INTEGRATED WATER PURIFICATION SYSTEM (IWPS)

PROGRESS REPORT

MARCH-SEPTEMBER 2016

KAMPONG SPEU, CAMBODIA

SARABURI, THAILAND

HONOLULU, HAWAII

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This report provides details on the progress of the Integrated Water Purification System (IWPS) project, including accounts of the Angkor Sentinel 2016 (AS16) Technology Demonstration (TD), the Crimson Viper 2016 Field Experiment (FE), and the Technology Experimentation Insertion Meeting (TEIM) IWPS brainstorming sessions. This document provides a summary of activities, findings, and feedback gathered by the Technology Experimentation Center (TEC) and does not represent the formal position of Naval Air Warfare Center or the Department of the Navy.

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ACRONYMS

AS16	Angkor Sentinel 2016
COI	Critical Operating Issue
CONOP	Concepts of Operation
CV16	Crimson Viper 2016
DoD	Department of Defense
DSTD	Defence Science and Technology Department
eMUBC	Expeditionary Modular Universal Battery Charger
FE	Field Experiment
FOB	Forward Operating Base
FR	First Response
HA/DR	Humanitarian Assistance Disaster Relief
IWPS	Integrated Water Purification System
MOE	Measure of Effectiveness
MOS	Measure of Suitability
NAVAIR	Naval Air Systems Command
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NGO	Non-governmental Organization
OSD	Office of the Secretary of Defense
OSHA	Occupational Safety and Health Administration
PKO	Peace Keeping Operation
REAL	Renewable Energy Area Lighting
RRTO	Rapid Reaction Technology Office
SME	Subject Matter Expert
SPM	Squad Power Manager
STAESS	Soldier Transportable Alternative Energy Storage System
TD	Technology Demonstration
TDS	Total Dissolved Solids
TEC	Technology Experimentation Center
TEIM	Technology Experimentation Insertion Meeting
UN	United Nations
USPACOM	US Pacific Command
WPS	Water Purification System

UNITS OF MEASURE

AC	Alternating Current
Ah	ampere hour
Amps	amperage
C	Celsius
cu ft	cubic feet
D	Direct Current
F	Fahrenheit
ft.	feet
gal	gallons
GPD	gallons per day
gtts	drops

hrs	hours
Hz	hertz
in.	inches
kg	killogram
kW	kilowatt
l	liter
lbs.	pounds
min	minute
mg	milligram
ml	milliliters
mm	millimeter
NTU	Nephelometric Turbidity Unit
oz	ounces
pH	potential for hydrogen
ppb	parts per billion
ppm	parts per million
sq ft	square foot
V	volts
VAC	Voltage AC
VDC	Voltage DC
W	watts
Whrs	watt hours

EXECUTIVE SUMMARY

This report provides details on the progress of the Integrated Water Purification System (IWPS) project, including accounts of the Angkor Sentinel 2016 (AS16) Technology Demonstration (TD), the Crimson Viper 2016 Field Experiment (FE), and the Technology Experimentation Insertion Meeting (TEIM) IWPS brainstorming sessions. Complete, standalone AS16 and CV16 reports are provided in Annexes A and B.

The IWPS project seeks to develop an integrated advanced pre-filtration water purification system that incorporates renewable energy technologies. The IWPS prototype is being developed to support multiple missions including Humanitarian Assistance and Disaster Response (HA/DR), and austere forward operating bases (FOB). The TEC developed three Critical Operational Issues (COIs) to assess the utility of the candidate technologies; does the capability provide potable water from local sources for the operators, the local populace, and the local first responders, is the IWPS transportable to support various missions including austere FOBs and HA/DR, and does the IWPS power source provide reliable power primarily from renewable sources. Depending on the event, not all COIs, objectives, and/or measures may be addressed.

AS16 technology insertion was conducted March 6-26 in Kampong Speu, Cambodia. The event focused on integrating and demonstrating Water Purification Systems (WPS) and energy technologies in a relevant operational environment. A total of six technologies participated in static displays and/or demonstrations during the event. These technologies included the First Response (FR) WPS, SilverDYNE additive, Soldier Transportable Alternative Energy Storage System (STAESS), Renewable Energy Area Lighting (REAL), the Expeditionary Modular Universal Battery Charger (eMUBC), and Squad Power Manager (SPM) energy technologies. Data collected during AS16 suggested that the SilverDYNE additive would not be a good fit for the IWPS project. As a result, the SilverDYNE additive was more rigorously tested during CV16. The FR had problems with the chlorine injector, and other minor maintenance issues. Many of these issues were quickly addressed in the field and the chlorine injector was replaced prior to CV16. The STAESS technology successfully supported all power requirements for the water purification TD.

The CV16 FE was conducted at Fort Adisorn, Calvary Center, Saraburi, Thailand, August 29-9 September. A total of nine technologies were tested and integrated during CV16. These technologies included the FR, Modus, Guardian, and Roving Blue WPSs, the SilverDYNE and O-Pen additive technologies, and the STAESS, SPM, and Flex Fuel 1 kW generator. Ninety-one total water samples were collected and tested in a field environment during CV16. The FR and Modus appeared to show the most promise for meeting the IWPS project objectives. Both systems are capable of producing an adequate amount of product water, and are relatively easy to transport. The Roving Blue WPS demonstrated promise during initial testing, but the system is unable to produce the threshold level of product water of 1,000 gallons per day. The O-Pen and SilverDYNE additives did not appear to provide any additional value to the product water of the WPSs, and were unable to treat product water on their own. The STAESS and SPM technologies successfully integrated with and supported the WPS power requirements and should be included in future tests.

During the TEC TEIM, water purification and renewable energy SMEs from various Department of Defense (DoD) and private organizations were provided an overview of the IWPS project, including event specific details, and some preliminary findings. The group was asked to help the TEC team brainstorm achievable goals and a future prototype design. Major recommendations included the use of chlorine, and the development of a dual valve that would allow chlorine to be removed at the point of distribution when required. The proposed prototype includes the FR 1000, or Modus WPS, the STAESS as the primary renewable energy source, the SPM, the Flex Fuel 1kW generator as a backup power source, and the proposed dual valve system that incorporates carbon filtration for chlorine removal when required.

The TEC created a schedule of events to support the identified way forward for the IWPS project. This schedule includes upgrading current capabilities, integrating new capabilities, a test event in a lab environment in early 2017, and a final field experiment and report in the third quarter of 2017. The TEC team will continue to work with developers to utilize sample data, lessons learned, and user/SME feedback to ensure the final IWPS prototype can successfully meet the project objectives.

IWPS project experimentation during AS16 and CV16, and the brainstorming and planning sessions during the TEC TEIM were very successful. During AS16 and CV16 the TEC team identified and mitigated a number of limitations that occurred in the field and successfully collected valuable data. The data collected, the lessons learned, and the feedback from SMEs during all three of these events will help shape future IWPS project test events and the final IWPS prototype.

INTRODUCTION

This report provides details on the progress of the Integrated Water Purification System (IWPS) project, including accounts of the Angkor Sentinel 2016 (AS16) Technology Demonstration (TD), the Crimson Viper 2016 (CV16) Field Experiment (FE), and the Technology Experimentation Insertion Meetings (TEIM). These events were supported by the Royal Cambodian Army, Royal Thai Army, Department of Defense and private sector organizations. This report covers the Technology Experimentation Center (TEC) activities during AS16 March 6-26, CV16 from August 29-9 September, and the TEIM IWPS progress review and brainstorming sessions held September 21-23, 2016 in Honolulu, Hawaii at the TEC headquarters. Complete, standalone AS16 and CV16 reports can be found in Annexes A and B.

Purpose

The IWPS project seeks to develop an integrated advanced pre-filtration water purification system that incorporates renewable energy technologies. The IWPS is being developed to support multiple missions including Humanitarian Assistance and Disaster Response (HA/DR), and support in austere forward operating bases.

The purpose of field demonstrations and experimentation is to provide a valuable, real world environment that cannot be replicated in a lab. AS16 and CV16 were identified as valuable TD and FE locations because they provided the opportunity to conduct aspects of the project in operationally relevant environments.

Background

IWPS is a TEC led project, sponsored by the Office of the Secretary of Defense (OSD), Rapid Reaction Technology Office (RRTO). The TEC is a U.S. Government network of technology and operational community subject matter experts working together to enable the warfighter by conducting technology demonstrations, experiments, and assessments in relevant operational venues and environments. As the project lead, the TEC is responsible for coordinating and executing all aspects of the IWPS project to include prototype design, assessment, logistics, demonstration, experimentation, feedback collection, and reporting. RRTO develops risk-reducing prototypes and demonstrations of land, sea, and air systems that address mission-focused combatant command, joint-Service, and interagency capability needs to counter emerging threats and provide a hedge against technical uncertainty. RRTO provides the flexibility to respond to emergent Defense Department needs and address technology surprises within the years of execution and outside the two-year budget cycle, enabling the fielding of solutions to time-sensitive problems. RRTO is the IWPS project sponsor.

The project was designed to fill a gap for a complete, renewable energy powered water purification system that would be suitable for multiple mission types. The IWPS requirements include the production of 1,000 liters (threshold) to 1,000 gallons (objective) of safe, odorless, tasteless, product water per day.

The TEC project team was identified and began coordinating field events to support the IWPS project objectives in the beginning of December 2015. The First Response (FR) water purification system (WPS) was selected for integration with a nanoparticle colloidal silver additive, and various renewable energy technology options, for demonstration in AS16. Coordination for the AS16 demonstration including identifying participating technologies, demonstration planning, logistics and customs requirements, communication with participating U.S. and Cambodian forces, and site surveys were conducted between December 2015 and March 2016.

CV16 was identified as a follow up FE venue for the IWPS prototype and coordination and assessment design began in February of 2016 and extended until execution in August and September of 2016. One of the major themes for CV16 was HA/DR which directly aligned with IWPS objectives. As a result, the venue provided a valuable opportunity to continue testing the FR water purifier, alongside new potential candidates for water purification, to help identify the best system for initial filtration. Additional tests on chlorine additive alternatives were conducted including tests to confirm the issues identified with the SilverDYNE additive during AS16. Various renewable energy technologies were integrated with the water purification systems to help identify a suitable power source for the final integrated prototype system.

In late September 2016, the TEC conducted a TEIM that focused on water purification issues and initiatives. A significant portion of these meetings included an IWPS project review and brainstorming sessions. These sessions included Subject Matter Experts (SME) from various Department of Defense (DoD) and private sector agencies. The results of these sessions will help fuel the way ahead for the IWPS project including prototype design and future test events.

Participating Technologies

This section provides a list of the technologies that participated in the AS16 and CV16 IWPS events. More detailed technology descriptions for each technology are provided in Annex A (AS16 report) and Annex B (CV16 report).

Water Purification Technologies

- First Response 1,000 and 5,000
- Guardian
- MSR Modus
- Roving Blue Water Purification System

Additive Technologies

- SilverDYNE
- Roving Blue O-Pen

Renewable Energy Technologies

- Soldier Transportable Alternative Energy Storage System (STAESS)
- Renewable Energy Area Lighting (REAL)
- Expeditionary Modular Universal Battery Charger (eMUBC)
- Squad Power Manager (SPM)
- Flex Fuel 1kW Generator
- MicroCube

IWPS Project Schedule

The following table provides a summary of the IWPS major events, including potential future events. All future events have not been confirmed and are subject to change.

Table 1. IWPS Project Schedule

Date(s)	Event Description	Event Type	Location	Status
12/15	TEC IWPS Project Team Development	Administration	Hawaii	Complete
12/15-2/16	AS16 Planning and Logistics	Support	Cambodia/Hawaii	Complete
2/16-7/16	CV16 Planning and Logistics	Support	Thailand/Hawaii	Complete
3/16	AS16 Execution	Event/Test	Cambodia	Complete
3/16-6/16	Philippines and Hawaii limited water sample testing	Event/Test	Philippines/Hawaii	Complete
8-16-9/16	CV16 Execution	Event/Test	Thailand	Complete
9/16	TEIM	Administration/ Support	Hawaii	Complete
12/16-1/17	Demo Planning	Support	Hawaii	Pending
10/16	Integration Requirements	Support	Seattle	Pending
12/16-2/17	Technology Integration	Integration	Seattle	Pending
2/17	Prototype Demonstration	Event/Test	Seattle	Pending
3/17-4/17	Final Demonstration Planning	Support	Hawaii	Pending
3/17	Prototype Update if required	Integration	Seattle	Pending
4/17-5/17	Ship Prototype for Final Test Event	Support	TBD	Pending
5/17-6/17	Final Test Event	Event/Test	TBD	Pending
7/17-9/17	Final Report Development and Distribution	Administration	Hawaii	Pending

ASSESSMENT METHODOLOGY

The following section provides a summary of the IWPS overall assessment approach, including detailed explanations of the Critical Operational Issues (COIs), objectives, and measures used to help develop and assess the IWPS prototype.

General Assessment Approach

The TEC developed three COIs (see Table 2) to assess the utility of the IWPS prototype components. These COIs, objectives, and measures will be used throughout the IWPS project. Depending on the event, not all COIs, objectives, or measures may be addressed. The TEC team will determine what aspects of the assessment approach are applicable to each event, and design event specific assessment plans as required.

The IWPS project will use the following definitions for COI, Objective, and MOE/MOS:

- A **COI** is phrased as a question and must be answered in order to properly evaluate operational effectiveness and operational suitability.
- **Objectives** are statements that break down the COI into clearly defined manageable tasks and are developed to group or organize the measures needed to resolve the COI.
- A **MOE/MOS** is an expression of a quantitative (objective) or qualitative (subjective) "operational" measure that is a key indicator of task accomplishment.

