water pressure
            - Hot/cold water taps (next to each other)
                - Any issues?

- Airbeam Tent
    - How many were occupying the tent?
    - Layout
    - Comfort inside tent
        - Temperature/environment
        - Ventilation
        - Noise level
        - Lighting
    - Convenience outlets (2kW vs. FP 4-6kW) – at least 20 provided separately from MILHUT but nearly identical to how they would be provided
        - Did you use them?
        - Were there enough? Did they provide enough power?

- Power TRICON (contains heater, ACs, generator, battery bank):
    - Did any Soldiers interact with this TRICON?
        - LCD screen (current fuel levels, water levels, battery charge level, etc.)

Other:

- What size camp is the MILHUT system most appropriate for? (50, 300, 1000)
- How many Soldiers can this system support? (Squad, platoon, company, etc.)
    - Could multiple MILHUTs be used to support larger groups of Soldiers?
- Is the MILHUT practical in an operational environment?
    - If YES, under what circumstances (mission type and duration)?
    - If NO, what environment is the MILHUT best suited for? How do you envision it being used?
    - Maintenance, durability, transport, etc.
    - Footprint?
- Any safety concerns?
- What do you like about the system? What don't you like?
- Suggestions for improvement? Anything you would add or take away?
    - Additional capabilities?
    - Other features?
    - Different configuration?

Appendix C – Ration Packaging Discussion Guide

Lightweight and Compostable Fiberboard
Focus Group Discussion Guide

Base Camp Integration Lab (BCIL), Fort Devens, MA

Introduction:

We are research and engineering psychologists from the Natick Soldier Research, Development, and Engineering Center (NSRDEC) located in Natick, MA. We have experience in conducting focus groups and creating questionnaires to collect feedback on clothing and equipment.

Past experience:

- What experience do you have with ration boxes?
- What experience do you have with MREs/MRE packaging?

Unboxing:

- How easy/difficult was it to open the boxes?
    - Was the ease of unboxing acceptable? Too difficult?
- Did you or would you need any tools to open either of the boxes?
    - Need for both boxes? Or just one?
- Likes and dislikes
- Recommendations for improvement to the box

Packaging Material:

- Did you notice anything different about the boxes?
    - Coated corrugated versus solid fiberboard
    - Weight?
    - Size?
- Foresee any durability problems with the boxes?
- Recommendations for improvement to packaging material

Recyclable:

- Corrugated is recyclable while solid fiberboard is not
    - Benefits?
- How would you dispose of MRE boxes and packaging in the field?

MRE Packaging:

- How easy/difficult was it to open the packaging?
- Pros/cons of current Meal Bag versus new vacuum packaging
- Any uses of the current MRE packaging that the vacuum packed MRE packaging could not provide?
- Foresee any durability problems with the new MRE packaging?

Overall:

- How do the corrugated boxes compare overall to the current solid fiberboard boxes?
- Are the new boxes practical in an operational environment?
    - How would you transport MREs in an operational environment?
    - Does new box provide any benefits that the current box does not?
    - Does new MRE packaging provide any benefits that the current does not?
- Benefits of fitting more MREs/box?
- Overall likes and dislikes
- Recommendations for improvement