Table 2. CV16 Water Purification COIs and Objectives

COI 1: Does the capability provide potable water from local sources for the operators, the local populace, and the local first responders?
Objective 1.1: Assess the quality of the product water
Objective 1.2: Assess water technology component portability
Objective 1.3: Assess water output quantity
Objective 1.4: Assess water technology operations and maintenance training
Objective 1.5: Assess water purity after storage
Objective 1.6: Assess water technology maintenance actions
Objective 1.7: Assess water technology environmental operating conditions
Objective 1.8: Assess operational safety
Objective 1.9: Assess power consumption
Objective 1.10: Assess semi-autonomous operations

COI 2: Is the IWPS transportable to support various missions including austere FOBs and HA/DR?
Objective 2.1: Assess air transportability
Objective 2.2: Assess land transportability

COI 3: Does the IWPS power source provide reliable power primarily from renewable sources?
Objective 3.1: Assess power type
Objective 3.2: Assess power availability
Objective 3.3: Assess power technology component portability
Objective 3.4: Assess ability to safely operate
Objective 3.5: Assess power technology environmental operating conditions

Objective 3.6:	Assess power technology maintenance actions
Objective 3.7:	Assess power technology training
Objective 3.8:	Assess semi-autonomous operations
Objective 3.9:	Assess renewable energy source

COI 1: Does the capability provide potable water from local sources for the operators, the local populace, and the local first responders?

The goal of this COI is to evaluate the effectiveness and suitability of the water technologies to provided potable water from local sources.

Objective 1.1: Assess the quality of the product water
This objective seeks to characterize the quality of the purified water produced. The measures will determine if fecal coliform is present in the product water, both threshold and objective level is "No" coliforms. The threshold and objective levels for Total Dissolved Solids (TDS) and NTU are provided in Table 2. In addition to the objective data, the TEC will gather subjective data, via questionnaires, regarding the quality of the water. Users and SMEs will rate the smell and color of the product water

Table 3: Objective 1.1 Data Matrix

Measure	Source	Product
MOE 1-1-1: Presence of fecal coliform bacteria per 100 mL	Event Log	Table
MOE 1-1-2: Count of TDS	Event Log	Table
MOE 1-1-3: Count of NTU	Event Log	Table
MOS 1-1-4: User rating of water smell	Questionnaire	Chart/Text
MOS 1-1-5: User rating of water color	Questionnaire	Chart/Text

Objective 1.2: Assess water technology component portability
This objective seeks to characterize the portability of the water purification technology. Portability is the weight, number of personnel required to lift, volume of the technology. The number of personnel required was reported by the least number required which was determined by dividing the component's weight by 50 lbs., and the maximum number required which was determined by dividing the component's weight by 35 lbs.

Table 4: Objective 1.2 Data Matrix

Measure	Source	Product
MOE 1-2-1: Weight of system	Event Log	Table
MOE 1-2-2: Number of personnel required to lift	Event Log	Table
MOE 1-2-3: Volume of water technology	Event Log	Table
MOS 1-2-4: User rating of portability	Questionnaire	Chart/Text
MOS 1-2-5: SME rating of portability	Questionnaire	Chart/Text

Objective 1.3 Assess water output quantity

This objective seeks to characterize the amount of purified water produced (in gallons per day), number of people the water support per day and the amount of liquid waste (effluent) created though the purification process. Gallons per day was the determined by multiplying the average number of gallons of product water produced in an hour by the number of operating hours. The number of personnel supported was determined by dividing the gallons produced in one operational day by the standard of 2 gallons per day. The effluent produced by each technology will also be reported as gallons per day and calculated using the same formula as gallons produced per day.

Table 5: Objective 1.3 Data Matrix

Measure	Source	Product
MOE 1-3-1: Gallons of purified water per day	Event Log	Table
MOE 1-3-2: Number of personnel supported	Event Log	Table
MOE 1-3-3: Gallons of effluent per day	Event Log	Table

Objective 1.4: Assess water technology training

The TEC will gather objective and subjective data in order to assess the water technology training. Objective data includes the time required for operates to become proficient with the system, training requirements (i.e., slide and projectors or on-site) and training materials. Users will rate the adequacy and time allocated for classroom and hands-on training.

Table 6: Objective 1.4 Data Matrix

Measure	Source	Product
MOE 1-4-1: Time to achieve user proficiency	Event Log	Text
MOE 1-4-2: Characterize training requirements	Event Log	Text
MOE 1-4-3: Characterize training materials	Event Log	Text
MOS 1-4-4: User rating of classroom training	Questionnaire	Chart/Text
MOS 1-4-5: User rating of hands-on training	Questionnaire	Chart/Text
MOS 1-4-6: User train the trainer recommendation	Questionnaire	Chart/Text

Objective 1.5: Assess water purity after storage

After CV16 water samples will be stored to determine water purity after storage. The TEC will validate the purity of the stored water, to the standards outlined in TB Med 877, after up to a week of storage. The TEC will gather data regarding the residual chlorine in the stored water. The chlorinated product water will be tested for the presence of residual chlorine. The presence of residual chlorine at a minimum of approximately 0.2 mg/L indicates that essentially all bacteria and viruses have been killed, and that the water is no longer contaminated with fecal or other organic matter. The chlorine residual should not be greater than 0.6 mg/L so the taste of the chorine is acceptable.

Table 7: Objective 1.5 Data Matrix

Measure	Source	Product
MOE 1-5-1: Amount of residual chlorine	Event Log	Table

Objective 1.6: Assess water technology maintenance actions

A formal reliability, availability, and maintainability assessment will not be conducted since it is beyond the scope of the IWPS project. However, the TEC will gather any routine maintenance on event logs conducted during CV16. The TEC will record maintenance actions taken, where the maintenance occurred, required supplies, and any other relevant details about the maintenance event. Results will be reported in a narrative format.

Table 8: Objective 1.6 Data Matrix

Measure	Source	Product
MOE 1-6-1: Time required to perform maintenance	Event Log	Text
MOE 1-6-2: Characterize maintenance location	Event Log	Text
MOE 1-6-3: Characterize maintenance as routine or major	Event Log	Text
MOE 1-6-4 Number and type of proprietary components	Event Log	Text
MOE 1-6-5: Number and type of supplies or special tools	Event Log	Text
MOS 1-6-6: User rating of ease to conduct maintenance	Questionnaire	Chart/Text
MOS 1-6-7: SME rating of ease to conduct maintenance	Questionnaire	Chart/Text

Objective 1.7: Assess water technology environmental operating conditions
The environmental conditions include the time and temperature the technology can be stored, the operating temperature and time and the temperature of the source water that can be purified. The temperatures will be reported in degrees, time in days, and the maximum and minimum temperature range of the water source. During CV16 a TEC SME will characterize the ability of the technology to operate in rain, snow, heat, cold, wind, humidity, dust, and hail.

Table 9: Objective 1.7 Data Matrix

Measure	Source	Product
MOE 1-7-1: Maximum temperature with system in storage	Event Log	Table
MOE 1-7-2: Maximum temperature with system in operation	Event Log	Table
MOE 1-7-3: Temperature ranges of source water	Event Log	Table
MOE 1-7-4: Characterize ability to operate in rain	Event Log	Table
MOE 1-7-5: Characterize ability to operate in snow	Event Log	Table
MOE 1-7-6: Characterize ability to operate in heat	Event Log	Table
MOE 1-7-7: Characterize ability to operate in cold	Event Log	Table
MOE 1-7-8: Characterize ability to operate in wind	Event Log	Table
MOE 1-7-9: Characterize ability to operate in humidity	Event Log	Table
MOE 1-7-10: Characterize ability to operate in dust	Event Log	Table
MOE 1-7-11: Characterize ability to operate in hail	Event Log	Table

Objective 1.8: Assess ability to safely operate
A TEC SME will provide information on whether each water technology complies with DoD and OSHA standards. Users will provide a rating regarding the ability to safely operate the technology.

Table 10: Objective 1.8 Data Matrix

Measure	Source	Product
MOE 1-8-1: Characterize compliance with safety requirements	Event Log	Table
MOS 1-8-2: User rating of safety	Questionnaire	Chart/Text
MOS 1-8-3: SME rating of safety	Questionnaire	Chart/Text

Objective 1.9: Assess power consumption

Power consumption will be recorded as the average number of watts required to produce a gallon of water.

Table 11: Objective 1.9 Data Matrix

Measure	Source	Product
MOE 1-9-1: Number of watts required to produce 1 gallon of water	Event Log	Table

Objective 1.10: Assess semi-autonomous operations

The semi-autonomous capability ensures the water purification technology does not have to be constantly manned and will automatically shut off prior to a system failure.

Table 12: Objective 1.10 Data Matrix

Measure	Source	Product
MOE 1-10-1: Time of unattended operations	Event Log	Text
MOE 1-10-2: Characterize automatic shut off capability	Event Log	Text
MOE 1-10-3: Characterize power performance monitoring capability	Event Log	Text
MOE 1-10-4: Characterize embedded diagnostic capability	Event Log	Text
MOE 1-10-5: Characterize start and stop process	Event Log	Text
MOS 1-10-6: User rating of semi-autonomous capability	Questionnaire	Chart/Text
MOS 1-10-7: SME rating of semi-autonomous capability	Questionnaire	Chart/Text

COI 2: Is IWPS transportable to effectively support various missions including austere FOBs and HA/DR missions?

The goal of this COI is to determine whether the water purification technology components are transportable via commercial and military air and ground.

Objective 2.1: Assess air transportability

This objective will assess the transportability of the water purification technologies by commercial or military aircraft. The system should not require any special cargo handling equipment.

Table 13: Objective 2.1 Data Matrix

Measure	Source	Product
MOE 2-1-1: Characterize air transportability	Event Log	Text
MOE 2-1-2: Characterize special cargo handling requirements	Event Log	Text

Objective 2.2: Assess land transportability
This objective will assess the transportability of the water purification technologies by land. The land transport vehicle could be either a light truck or trailer. The system should be rugged enough to operate after being transported by the vehicle. Users and SMEs will provide feedback on the ruggedness of each system

Table 14: Objective 2.2 Data Matrix

Measure	Source	Product
MOE 2-2-1: Characterize land transport vehicle	Event Log	Text
MOE 2-2-2: Characterize ruggedness	Event Log	Text
MOE 2-2-3: SME rating of system ruggedness	Event Log	Text
MOE 2-2-4: User rating of system ruggedness	Event Log	Text

COI 3: Does the IWPS power source provided reliable power from primarily renewable sources?

The goal of this COI is to determine whether the power capability generates enough power, primarily from renewable sources, to operate the water purification technology.

Objective 3.1: Assess power type
The power output should facilitate running the water purification technology, operating on 110/220 VAC DC. The power source should include additional auxiliary outlets. To ensure local power needs are met if necessary, the power source should include international adapter kits and a power inverter with true sine wave output.

Table 15: Objective 3.1 Data Matrix

Measure	Source	Product
MOE 3-1-1: Characterize type of power output	Event Log	Table
MOE 3-1-2: Number and type of auxiliary power outlets	Event Log	Table
MOE 3-1-3: Number of international adapter kits	Event Log	Table
MOE 3-1-4: Characterize power inverter	Event Log	Table

Objective 3.2: Assess power availability
This objective seeks to characterize the amount of power output in a day, the down time due to power interruptions. While the power should be available 24/7, power interruptions should not exceed 60 minutes.

Table 16: Objective 3.2 Data Matrix

Measure	Source	Product
MOE 3-2-1: kWh generated per day	Event Log	Table
MOE 3-2-2: Time of power interruptions	Event Log	Table
MOE 3-2-3: Average time operational in 24 hour day	Event Log	Table

Objective 3.3 Assess power technology component portability

This objective seeks to characterize the portability of the power technology. As with the water technology, portability is the weight, number of personnel required to lift, and volume of each component of the technology. The number of personnel required was reported by the least number required which was determined by dividing the component's weight by 50 lbs., and the maximum number required which was determined by dividing the component's weight by 35 lbs.

Table 17: Objective 3.3 Data Matrix

Measure	Source	Product
MOE 3-3-1: Weight of power source component	Event Log	Table
MOE 3-3-2: Number of personnel required to lift power source	Event Log	Table
MOE 3-3-3: Volume of power source component	Event Log	Table
MOS 3-3-4: User rating of power source portability	Questionnaire	Chart/Text
MOS 3-3-5: SME rating of power source portability	Questionnaire	Chart/Text

Objective 3.4: Assess ability to safely operate

The power source technology should comply with DOD and OSHA standards. SMEs will provide a rating regard the ability to safely operate the technology.

Table 18: Objective 3.4 Data Matrix

Measure	Source	Product
MOE 3-4-1: Characterize compliance with safety requirements	Event Log	Table
MOS 3-4-2: User rating of safety	Questionnaire	Chart/Text
MOS 3-4-3: SME rating of safety	Questionnaire	Chart/Text

Objective 3.5: Assess power technology environmental operating conditions

The environmental conditions for each IWPS component are the same since most components of the kit were stored and operated at the same location. These measures are repeated for each component of the IWPS since they are independently operated and assessed.

Table 19: Objective 3.5 Data Matrix

Measure	Source	Product
MOE 3-5-1: Maximum temperature with system in storage	Event Log	Table
MOE 3-5-2: Number of storage days	Event Log	Table
MOE 3-5-3: Maximum temperature with system in operation	Event Log	Table
MOE 3-5-4: Number of operational days	Event Log	Table
MOE 3-5-5: Characterize ability to operate in rain	Event Log	Table
MOE 3-5-6: Characterize ability to operate in snow	Event Log	Table
MOE 3-5-7: Characterize ability to operate in heat	Event Log	Table

MOE 3-5-8: Characterize ability to operate in cold	Event Log	Table
MOE 3-5-9: Characterize ability to operate in wind	Event Log	Table
MOE 3-5-10: Characterize ability to operate in humidity	Event Log	Table
MOE 3-5-11: Characterize ability to operate in dust	Event Log	Table
MOE 3-5-12: Characterize ability to operate in hail	Event Log	Table

Objective 3.6: Assess power technology maintenance actions
As stated above, a formal reliability, availability, and maintainability assessment will not be conducted since it is beyond the scope of the IWPS project. However, the TEC will gather any maintenance issues on event logs conducted during CV16. The TEC will record the maintenance actions taken, where the maintenance occurred, maintenance level, the number of occurrence(s), number of proprietary components, and special tools required for the maintenance.

Table 20: Objective 3.6 Data Matrix

Measure	Source	Product
MOE 3-6-1: Time required to perform routine maintenance	Event Log	Text
MOE 3-6-2: Characterize maintenance location	Event Log	Text
MOE 3-6-3: Number and type of proprietary components required	Event Log	Text
MOE 3-6-4: Number and type of special tools required	Event Log	Text
MOS 3-6-5: User rating of ease to conduct maintenance	Questionnair	Chart/Text
MOS 3-6-6: SME rating of ease to conduct maintenance	Questionnair	Chart/Text

Objective 3.7: Assess power technology training
The TEC will gather objective and subjective data in order to assess the power technology training. Objective data includes the time required for operates to become proficient with the system, training requirements (i.e., slide and projectors or on-site) and training materials to ensure local nations can understand material and pre-event training can be conducted to maintain proficiency. Users will rate the adequacy and time allocated for classroom and hands-on training as well as the adequacy of the user manuals and handout material.

Table 21: Objective 3.7 Data Matrix

Measure	Source	Product
MOE 3-7-1: Time to achieve user proficiency	Event Log	Text
MOE 3-7-2: Characterize training requirements	Event Log	Text
MOE 3-7-3: Characterize training materials	Event Log	Text
MOS 3-7-4: User rating of classroom training	Questionnaire	Chart/Text
MOS 3-7-5: User rating of hands-on training	Questionnaire	Chart/Text
MOS 3-7-6: User rating of documentation	Questionnaire	Chart/Text
MOS 3-7-7: User train the trainer recommendation	Questionnaire	Chart/Text

Objective 3.8: Assess semi-autonomous operations

This objective seeks to ensure there is a semi-autonomous capability that ensures the power source technology does not have to be constantly manned and will automatically shut off prior to a system failure.

Table 22: Objective 3.8 Data Matrix

Measure	Source	Product
MOE 3-8-1: Time of unattended operations	Event Log	Text
MOE 3-8-2: Characterize automatic shut off capability	Event Log	Text
MOE 3-8-3: Characterize power performance monitoring capability	Event Log	Text
MOE 3-8-4: Characterize embedded diagnostic capability	Event Log	Text
MOE 3-8-5: Characterize start and stop process	Event Log	Text
MOS 3-8-6: User rating of power performance monitoring capability	Questionnaire	Chart/Text
MOS 3-8-7: User rating of embedded diagnostic capability	Questionnaire	Chart/Text

Objective 3.9: Assess renewable energy source
This Objective will characterize the type of energy source used, either hybrid or renewable, used by the power technology. In addition to the objective data, the TEC will gather subjective data from the user regarding the ruggedness and ease of cleaning the energy source

Table 23: Objective 3.9 Data Matrix

Measure	Source	Product
MOE 3-9-1: Characterize type of energy source	Event Log	Text
MOS 3-9-2: User rating on ruggedness of component	Questionnaire	Chart/Text
MOS 3-9-3: SME rating on ruggedness of component	Questionnaire	Chart/Text
MOS 3-9-4: User rating of ease to clean	Questionnaire	Chart/Text
MOS 3-9-5: SME rating of ease to clean	Questionnaire	Chart/Text

Metrics

The IWPS project does not have go/no-go criteria. Instead, the intent is to determine the operational utility of the capabilities in relation to the IWPS objectives by determining if each technology can meet the threshold or objective level parameters established by the TEC team (Table 24 and 25). If the threshold level is not met, the capability might still demonstrate some operational utility if the users and/or SMEs have a positive opinion of the system. It is also possible that thresholds and objective levels might change as the project evolves and new data considered. Thresholds and objectives for power sources will be developed and assessed at a later date.

Table 24. Water Metrics

Parameter	Threshold	Objective	Comments
Purification	Coliforms/ecoli: 0	Coliforms/ecoli: 0	Technical Bulletin Med 577 Humanitarian Charter and Minimum Standards in Disaster Response (Chapter 2)
	TDS: 1,000 mg/L	TDS: 1,000 mg/L	
	Turbidity: 1 NTU	Turbidity: 1 NTU	
Component Portability	< 300 lbs	< 200 lbs	
	6 person lift	4 person lift	
	<54 cu ft	<27 cu ft	
Water Production Quantity	1000 liters	1000 gallons	Gallons in a 24 hour day
Training for operation and routine maintenance	2 hours	< 1 hour	Local population to set-up, operate and maintain
Water Storage (1 week)	≥0.2 mg/L ≤ 0.6 mg/L	≥0.2 mg/L ≤ 0.6 mg/L	0.2 mg/L indicates that essentially all bacteria and viruses have been killed 0.6 mg/L so the taste of the chorine is acceptable
Flow Rate While Dispensing	TBD	TBD	

The following Parameters apply to IWPS components. The intent is to determine if each technology is transportable via military and commercial air and ground transport systems.

Table 25. Transportability Metrics

Parameter	Threshold	Objective	Comments
Air Transportable	Transported via MILAIR or Commercial	Transported via MILAIR or Commercial	None
Ground Transportable	Light truck or trailer	Light truck or trailer	None

AS16 Summary of Events and Findings

Angkor Sentinel is an annual bilateral, army-to-army, exercise conducted between the U.S. Army and Royal Cambodian Army. AS16 technology insertion focused on integrating and demonstrating IWPS project WPS and energy technologies in a relevant operational environment. Additionally, some limited data collection was conducted on product water, and power production/consumption. A total of six technologies participated in static displays and/or demonstrations during the event. These technologies included the First Response WPS, SilverDYNE additive, and STAESS, REAL, eMUBC, and SPM-622 energy technologies. TD activities were conducted March 6-26 2016.

During the Cambodian Science & Engineering Festival, the TEC team was able to demonstrate and brief water and energy capabilities to various visitors including students, technologists, non-governmental organizations (NGOs), and government representatives. This event was an excellent lead into AS16 operations. AS16 operations were conducted at the Training Center for Multinational Peacekeeping Forces, United Nations (UN) Peace Keeping Operation (PKO) base, Kampong Speu Province, Cambodia. The water purification technology demonstration portion of the event successfully demonstrated the FR and SilverDYNE technologies, while performing some limited data collection that will be applied to future assessments. The data collected during this event suggested that the SilverDYNE additive likely would not be a good fit for the IWPS project. Additional testing should be conducted to determine if SilverDYNE additive might add value to the IWPS protype. The TEC team identified issues with the FR chlorine injector and system maintenance that should be addressed prior to future testing. The STAESS technologies integrated with and successfully supported all power requirements for the water purification TD.

Visitors were very impressed by the AS16 IWPS TD technologies and expressed a desire to have the TEC team return to future AS events to provide additional technology demonstrations and assessments. Overall, AS16 was a successful event for the IWPS project. Lessons learned from demonstrating the FR WPS, testing the SilverDYNE additive, and integrating the energy technologies will help shape future IWPS events and the final IWPS prototype.

CV16 Summary of Events and Findings

The Crimson Viper Field Experiment is conducted annually between the Royal Thai Ministry of Defence (MOD) Defence Science and Technology Department (DSTD) and the TEC as the CV executive agent for US Pacific Command Science and Technology Office (USPACOM J85). CV16 provided an experimentation venue for IWPS technologies to be tested and demonstrated in a relevant field environment. CV16 was executed by the TEC under the ambit of the Thai-American Consultations (TAC) Joint Statement.

CV16 FE was conducted at Fort Adisorn, Calvary Center, Saraburi, Thailand. During CV16 the TEC team tested and integrated four WPS, two water purification additives, and three energy technologies. These technologies included the FR, Modus, Guardian, and Roving Blue WPSs, the SilverDYNE and O-Pen additive technologies, and the STAESS, SPM, and 1 kW generator.

Ninety-one total water samples were collected and tested in a field environment during CV16. These samples were tested under three major testing categories; initial testing, contamination testing, and storage testing. The FR and Modus appeared to show the most promise for meeting the IWPS project objectives. Both systems are capable of producing an adequate amount of product water, and are relatively easy to transport. Both systems had maintenance issues that impacted their performance during the event. These issues are being reviewed and should be addressed prior to any future events. The FR and Modus water sample data showed promise for these systems to effectively purify highly turbid and contaminated source water. It is recommended that additional tests be conducted with these technologies. The Roving Blue WPS demonstrated promise during initial testing, but the system is unable to produce the threshold level of product water of 1,000 gallons per day. The O-Pen and SilverDYNE additives did not appear to provide any additional value to the product water of the WPSs, and were unable to treat product water on their own. The STAESS and SPM technologies successfully integrated with and supported the WPS power requirements and should be included in future tests.

Overall, the IWPS test event during CV16 was a success. The TEC team identified and mitigated a number of limitations that occurred in the field and successfully collected valuable data on 9 total technologies. The data collected, and the lessons learned, during CV16 will help shape the IWPS prototype and future IWPS project test events.

TEIM OBSERVATIONS AND RECOMMENDATIONS

As part of the TEC TEIM, water purification and renewable energy SMEs from various DoD and private organization were provided an overview of the IWPS project, including event specific details, and some preliminary findings. Once participants were familiar with the project the group was asked to help the TEC team brainstorm the way ahead in regards to achievable goals and prototyping. This section provides a summary of the observations and recommendation recorded during the event.

IWPS Objectives

The original objectives described as part of the IWPS project included:

- 1,000 to 5,000 gallons per day of safe product water (objective)
- Odorless product water
- Tasteless product water
- Long lasting cleansing effect product water
- The ability to maintain purity even if passed to a contaminated container
- A high efficiency/low maintenance pumping system
- Ability to support multiple mission types
- The incorporation of renewable energy

Additional objectives discussed that were not part of the original project description included:

- Colorless product water
- Distribution of product water
- Transportability of the system
- Maintainability of the entire system
- Development of training materials including visual disclaimers to help educate consumers

TEIM Recommendations

The TEIM discussion helped to define some objectives, and provide an understanding of the relationship of each objective to the effectiveness of the final prototype. Some original project objectives will likely need to be reexamined to determine if they are achievable given current available technology.

Objective 1: 1,000 to 5,000 gallons per day of safe product water (objective)
When considering current available technology, the variation in source water and its impact on water production, the need for ease of transport, and the ability to scale up an initial prototype, it was determined that the updated prototype should have an objective level of 1,000 gallons per day and a threshold level of 1,000 liters per day (approx. 264 gallons). This would support approx. 132 people at the standard rate of 2 gallons per day.

Water Safety and Storage
The participants discussed what additive would best address the need to obtain safe product drinking water while considering the other project requirements. The result was an overwhelming agreement that chlorine is the best option. Some of the reasons given to support this decision included; least expensive option, easiest to obtain or make in country, easy to measure correct dosage, additive with the most research and data to support use, and longest effective residual time. Additionally, it was stated that a small

electro chlorinator should be included as part of the prototype to expedite the obtainment of chlorine if needed.

Objective 2: Odorless product water

The original project was based on the assumption that consumers would have an aversion to the smell of chlorine. As a result, a Nano colloidal silver technology (SilverDYNE) and an ozone technology were included in sample tests to determine effectiveness in providing an odorless and safe additive. Discussions during the TEIM revealed that not all parts of the world have an aversion to the smell of chlorine. While some rural Asian countries are suspicious of the smell, some African countries find the smell to be a reassurance that the water is clean. This presented a new and valuable consideration. The team had previously agreed that chlorine would be added to the product water. To address the chlorine proclivities of an individual country the team decided a piece of hardware should be developed to address the chlorine smell issue. This hardware should be a double faucet adaptor that connects to the product water storage container and allows the user to either dispense water with chlorine added, or run the product water through a carbon filer to remove the chlorine. This adaptor would allow the IWPS system to address the issue of resistance to chlorine odor and taste, while still guaranteeing product water safety at the point of distribution.

Objective 3: Tasteless product water

The major issue discussed for this objective was the presence of chlorine or other additive taste. This objective is addressed by the removal of chlorine from the product water when needed. In those consumer populations where chlorine is preferred, the objective for tasteless water is no longer required.

Objective 4: Long lasting cleansing effect product water

The majority of the discussion on objective 4 focused on defining what "long lasting cleansing effect" means, and what is reasonable. For the current IWPS project the team agreed that a long lasting cleaning effect could only be guaranteed if the product water is housed within a storage tank, and a residual of chlorine is maintained. Without maintenance, stored water should be given the correct amount of chlorine to maintain purity for 24 hours, where the residual after 24 hours meets the international standard of 0.2 ppm.

Objective 5: The ability to maintain purity even if passed to a contaminated container

When addressing objective 5, participants were asked to consider what is achievable within the current IWPS project timeline. It was determined that the simplest, most effective way to maintain purity when passed to a contaminated container would be to provide a means for consumers to wash their containers. Containers would be washed in a high concentration chlorine wash prior to having product water dispense into their container. Given the vast variation in containers used, and the need for consumers to agree to wash their personal containers, product water could only be guaranteed at the point of distribution. Two primary paths for distribution where identified. The first path, depicted in Figure 1, assumes the operators have the time and equipment to set up a storage container, and takes into account the possibility of running the product water through a second carbon filter to remove chlorine smell and taste.

Figure 1. Product Water Distribution Path 1

The second path, depicted in Figure 2, assumes product water is dispensed directly to the consumer, with product water being chlorinated if possible, or consumers' containers sanitized if not.

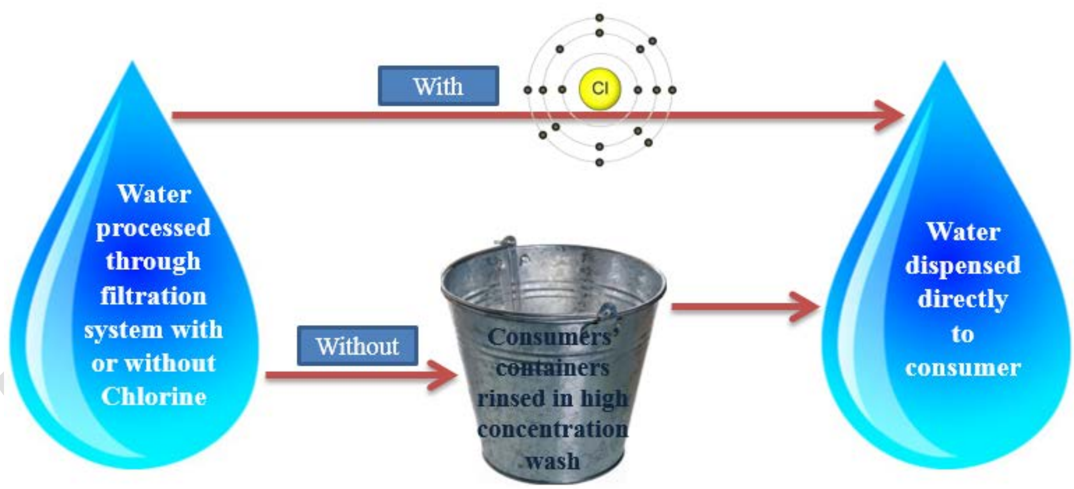

Figure 2. Product Water Distribution Path 2

Additional distribution methods could be explored as part of a follow on to the initial IWPS project. New bagging technologies could help ensure that clean water reaches more consumers, help expedite the distribution of product water, and relieve the need to setup a sanitizing station for consumers' personal containers.

Objective 6: A high efficiency/low maintenance pumping system

Based on AS16, CV16, and other limited tests, it was agreed that the motor for the FR system could be improved. The current motor is less efficient than it could be, and a number of maintenance issues have occurred during each of the events. Additionally, it was suggested that data logging instrumentation be installed on the system to help ensure the efficiency and performance. TEC SMEs will work to identify and integrate new parts for future IWPS test events.

If the IWPS project is continued beyond the current project requirements it is suggested that data be collected on the consumables and spare parts required to adequately support the maintenance of the system. Additional testing should also be conducted including environmental testing of the equipment while operating and storage temperature range when stationary and during transport. While these goals fall outside of the current IWPS scope, they could be addressed in a follow on project.

Objective 7: Ability to support multiple mission types

The IWPS project seeks to develop a system that can support multiple mission types, with the primary focus being on HA/DR. As a result a number of additional requirements were discussed to help achieve this goal. A major concern for the deployment of any equipment is the transportability of the system. The team identified a number of goals to help ensure that the IWPS system is easily transportable to support multiple mission types. These goals include; each component should weight no more than 100 lbs., each component should be 2 man portable, each component should be transportable on commercial air, no inclusion of hazmat materials, components should be ruggedized and stored in pelican cases, and the entire system should fit on one 463L pallet for ease of transport by the military if necessary. During this iteration of the IWPS project, and given that transportability was not an initial objective of the project, not all of these goals will likely be met. However, the TEC team will work to address the issues that are achievable during this iteration, and will develop plans to continue development if required.

Training should also be addressed as a follow-on objective of the project, with a focus on supporting multiple mission types. The current IWPS project focuses on developing a prototype, but any future plans should include the development of training materials that can be used in any location around the world. Specifically, pictographic training documents and signage should be developed to help educate local operators and consumers.

Objective 8: The incorporation of renewable energy

The primary focus of the IWPS project has been on the water purification aspect of the system. However, the integration of renewable energy is vital for the system to effectively support HA/DR missions. The team identified a combination of energy technologies to incorporate with the next prototype for testing. They also identified three considerations that should be incorporated into the power plan for the IWPS. These considerations include; ability to locally source car batteries to eliminate the need to ship batteries, locally sourced fuel, and the requirement for night time ops. If night time ops are deemed to be a desirable goal for the current or future IWPS prototype, a compact, renewable energy lighting systems could be included in the kit.

IWPS Prototype

The next iteration of the IWPS prototype was designed, based on previous IWPS events, including the TEC TEIM discussions. This design will be tested at the next IWPS demonstration or assessment event. This prototype includes the First Response 1000, or Modus water purification systems, the STAESS as the primary renewable energy source, the SPM, the Flex Fuel 1 kW generator as a backup power source, and the proposed dual valve system that incorporate carbon filtration for chlorine removal when required. This prototype is depicted in Figure 3 below.

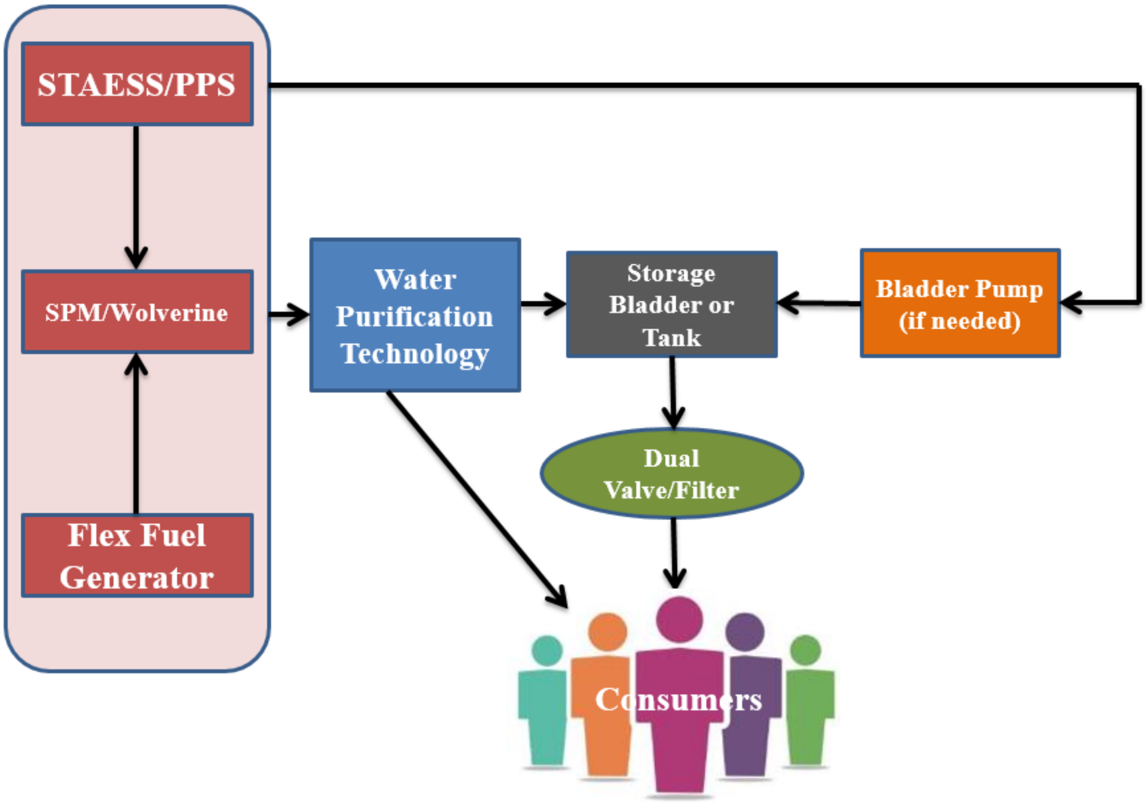

Figure 3. IWPS Prototype Design

ANNEX A: IWPS TECHNOLOGY DEMONSTRATION IN AS16

Angkor Sentinel 2016
Technology Demonstration
Final Report

March 2016
Kampong Speu, Cambodia

May 2016

This report provides information on the technology demonstration conducted during exercise Angkor Sentinel 2016. This document provides a summary of activities, findings, and feedback gathered by the Technology Experimentation Center (TEC) and does not represent the formal position of the Department of the Navy.

This report is approved for public release, distribution unlimited. The use of trade names in this document does not constitute an official endorsement, approval, or the use of such commercial hardware or software. This document may not be cited for purposes of advertisement.

Shujie Chang, P.E.
Director, TEC

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ACRONYMS

AOR	Area of Responsibility
a-Si	Amorphous Silicon
AS16	Angkor Sentinel
CDRUSPACOM	Commander, U.S. Pacific Command
CONOP	Concept of Operations
CPX	Command Post Exercise
eMUBC	Expeditionary Modular Universal Battery Charger
FOB	Forward Operating Base
HA/DR	Humanitarian Assistance / Disaster Relief
IED	Improvised Electronic Device
ITC	Institute of Technology
LED	Light Emitting Diode
Mono c-Si	Monocrystalline Silicon
NGO	Non-governmental Organization
PAO	Public Affairs Office
PKO	Peace Keeping Operation
PM	Preventative Medicine
RCA	Royal Cambodian Army
REAL	Renewable Energy Area Lights
RE/PM	Renewable Energy / Power Management
SME	Subject Matter Expert
SPM	Squad Power Manager
STAESS	Soldier Transportable Alternative Energy Storage System
STEM	Science, Technology, Engineering, and Mathematics
TEC	Technology Experimentation Center
UF	Ultra-filtration
UN	United Nations
USARPAC	U.S. Army Pacific
USB	Universal Serial Bus
USPACOM	U.S. Pacific Command
TD	Technology Demonstration
TDS	Total Dissolved Solids
TSC	Theater Sustainment Command

UNITS OF MEASURE

Ah	ampere hour
C	Celsius
ft.	feet
gal	gallons
GPD	gallons per day
hrs	hours

in.	inches
kw	kilowatt
l	liter
ml	milliliters
ppm	parts per million
sq ft	square foot
V	volts
VAC	Voltage AC
VDC	Voltage DC
W	watts
Whrs	watt hour

EXECUTIVE SUMMARY

Angkor Sentinel is an annual bilateral, army-to-army, exercise conducted between the U.S. Army and Royal Cambodian Army. AS is a U.S. Army Pacific (USARPAC) capstone theater security cooperation program. AS16 was the inaugural year for technology insertion by the TEC in support of US Pacific Command Science and Technology Office (USPACOM J85) objectives. The purpose was to demonstrate leading edge technologies and proposed Concepts of Operation (CONOP), in relevant operational conditions to gather relevant feedback in support of the Integrated Water Purification System (IWPS) project. AS16 also provided the opportunity for engagement with the Royal Cambodian Army (RCA) partners.

Technology insertion focus areas for IWPS in AS16 included water purification and renewable energy/power management. A total of six technologies were used as static displays and/or demonstrated during the event. AS16 technologies included the First Response, SilverDYNE, STAESS, REAL, eMUBC, and the SPM-622. Technology demonstration (TD) activities were conducted March 6-26 2016.

AS16 operations were conducted at the Training Center for Multinational Peacekeeping Forces, United Nations (UN) Peace Keeping Operation (PKO) base, Kampong Speu Province, Cambodia. The water purification TD portion of the event successfully demonstrated the First Response and SilverDYNE technologies, while providing the opportunity for some limited data collection. The TEC team identified some potential issues with the First Response system that can be easily addressed prior to future testing. Additionally, the team recommended additional testing of the SilverDYNE technology in both laboratory and field environments.

The renewable energy/power management (RE/PM) TD provided observers the opportunity to observe and use valuable RE/PM technologies. The STAESS supported all power requirements for the water purification TD, and REAL powered multiple other small electronic devices. The TEC team trained a user on the SPM-622 technology who used the technology to support the Intel cell located near the TEC team's main operating site.

Visitors were very impressed by the technologies and expressed a desire to have the TEC team return to future AS events to provide technology demonstrations, assessments, and warfighter capabilities. AS16 was a successful event for technology insertion and partner nation S&T collaboration efforts. The data collected from each of the demonstration events will help shape continued technology development for the IWPS prototype and future S&T engagement efforts.

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INTRODUCTION

Purpose

The purpose of this event was to demonstrate leading edge technologies and proposed Concepts of Operation (CONOP) in relevant operational conditions to gather relevant feedback for the IWPS prototype. Angkor Sentinel 2016 (AS16) also provided engagement opportunities with Royal Cambodian Army (RCA) partners. This report covers the Technology Experimentation Center (TEC) activities from March 6-26, 2016.

Background

IWPS is a TEC led project, sponsored by the Office of the Secretary of Defense (OSD), Rapid Reaction Technology Office (RRTO). The TEC is a U.S. Government network of technology and operational community subject matter experts working together to enable the warfighter by conducting technology demonstrations, experiments, and assessments in relevant operational venues and environments. The TEC is responsible for coordinating and executing all aspects of the IWPS project to include prototype design, assessment, logistics, demonstration, experimentation, feedback collection, and reporting. RRTO develops risk-reducing prototypes and demonstrations of land, sea, and air systems that address mission-focused combatant command, joint-Service, and interagency capability needs to counter emerging threats and provide a hedge against technical uncertainty. RRTO provides the flexibility to respond to emergent Defense Department needs and address technology surprises within the years of execution and outside the two-year budget cycle, enabling the fielding of solutions to time-sensitive problems. RRTO is the IWPS project sponsor.

The project was designed to fill a gap for a complete, renewable energy powered water purification system that would be suitable for multiple mission types. The IWPS requirements include the production of 1,000 liters (threshold) to 1,000 gallons (objective) of safe, odorless, tasteless, product water per day.

The TEC project team was identified and began coordinating field events to support the IWPS project objectives in the beginning of December 2015. The First Response (FR) water purification system (WPS) was selected for integration with a nanoparticle colloidal silver additive, and various renewable energy technology options, for demonstration in AS16. Coordination for the AS16 demonstration including identifying participating technologies, demonstration planning, logistics and customs requirements, communication with participating U.S. and Cambodian forces, and site surveys were conducted between December 2015 and March 2016.

Angkor Sentinel is an annual bilateral, army-to-army, exercise conducted between the U.S. Army and Royal Cambodian Army. AS is a U.S. Army Pacific (USARPAC) capstone theater security cooperation program. AS16 was the seventh iteration of Angkor Sentinel, with major forces provided by the Cambodian Army headquarters and U.S. 8th Theater Sustainment Command (TSC).

. Technologies that participated in AS16 were divided into one of two focus areas. The identified focus areas for AS16 technology insertion included water purification and renewable energy/power management. A total of six technologies participated in static displays and/or demonstrations, within the identified focus areas, during AS16.

AS16 Objectives

USARPAC has identified three major objectives for AS events. These objectives include:

- Ensure robust army-to-army engagement
- Engage with wide range of Cambodian Forces
- Army Headquarters, MOD, Gendarmerie, Medical Command, NPMEC

Major objectives for the AS16 Command Post Exercise (CPX) included:

- Improve Staff Interoperability
- Sustain Angkor Sentinel as a robust capacity building activity
- Improve Ability to Operate in a Multinational environment
- Improve Humanitarian Assistance / Disaster Relief (HA/DR) Capability
- Conduct Battalion Staff Training CPX

AS16 Exercise Schedule

Figure 1 provides a summary of the AS16 exercise schedule of events. All scheduled events occur in March, 2016.

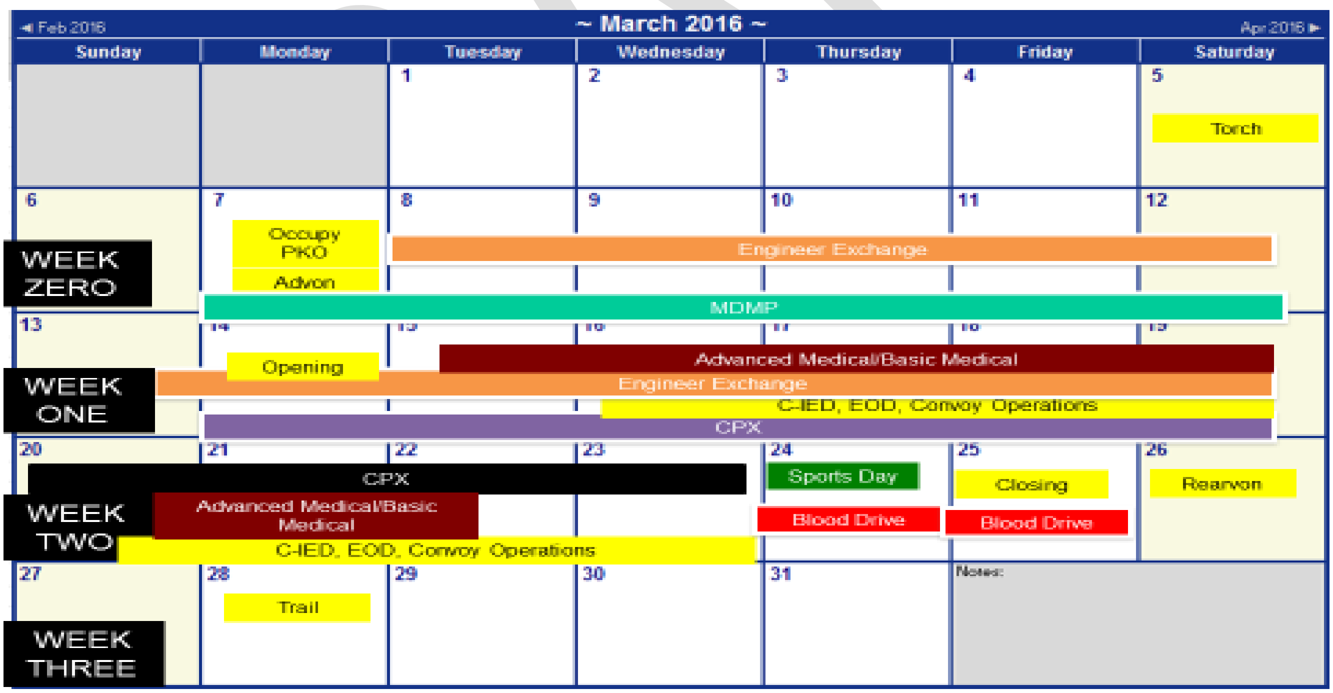


Figure 4: AS16 Exercise Schedul

EXECUTION

Locations

AS16 technology insertion was conducted at the Training Center for Multinational Peacekeeping Forces, United Nations (UN) Peace Keeping Operation (PKO) base, Kampong Speu Province, Cambodia.

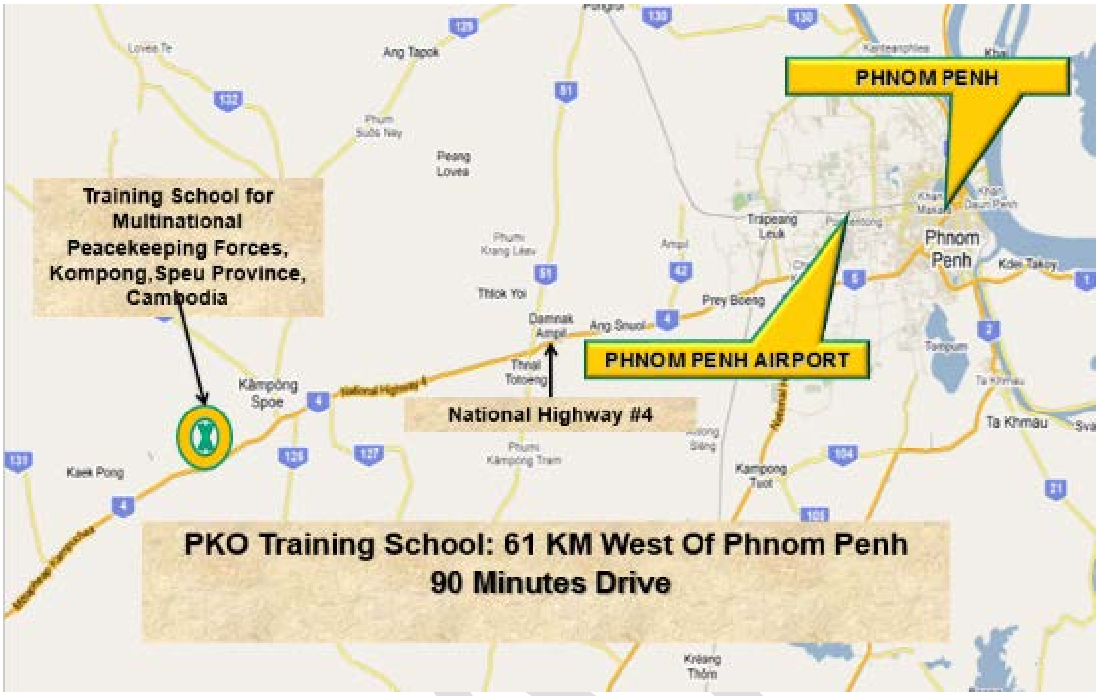


Figure 5: AS16 Locations Summary

The Training Center for Multinational Peacekeeping Forces is located along National Highway #4, Tourl Village, Mohasang Commune, Phnom Sroch District, Kamong Speu.

Figure 6: UN PKO Front Gate

AS16 Technology Experimentation Schedule

The following table provides a brief summary of the AS16 technology experimentation team's schedule of events.

Table 26: AS16 Schedule

Date	Location	Arrivals (A) Departures (D)	Event
6 Mar	Phonm Penh	Frank Duran (A) Joe Martinez (A)	TEC AS16 OPS/Log Lead and Analyst arrive
7 Mar	Phonm Penh		Inventoried cargo Met with US Embassy to discuss TEC AS16 CONOPS Met with festival lead
8 Mar	Phonm Penh		Setup for the Science and Engineering Festival
12 Mar	Phonm Penh	Main body (A)	TEC AS16 Main body arrives
13 Mar	PKO Base		Final Site Survey
14 Mar	PKO Base		0800, Opening ceremony TEC technology static display/demonstration
14-24 Mar	PKO Base		Technology demonstrations and assessments
25 Mar	PKO Base and Phonm Penh		Closing Ceremony, Ship cargo
26 Mar	Phonm Penh	Advon and Main body (D)	TEC team departs

TEC Roster

The following table provides a list of AS16 technology demonstration participants.

Table 27: TEC Roster

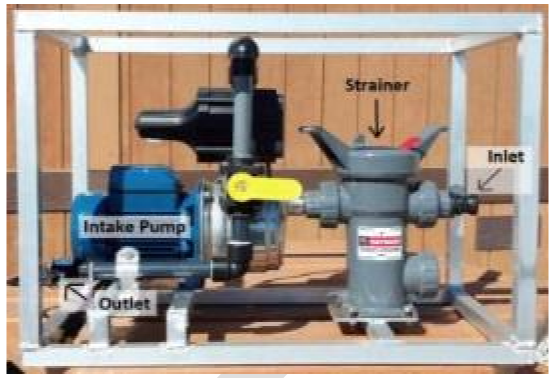
CIV/CTR	Last Name	First Name	Billet
CIV	Chang	Shujie	TEC Director
CTR	Duran	Frank	TEC AS16 Lead
CTR	Martinez	Joe	TEC Lead Data Collector
CTR	Chaney	James	Renewable Energy SME
CTR	Tolley	Dan	Nano Colloidal Silver SME

Technology Description

The following section provides a brief description of each of the technologies that participated in AS16.

First-Response Freshwater Purifiers (1000 and 5000)

The First-Response systems have Superior Ultra-filtration (UF) membrane capability to remove all microorganisms and virtually all suspended solids and turbidity in one stage. A unique cleaning capability for the UF membrane that does not require power nor sophisticated instrumentation and control. **Capability**: Produces 1000 and 5000 gallons purified water per day. Easy to transport, set-up and train.



SilverDYNE Water Treatment

SilverDYNE is a water compound, with a natural silver based, stable suspension, non-toxic, non-chemical and non-hazardous product, that when used as directed will not only disinfect water, but can also extend the shelf life of most fruits and vegetables without any taste, odor, color, or toxicity. SilverDYNE is unique because of the way it is engineered. It uses special clustering de-ionized water and engineering process that keeps the silver particles in suspension, for increased absorption and efficiency as well as guided particle direction for the elimination of bacteria. SilverDYNE uses true natural silver consisting of both elemental and ionic particles providing the ultimate particle surface area and an extremely high efficiency index.

Soldier Transportable Alternative Energy Storage System (STAESS)

The STAESS consists of efficient foldable photo-voltaic panels and battery packs to provide power. The STAESS is a soldier-portable, rapid-charging photo-voltaic renewable energy system that is modular and expandable to allow for simple set up, transport, and easy operation. The size, efficiency, and power output vary depending on the configuration of modules.

The Renewable Energy Area Lights (REAL) is a solar powered Light Emitting Diode (LED) lighting system that comes in two sizes the REAL Small and the REAL Large. The REAL system is designed to work off of various power sources, including solar. These systems can be used to light a small tented area, or a football field sized Forward Operating Base (FOB). Additionally, the systems include universal serial bus (USB) ports for charging phones and other auxiliary devices.

Expeditionary Modular Universal Battery Charger (eMUBC) is a modular charger that provides soldiers with a lightweight option to recharge military batteries and USB devices. Its contemporary design allows soldiers to charge a multitude of equipment in a centralized location with one charger.

Squad Power Manager (SPM) is a compact, rugged, intelligent charger and power converter. It intelligently adjusts to changing operational conditions and requirements to optimize powering devices and charging batteries.

Data Sources

The TEC team utilized the following data sources to collect data and feedback during AS16.

Daily Hotwashes

Technology specific data, event details, and administrative comments were collected each day as part of the daily hotwash. Power Points were designed to focus on, and compliment the individual focus areas for each technology. These slides were used to collect relevant data where appropriate.

Questionnaires/Surveys
The AS16 SMEs and the SPM-622 user completed questionnaires/surveys designed primarily to gather feedback on the AS16 technology demonstrations.

Interviews
When appropriate, AS16 observers were asked to participate in interviews with data collectors on a noninterference basis. Questions will be designed to collect observer feedback on the AS16 technologies.

Photographs
Data collectors captured photographs to support the event. Data collectors ensured photographs remained unclassified and were approved for release by the appropriate agencies.

WATER PURIFICATION
TECHNOLOGY DEMONSTRATION

The TEC conducted a demonstration of the First Response and Silver Dyne technologies under expeditionary conditions, during AS16 in the Kingdom of Cambodia from 12-17 March, 2016. This demonstration was conducted as part of the Integrated Water Purification System (IWPS) project. Observations and feedback collected during AS16 will help inform future IWPS porotypes. The water purification TD was conducted at the Training Center for Multinational Peacekeeping Forces, Peace Keeping Operation base, Kampong Speu Province, Cambodia.

The First Response served as the central technology for extracting and dispersing the source and product water during the demonstration. SilverDYNE, a water purification additive, was demonstrated as an alternative to the use of chlorine in source and product water.

Water Purification TD Technologies

The following section provides a more detailed summary of the First Response and SilverDYNE technologies' capabilities along with technology specifications where available.

First Response
The First-Response Water Purifiers were developed for mobility and long-term operation in remote areas under challenging conditions. The equipment is designed to meet the need for water treatment in emergency, disaster relief operations, and remote communities around the world. A variety of production capacities are available utilizing a core technology of ultra-filtration membranes, activated carbon and chlorine addition. Currently, three production capacities are being developed - 2,000 GPD, 5,000 GPD and 10,000 GPD.

The Purifiers use technologies that are lightweight, compact, mobile and able to operate effectively with any potential freshwater source, including difficult-to-treat surface waters with high turbidity and high algae content. With their use of back-washable UF membranes and chlorine addition, the Purifiers are designed to provide microbiologically-safe potable water with a residual disinfectant. In addition, Activated Carbon is included as a treatment stage for taste enhancement.

Optional brackish water and seawater desalination stages are available to remove chemical contamination and high salinity.

The following is a partial list of specifications:

- **Freshwater Production Capacity** = 2,000 GPD (7,500 liters per day); 5,000 GPD (19,000 liters per day); 10,000 GPD (37,800 liters per day);
- **Twin Barriers** to Produce Microbiologically-Safe Drinking Water with a Residual Disinfectant – UF Membranes and Chlorine Addition;
- **Water Treatment Technologies** Selected for Effectiveness, Reliability, Ease of Operation, Low Maintenance, Minimal Logistic Resupply, Transportability and Minimum Cube & Weight;

- **Aluminum Equipment Frames** are Lightweight, Compact, Man-Portable (2-Man Lift) and Packaged for Pelican-style Boxes;
- **Low Power Requirement**; Systems can be Powered with a Variety of Power Sources (Solar, Wind, DC and AC Generator);
- **Optional Brackish Water and Seawater Desalination Stages** are being developed to complement the 5,000 and 10,000 GPD Systems (Seawater Desalination = 1,000 to 3,000 GPD);

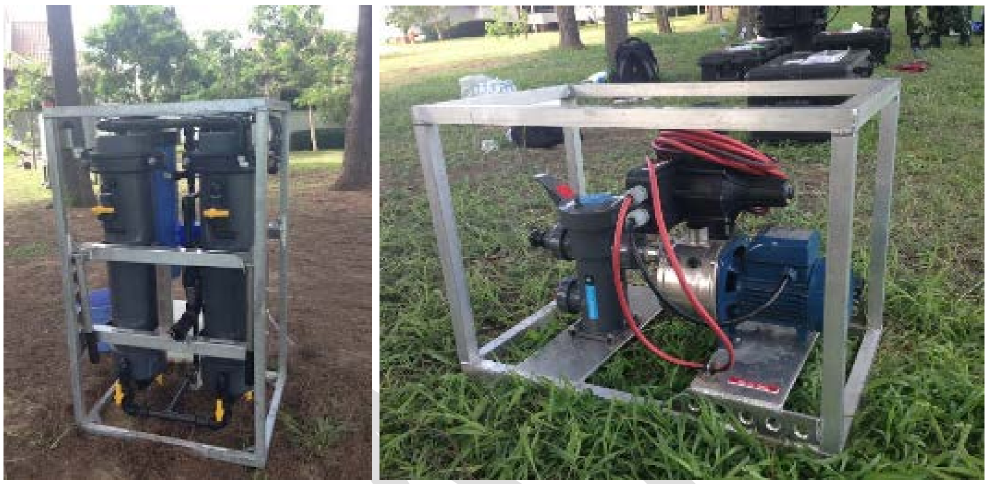


Figure 7: First Response 5000

SilverDYNE

According to World Health Alliance International:

"SilverDYNE is a water compound, with a natural silver based, stable suspension, non-toxic, non-chemical and non-hazardous product, that when used as directed will not only disinfect water, but can also extend the shelf life of most fruits and vegetables without any taste, odor, color, or toxicity. SilverDYNE is unique because of the way it is engineered. It uses special clustering de-ionized water and engineering process that keeps the silver particles in suspension, for increased absorption and efficiency as well as guided particle direction for the elimination of bacteria. We make true natural silver consisting of both elemental and ionic particles providing the ultimate particle surface area and an extremely high efficiency index." (*http://www.whaintl.com/index.php/SilverDYNE*)

Table 28: SilverDYNE Benefits

SilverDYNE Benefits	
• It will not alter the composition of water. • Odorless, non-corrosive, tasteless. • It can be used in a baby's bath to eliminate bacteria. • It can extend the shelf life of most fruits and vegetables by eliminating the bacteria on them. *(http://www.whaintl.com/index.php/SilverDYNE)	

Scope and Limitations

The First Response systems were demonstrated to U.S. and Cambodian observers during AS16. Some limited data collection on water quality results was collected. However, this data collection was only conducted as part of the AS16 demonstration and cannot be considered a technical assessment of the First Response technology capabilities.

During meetings with the AS16 Preventative Medicine (PM) and administrative representatives the TEC team determined certain limitations that would impact the water purification demonstration and data collection effort. The most important of these limitations was the lack of water testing equipment by the PM team and the local water testing lab's two-week requirement for testing water samples. Thus, the TEC team was only able to test a limited number of samples.

Location

The water purification demonstration site was selected by the TEC team during the AS16 final site survey. Operations were setup 50ft from a pond located inside of the UN PKO base. This pond was identified as the only natural source water available for purifying in the area. The pond is located near an old water purification facility that no longer operates. Thus, 10 truckloads of water were delivered daily to support AS16 operations. This water was housed in a reservoir near the treatment facility. The source water pond was approx. 3ft. deep with high sediment, turbidity, and bacteria levels. Contamination sources included, but were not limited to, laundry and local animals.

Figure 8: Source Water Location

Figure 9: Water TD Site Panoramic

Figure 10: Water Delivery Truck (Left) and Potable Water Holding Tank (Right)

Schedule

The following table provides a summary of the AS16 water TD events.

Table 29: AS16 Water TD Events

Date	Event(s)
3/7/16	Cargo inventoried and pulled for support of the Science and Engineering Festival
3/9-3/10/16	Static display at the Science and Engineering Festival
3/11/16	Transport to AS16 location
3/12/16	Inspected, inventoried, and staged equipment for AS16 operations
3/13-3/16/16	Main Operations
3/17/16	Final Sample Results

Demonstration Support Summary

The following section provides a summary of the water TD main operations.

Upon completion of support for the Cambodian Science and Engineering Festival the TEC team arranged transport of all technologies to the AS16 water TD site on March 11, 2016. Capt. Clack, AS16 preventative medicine officer, and SSG Nixon, military police, of the 130th Support Bn, 8th TSC, Scholfield Bks, HI, provided a tour the areas around the source water site including an old water purification facility. The Operations officer for DFAC and water life support provided the team with background information on the treatment facility. The facility is not currently operating due to a lack of trained personnel. On March 12th, the team inspected, inventoried, and staged all equipment to help expedite setup and operations the following day.

March 14th: The TEC team successfully deployed the First Response 5000 to begin water demonstrations and testing. After setup, the system operated for 2.5 hours, processing approximately 400 gallons of water. Technology briefs and demonstrations were provided to visitors as needed throughout the day.

Figure 11: March 13th Water TD Operations

Water Testing

The TEC team conducted 3 Total Dissolved Solids (TDS) tests and 1 Chlorine test. These tests were conducted using a handheld TDS reader and a standard, commercial off the shelf, water treatment test kit.

Total Dissolved Solids (TDS) test completed.

- Source water TDS = 258
- After treatment TDS = 279
- Bottled water TDS = 2.7

750 ml of Chlorine added to 2.5 gallons of water in the First Response injector, once purified the injector added 1 to 5 ppm depending on settings

- Chlorine test conducted on treated water
  - Results Total Chlorine 1.0 ppm

The source and treated water both fell within an acceptable range for TDS, with the maximum allowable TDS being 600 ppm. However, the chlorine results reflected only 1 ppm when the injector was set to 3-5 ppm. The First Response system works by creating a solution of 1500ml of chlorine and 5 gallons of water that is used as an additive, dispensed from the injector, to the processed water during the purification process. Based on the 1 ppm result the team concluded the injector was not functioning properly.

Figure 12: TDS Testing (Left) and Chlorine Test (Right)

Reliability and Maintenance
During setup, the team determined the 120V pump, setup for use with the First Response 5000, was not operating properly. The pump would operate for approximately 30 seconds and then shut off. The team integrated the pump from the First Response 1000 into the 5000 to begin operations. Thus, the First Response 1000, was not used during the AS16 water TD. The team also noticed that the on/off switch was broken on both the First Response 1000 and 5000. Once power was applied to the pumps they automatically turn on and the user is unable to turn them off unless the systems are unplugged.

During water testing the team observed that the ppm rate was not accurate. The system was set to dispense for product water at 5 ppm, but the product water only tested at 1 ppm. The team concluded that the injector was faulty, but, with no available replacement parts, was unable to address the issue during the demonstration. The 1 ppm reading represents a shorter storage period for treated water due to a shortened period of protection against bacteria.

SME Feedback
- Better transit and containment case
- Priming water pumps requires extra time and effort. The current system should incorporate a self-priming pump.
- The manual states 5 gal of water to 1500ml chlorine at injector. The team set the system for 5 ppm product water, but the injector was not functioning properly to provide the necessary 3-5 ppm. Recommend that the injector be serviced or replaced before any future tests or demonstrations.
    - Injector hose has air bubbles. In the past tiny air bubbles have been observed, but these were large bubbles that seemed to impact the flow of the injector.

Observer Feedback
- Mount on High Mobility Multipurpose Wheeled Vehicle (HMMWV) with STAESS system for forward HADR. –MAJ Gipson
- AS16 military personnel were interested in using the product water, but Preventative Medicine did not have the tools to verify the water quality- MAJ Gipson

March 15th: The TEC team successfully deployed the First Response 5000 to begin water demonstrations and testing. After setup, the system operated for 4.5 hours, processing approximately 900 gallons of water. The TEC team briefed Bn Commander COL Albert and his SGT MAJ Obeada on AS16 technologies. The team also demonstrated the First Response to 10 Royal Cambodian soldiers and 5 U.S. Army soldiers.

Figure 13: COL and SGT MAJ Briefings (Left) and Soldier TD (Center and Right)

Water Testing

The TEC team conducted source water testing as part of the AS16 water TD. Water testing included several parameters such as the presence of lead, pesticides, iron, hardness, etc. Six separate samples were tested including the source water, source water treated with chlorine, source water treated with SilverDYNE, filtered water (using the First Response), filtered water treated with chlorine, and filtered water treated with SilverDYNE. Bacterial testing required 48 hours for processing. The following table provides a summary of the results processed on March 14.

Table 30: March 14 Water Testing Results

Tested Item	Source	Source / Chlorine (.1ml per l)	Source / SilverDYNE (.1ml per l)	Filtered Water	Filtered Water with Chlorine (1 l to 5000 l of water)	Filtered Water / SilverDYNE (450 ml to 5000 l)
Total Dissolved Solids	272	348	267	284	282	266
Lead	Negative	Negative	Negative	Negative	Negative	Negative
Pesticide	Negative	Negative	Negative	Negative	Negative	Negative
pH	8.5	8.5	8.5	8.5	8.5	8.5
Total Alkalinity	500	500	500	500	500	500
Total Chlorine	0	1	0	0	0	0
Total Hardness	50	50	50	50	50	50
Free Chlorine	0	0.5	0	0	0	0
Chloride	500	500+	500	500	500	500
Sulfate	0	0	0	0	0	0
Total Nitrate	0	0	0	0	0	0
Total Nitride	0	0	0	0	0	0
Copper	0	0	0	0	0	0
Iron	0	0	0	0	0	0
Hydrogen Sulfide	0.3	0.3	0.3	0.3	No Color	No Color

Figure 14: Bacteria Testing (from left to right, source, chlorine, SilverDYNE, Filtered w/SilverDYNE, and Filtered w/chlorine)

Reliability and Maintenance
The TEC team noted issues with the backwash instructions due to the broken on/off switch which resulted in delays during backwash maintenance.

SME Feedback

- Once the team identified that the issues with the backwash procedures were due to the on/off switch being broken the team adapted by manually starting the pump when Feed Module A or B was open during the backwash procedure. This successfully mitigated the issue for the remainder of the event.
- Scheduled maintenance for the systems should be completed prior to event execution. Specifically, the filter cleaning with chlorine when the system has not been operated for 7 days.

Observer Feedback

- All Soldiers were engaging in the briefs and had lots of questions regarding operation and environmental considerations.
- Both COL and SGT MAJ seemed very interested about the equipment and expressed their gratitude for us participating in AS16.

March 16th: On the final day of the AS16 water TD, the TEC team successfully performed two backwash scenarios based off the new procedure developed by the team. The team also developed and tested a new procedure for long term storage shutdown, and measured the amount of water needed to complete this process. The team also provided demonstrations and briefs for the Commanding General, 8th Theater Sustainment Command, United States Army Pacific- MG General Dorman, Office of Defense Cooperation representative – US Embassy, and other high ranking Cambodian and U.S. Army Warfighters. Finally, the team provided a video interview to the U.S. Army AS16 Public Affairs Office (PAO) for use in the AS16 highlight video.

Water Testing
No water testing was conducted on the final day of AS16 operations.

Reliability and Maintenance
The First Response 5000 was cleaned, dissembled, and dried in preparation for shipment. No other reliability or maintenance issues were recorded.

SME Feedback

- Developed and tested a new procedure for long term storage shutdown. Also measured the amount of water needed to complete this process.
  - Using a 50 gal drum of clean chlorinated water, perform a closed loop wash through.
  - Use the same clean water for final backwash at final closeout
  - Follow standard process for long term storage
  - Dried pumps and filters.

Observer Feedback

- Discussed MG Dorman's goals of having closer ties between experimentation and assessment groups and the emergency relief Military units eg: TEC support during Typhoon Haiyan in Philippines
- The General was very interested in potential reduction of logistic support with regards to power and water. He actively engaged in the review of every technology and spent a total of 30 minutes at our test site.

March 17th: Primary operations were finished on March 16th. However, the TEC team returned to the testing site on March 17th to check the water test samples taken and tested on the 15th. The test required a 48-hour incubation period. The plain source water, and the source water with two drops of Nano colloidal silver (SilverDYNE) showed positive signs of bacteria presence. The source water with two drops of chlorine, the filtered water containing chlorine and the filtered water containing the SilverDYNE were all negative in the presence of bacteria.

Table 31: Water Sample Test Results

Test Sample	Result
Source Water	Turned positive on presence of bacteria after 24hours.
Source Water + 2 Drops Chlorine	Turned negative for presence of bacteria after 48 hours
Source Water + 2 Drops SilverDYNE	Turned positive for presence of bacteria after 48 hours
Purified Water + 5PPM Chlorine	Turned negative for presence of bacteria
Purified Water + SilverDYNE	Turned negative for presence of bacteria. Result is inconclusive because the bacteria was likely eliminated by the First Response Ultra filtration.

SME Feedback

Based on the limited water testing conducted during AS16 the TEC SMEs concluded that the SilverDYNE technology requires more testing to confirm its ability to purify contaminated source water. The two drops used in the small amount of source water that returned a positive result for bacteria, should have purified a significantly larger amount of water. The water filtered through the First Response, and then treated with SilverDYNE that did not result in the presence of bacteria was likely the result of the First Response filtration. However, more rigorous testing must be conducted to support these observations.

Figure 15: Water Sample Test Results

SME Survey Feedback

The following provides a summary of responses to survey questions about the technologies that participated in the AS16 water demonstration event. Responses were taken directly from SME surveys with only minor grammatical modifications. The two SMEs surveyed have conducted numerous test events for various water purification and renewable energy technologies. All responses should be considered within the limited demonstration and testing parameters discussed in this report.

1. **Please provide your overall impressions of the First Response system.**

   Response 1: Except for one pump, the First Response WPS performed with no maintenance issues. The maintenance procedure for the First Response needs to be modified. The instructions were missing some steps needed to complete the backwash**.**

   Response 2: The First Response 5000 Gallon per day (GPD) system worked as intended. We only used the 5000 GPD because one of the pumps was not operational. The 1000 GPD system was not used because of the bad pump. Set up was very easy and intuitive. Maintenance (back washing the system) was a bit confusing. The First Response Manual was not clear on when to turn on and off the pump during the backwash process. The team took notes and will work on updating the manual for future events. NOTE: This could be because the pump is supposed to automatically shut off at during specific phases of the backwash process.

2. **Please provide your overall impressions of the First Response system using the chlorine additive.**

   Response 1: The purified water with chlorine additive was negative on presence of bacteria.

   Response 2: Chlorine worked great. No issues.

3. **Please provide your overall impressions of the First Response system using the chlorine additive versus the SilverDYNE additive.**

   Response 1: The purified water using SilverDYNE additive was also negative on presence of bacteria. Based on the test conducted, chlorine presence is detected by smell and taste while the SilverDYNE has no test and smell.

   Response 2: SilverDYNE had a dark color to it. The amount of SilverDYNE needed to be added to the feed tank was unknown. Per the bacteria tests it would not have made a difference.

4. **Please provide your overall impressions of the SilverDYNE additive.**

   Response 1: Based on the testing, the SilverDYNE did not work on killing bacteria as claimed by the SilverDYNE company. Recommendation: More comprehensive testing for bacteria presence is needed in a laboratory environment.

Response 2: The team conducted bacteria testing on the source water at AS16. The test took 48 hours to complete. Once completed the bottle with SilverDYNE tested positive for bacteria. Based off the instructions on the bottle we should have seen no presence of bacteria. The amount of SilverDYNE added to the test bottle should have been enough to treat 1liter of water. The test bottles are approx. 30 ml. Based on the testing conducted at AS16, SilverDYNE did not kill bacteria as claimed by the SilverDYNE company. SilverDYNE needs to be tested and verified by an independent lab before using in a future experiment.

Water Purification TD Summary

The AS16 IWPS technology demonstration was conducted under expeditionary conditions, in the Kingdom of Cambodia from 12-17 March, 2016. The First Response served as the central technology for extracting and dispersing the source and product water during the demonstration. SilverDYNE, a water purification additive, was demonstrated as an alternative to the use of chlorine in source and product water.

The TEC team utilized a nearby pond for source water during the demonstration. The pond was approx. 3ft. deep with high sediment, turbidity, and bacteria levels. Contamination sources included, but were not limited to, laundry and local animals. A total of 6 types of samples were tested during the event. Samples were taken from the source water and tests conducted on the source water, the unfiltered source water using chlorine and SilverDYNE additives, source water filtered with the First Response with no additive, source water filtered with First Response using the chlorine additive, and source water filtered with First Response using the SilverDYNE additive. The TEC team conducted 3 TDS tests and 1 Chlorine test. These tests were conducted using a handheld TDS reader and a standard, commercial off the shelf, water treatment test kit. The source and treated water both fell within an acceptable range for TDS. With the maximum allowable TDS being 500 ppm. The chlorine results reflected expected ppm, and fell within an acceptable range. Additional water testing included several parameters such as the presence of lead, pesticides, iron, hardness, etc. Testing for the presence of bacteria required a 48-hour period. The results showed that the source water and unfiltered source water with SilverDYNE additive both tested positive for the presence of bacteria. Thus, TEC SMEs recommend additional field and/or laboratory testing of the SilverDYNE additive. The First Response performed as expected and was a valuable core technology for conducting the demonstration.

Overall the AS16 water purification technology demonstration was a successful event. TEC SMEs demonstrated valuable water purification technologies in an expeditionary environment to Cambodian and U.S. Soldiers. Visitors were very impressed by the technologies and expressed a desire to have the TEC team return to future AS events to provide additional technology demonstrations, assessments, and warfighter capabilities.

RENEWABLE ENERGY AND POWER MANAGEMENT (RE/PM) TECHNOLOGY DEMONSTRATION (TD)

The TEC conducted demonstrations and static displays of the STAESS, REAL, SPM-622, and eMUBC technologies under expeditionary conditions, during AS16 in the Kingdom of Cambodia from 12-17 March, 2016. This demonstration was conducted as part of the Integrated Water Purification System (IWPS) project. Observations and feedback collected during AS16 will help inform future IWPS porotypes. The RE/PM TD was conducted at the Training Center for Multinational Peacekeeping Forces, Peace Keeping Operation base, Kampong Speu Province, Cambodia.

The STAESS technology provided power to support the First Response 5000 during all water TD operations. REAL provided area lighting and power for small handheld electronic devices throughout the TD. SSG Rose, AS16 operations cell, was trained on and used the SPM-622 to help support operations during AS16. The TEC team and briefed and provided a static display for the eMUBC throughout the AS16 main operating window.

RE/PM TD Technologies

The following section provides a more detailed summary of the STAESS, REAL, SPM-622, and eMUBC technologies' capabilities, that participated in the IWPS RE/PM demonstration, along with technology specifications where available.

Soldier Transportable Alternative Energy Storage System (STAESS)
The STAESS consists of efficient foldable photo-voltaic panels and battery packs to provide power. The STAESS is a soldier-portable, rapid-charging photo-voltaic renewable energy system that is modular and expandable to allow for simple set up, transport, and easy operation. The size, efficiency, and power output vary depending on the configuration of modules.

Table 32: STAESS System Specifications and Benefits

System Specifications	System Benefits	
32 STORM modules (4kW) *The setup used during RIMPAC 2014 only included 24 panels	Easily deployable & transportable	 
24 volt DC (100Ah) battery pack x 4	High energy density, high power, minimal weight	
24 volt DC (200Ah) battery pack	Reduces threat of Improvised Electronic Devices (IED) to fuel supply convoys	
4000 watt inverter	Sustained life expectancy of battery technology	
Interface: 220/120 VAC, 24/12/5 VDC	Rapid battery charging	
MPPT 6kW capacity charge controllers	Modular design for scalability of power demand	
36kWh System (assuming full sun) allows for 1,500W per hour x 24		

The Renewable Energy Area Lights (REAL)

REAL is a solar powered Light Emitting Diode (LED) lighting system that comes in two sizes the REAL Small and the REAL Large. The REAL system is designed to work off of various power sources, including solar. These systems can be used to light a small tented area, or a football field sized FOB. Additionally, the systems include USB ports for charging phones and other auxiliary devices.

Figure 16: REAL Small Kit

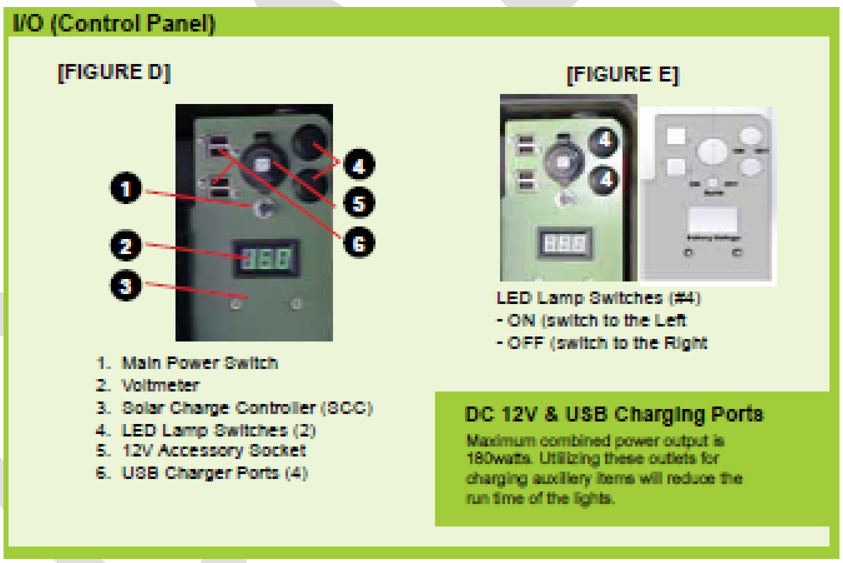


Figure 17: REAL Small I/O Control Panel

Table 33: REAL Small Parts Inventory

Number Included	Parts Inventory
1	Main charging case (built in charging, storage, and management system
2	STORM 140 solar modules
1	Solar Cable Harness
1	Tripod Base and Post
1	Lamp Set (2) w/Cable
1	AC Charger

Squad Power Manager 622 (SPM-622)

The SPM-622 unique system design combines leading edge advances in ultra-high efficiency power conversion, equipment power management, and energy harvesting technology in one product to offer benefits available nowhere else. The SPM system design offers a lightweight, compact, and rugged intelligent power management solution designed to withstand the harsh operating conditions of military field use. This unit directly powers virtually any man-packable military equipment, recharges a squad's batteries, and intelligently adjusts to changing mission conditions or requirements.

Figure 18: SPM-622

Table 34: SPM-622 Technical Specifications

PHYSICAL		INPUT/OUTPUT	
Size	1.25h x 4.4w x 3d in.	**Port Max Power**	150 W, 300 W
Weight	.9lbs.	**Port Max Current**	10 Amps
Color	Desert Sand	**Battery Voltage**	9-34 VDC, 12-28 V Nominal
Op Temp	-40 to 60 degrees C	**Port Protection**	Over-voltage, Over-current, Short-circuit, Reverse Polarity, Surge, EMI
# of Ports	Six Bi-directional	**Protection Reset**	Automatic Self-reset
Port Voltage	3-34 VDC	**Data Interface**	USB 1.0 Port
BATTERY		**ENERGY HARVESTING**	
Simultaneous Charge	Up to 3 batteries	**Harvester Ports**	Up to 2
Sequential Charge	Up to 5 batteries	**Harvest Range**	4-34 VDC
Military Support	BB-2590, BB2557, Li-80, Li-145, 28V Vehicle, Conformal Bat.	**Solar Algorithm**	Peak Power Point Tracking Fully Automatic
Commercial Support	AA, AAA, RCR-123, 12V Vehicle	**Primary Battery Harvesting**	Current Limited, Fully Automatic
Smart Charging	SMBus 1.1 and SMBus 2.0 Support, All Ports	**Fuel Cell Interface/Control**	Automatic
USER INTERFACE			
Port Charge/Status Indicator	Graphic display of all power levels & remaining mission time	**Control Keypad**	Up, Down, Enter, and Escape buttons

Expeditionary Modular Universal Battery Charger (eMUBC)

eMUBC solution is a scalable charging system that charges a wide range of military and commercial batteries, and provides for the addition of new batteries through software upgradability and an innovative modular design. The base unit weighs approximately 6 pounds, is small enough to be carried in a ruck sack, and is rugged enough to be vehicle mounted. Multiple eMUBC charging systems can be cascaded without requiring any tools. This system is based on technology from field-proven trials, and allows charging in heavy rain, and other harsh environmental conditions, without cover. The charger is optimized to provide the warfighter with the ability to harvest power from solar panels, and scavenge power from batteries (cable-free) and a variety of other power sources. The eMUBC combines the functions and capabilities of multiple battery chargers into one small, scalable package. It provides battery charging technology to the warfighter through a highly rugged, field-deployable, multi-battery modular solution for austere mission environments. The eMUBC has a built-in battery test/analyzer function that allows the user to display the “health” of batteries in a matter of seconds.

Figure 19: eMUBC

Table 35: eMUBC Technical Specifications

PARAMETER	PERFORMANCE
Simultaneous charging	8 batteries and 4 USB devices
Expandability	Multiple units can be connected from a single power source
Modularity	User configurable cups allow custom configurations (no tools)
Maximum Charge Power (per bay)	40W
Total INPUT Power	270W Typical
Input DC Voltage Range	10-33.6 VDC
Input DC Robustness	MIL-STD-1275D
Input AC Voltage Range	90-265 VAC
Input AC Robustness	MIL-STD-704F
Electrostatic Discharge	EC-61000-4-2
Chemistries	Lithium-ion, NiCad, NiMH
Smart Charging Protocols	Smart Battery Bus, DQ
Power Modes	SOLAR and Maximum power
Power Harvesting	Solar, external DC power sources such as BA-5390
Display	Multi-color LED display
Typical Charge Time	8 Rifleman batteries in < 3 hours, and 6 CWB-150 in 5 hours

Location

The RE/PM demonstration site was collocated with the water TD site during AS16. Operations were setup 50ft. from a pond located inside of the UN PKO base. This pond was identified as the only natural source water available for purifying in the area. The pond is located near an old water purification facility that no longer operates. Thus, 10 truckloads of water were delivered daily to support AS16 operations. This water was housed in a reservoir near the treatment facility.

Figure 20: RE/PM Site Location

Figure 21: RE/PM TD Site Panoramic

Schedule

The following table provides a summary of the AS16 water TD events.

Table 36: AS16 Water TD Events

Date	Event(s)
3/7/16	Cargo inventoried and pulled for support of the Science and Engineering Festival
3/9-3/10/16	Static display at the Science and Engineering Festival
3/11/16	Transport to AS16 location
3/12/16	Inspected, inventoried, and staged equipment for AS16 operations
3/13-3/16/16	Main Operations

Demonstration Support Summary

The following section provides a summary of the RE/PM TD main operations.

Upon completion of support for the Cambodian Science and Engineering Festival the TEC team arranged transport of all technologies to the AS16 RE/PM TD site on March 11, 2016. Capt. Clack and SSG Nixon provided a tour the areas around the site including an old water purification facility. On March 12th, the team inspected, inventoried, and staged all equipment to help expedite setup and operations the following day. The STAESS, REAL, and SPM-622 technologies demonstrations were conducted from March 14-16, 2016. The eMUBC was setup as a static display in the main TEC operating area throughout the demonstration.

March 14th: The TEC team successfully deployed the STAESS, REAL, and SPM-622 technologies for demonstration beginning on March 14, 2016. The eMUBC was setup as a static display in the main TEC operating area and briefed to visitors as needed. The STAESS was deployed to provide power for the First Response 5000 testing. After setup the system operated for 2.5 hours, providing 4kw of solar power run time. The REAL was deployed with one 140W solar panel and used to charge small hand held devices. REAL was used to light the test area overnight. Power usage by the system was recorded the following morning. The TEC team trained SSG Rose, AS16 operations cell, was trained on the SPM-622. SSG Rose took the SPM-622 technology to help support AS16 battery charging requirements during the demonstration period. Technology briefs and demonstrations were provided to visitors as needed throughout the day.

Power Summary

Table 37: Power Summary March 14.

<table>
<tr><th>Technology</th><th>Consumed</th><th>Inverter DC input</th><th>Total</th></tr>
<tr><td>STAESS</td><td>775 Whrs at the inverter output</td><td>29.1 VDC @ 38 amps (2 12V car batteries in series)</td><td>Total 1,941Whrs at inverter output</td></tr>
<tr><th>Technology</th><th colspan="2">Power Consumption</th><th>Hours of Operation</th></tr>
<tr><td>REAL</td><td colspan="2">70W provided to internal battery</td><td>Approx. 4 hrs.</td></tr>
</table>

Reliability and Maintenance

There were free range cattle in the area that posed a risk to the equipment, especially the solar panels deployed for each technology. Luckily no equipment was damaged during the event.

Feedback

TEC SMEs suggested possibly reducing the size of the charge controllers on the STAESS. They also noted that the inverters provide more capabilities than the 4kw STAESS needs. SSG Rose was very excited to learn about the SPM-622 and thinks it will be useful supporting the Ops cell.

Figure 22: STAESS Brief to MAJ Gipson (left) Roaming Cattle (middle) and SPM-622 Training (right)

March 15th: The STAESS was deployed to provide power for the First Response 5000 testing. After setup the system operated for 4.5 hours, providing 4kw of solar power run time. The REAL was deployed with one 140W solar panel and used to charge small hand held devices. The REAL was used to light the test site overnight, using one light. The voltage remaining at 8:30 a.m. indicated approx. 50% power remaining. A comparison of the 120W amorphous silicon (a-Si) solar panel to the 140W monocrystalline silicon (Mono c-Si) was conducted to note any major differences in capability. SSG Rose continued using the SPM-622 technology to help support AS16 battery charging requirements during the demonstration period. The TEC team provided demonstrations and briefs to ten Royal Cambodian Army personnel and five U.S. Army Soldiers.

Table 38: Solar Panel Specification

STORM 140W Panel	PowerFilm 120W Panel
140 Watts 5.98 amps@23.5 volts 62.25 Length X 23.75 Width 7.0 Lbs 13.65 watts per sq ft 20 watts per LB	120W 7.2 amps @15.4V 86" Length x 55" Width 6.7 lbs

Power Summary

The TEC team noted cloudy weather conditions for the majority of the day.

Table 39: Power Summary March 15.

Technology	Consumed	Inverter DC input	Total
STAESS	775 Whrs at the inverter output	29.1 VDC @ 35 amps (2 12V car batteries in series)	Total 3,640Whrs at inverter output
Technology	**Power Consumption**		**Hours of Operation**
REAL	70W provided to internal battery		Approx. 4.5 hrs.

Table 40: STAESS Detailed Power Consumption Log March 15.

Time	Irradiance	STAESS Amps/Volts Charging	STAESS Inverter Amps/Volts/Watts Delivered	REAL (lighting) input Watts/Battery Voltage
9:00	333	3.4/27.1	35/27.2/782	31.3/15.7
9:45	415	8.9/29.0	35/29.0/780	48.8/15.6
10:15	700	8.0/29.0	35/29.0/770	61/16.2
11:00	830	Full Charge/29.1	35/29.1/771	68/16.4
11:30	920	Full Charge/29.1	35/29.1/760	40/16.3
12:00	935	Full Charge/29.1	35/29.1/755	41/16.4
12:30	380	Full Charge/29.1	35/29.1/760	29/16.4
13:00	450	Full Charge/29.0	35/29.0/783	30/16.4

Reliability and Maintenance

Nothing significant to report.

Feedback

The TEC team noted that all of the soldiers were very engaged with the briefs and demonstrations. They asked many operational and environmentally focused questions. Some visitors were interested in how they could purchase the SPM-622 using unit funds, or if the technology will be fielded soon.

The comparison of the a-Si and Mono c-Si solar panels resulted in the TEC SMEs noting that the both panels produced power per individual specs. The only notable difference between the technologies was area, weight, and flexibility.

Figure 23: Brief to COL Albert, Bn Commadar (left) Brief and Demo Translated to Cambodian Soldiers (middle) Solar Panel Size Comparison (right)

March 16th: The STAESS was deployed to provide power for the First Response 5000 testing. After setup, the system operated for 3 hours, providing 4kw of solar power run time. The system also provided power for laptops, and other small electronic devices. The REAL was deployed with one 140W solar panel and used to charge small hand held devices. The REAL was used to light the test site overnight, using one light. The voltage remaining at 8:30 a.m. indicated approx. 70% power remaining. A comparison of the 120W a-Si solar panel to the 140W Mono c-Si was conducted to note any major differences in capability. SSG Rose returned the SPM-622 technology and completed a user survey and demographics form. The TEC team and SSG Rose provided demonstrations and briefs VIPs.

Power Summary

Table 41: Power Summary March 15.

Technology	Consumed	Inverter DC input	Total
STAESS	775 Whrs at the inverter output	29.1 VDC @ 35 amps (2 12V car batteries in series)	Total 1,923Whrs at inverter output
Technology	**Power Consumption**	**Hours of Operation**	
REAL	70W provided to internal battery	Approx. 3 hrs.	

Table 42: STAESS Detailed Power Consumption Log March 16.

Time	Irradiance	STAESS Amps/Volts Charging	STAESS Inverter Amps/Volts/Watts Delivered	REAL (lighting) input Watts/Battery Voltage
9:00	283	5.5/25	35/25.7/795	24/15.6
9:30	243	5/24.8	35/24.8/814	19.5/15.5
10:00	673	4.7/29	35/29/788	32/16
10:30	714	Full Charge/29.2	35/29.2/783	57/16.2
11:15	825	Full Charge/29.2	35/29.2/766	59/16.4

Reliability and Maintenance

Nothing significant to report.

Feedback

The TEC team noted that all of the visitors were very engaged with the briefs and demonstrations. The General was familiar with the eMUBC program and was very interested in all the participating technologies. The TEC SMEs noted quite a few water bottles in one of the many burn piles used to dispose of trash. With a good water purification system, many of these bottles could be eliminated.

Figure 24: MG Dorman SPM-622 Demo (left) SSG Rose Briefing SPM-622 (middle) Burn Pile (right)

STAESS and REAL SME Survey Feedback

The following provides a summary of responses to survey questions about the technologies that participated in the AS16 power demonstration event. Responses are taken directly from SME surveys with only minor grammatical modifications. The SMEs surveyed have conducted numerous test events for various water purification and renewable energy technologies. All responses should be considered within the limited demonstration and testing parameters discussed in this report.

1. **Please provide your overall impressions of the STAESS operations during AS16.**

   Response 1: STAESS used during Angkor Sentinel 16 was developed 5 years ago and was assessed and tested previously during major military training and exercises. This technology was also used during numerous disaster relief events in the Philippines. STAESS normally will use Lithium Ion Batteries for storage of energy collected to use the stored energy at night when sun is no longer available. Shipping of Lithium Ion batteries was an issue within the Pacific Region. No airline will accept transport of Lithium Ion batteries from Manila, Philippines to Phnom Penh, Cambodia, so the STAESS set was shipped to Cambodia less the lithium ion battery package. Upon arrival in Phnom Penh, the TEC team purchased two (2) 12 Volts car batteries as substitute for the Lithium Ion batteries. Two car batteries were need to make it 24 volts (in series) which is the requirement for the STAESS to operate. The new concept of using car batteries was tested during the Science and Engineering Festival, and proved to be effective as the lithium batteries, but car batteries do not store more energy and do not charge as fast as lithium ion batteries. During the execution of Angkor Sentinel 16, the STAESS was used to power up the First Response 5000 GPD capacity which requires 750 watts of electricity. With 100 percent sun available the STAESS produces 4000 watts of electricity enough to support five (5) First Response WPSs. At one time, it was cloudy and the sun availability was at 28%, the STEASS was still able to provide power requirements to the First Response WPS. During the AS16 VIP day, MGen Doorman (8th Theater Support Command Commander) was impressed with the STAESS performance (unlike a generator, the STAESS is silent, no oil or fuel required to operate).

   Response 2: STAESS provided 100% of all the power needed to operate the First Response during the entire AS16. Even with low solar radiance in the morning the 4 KW solar panels produced enough energy to run the First Response with surplus energy to charge the 24 V battery bank. Deployment of the STAESS took less than 15 minutes. It should also be noted that the STAESS operated without the Lithium Iron Phosphate batteries that is part of the system package, instead we purchased locally 70 AH 12 V car batteries. We connected 2 of the 12 V car batteries to get the 24 V needed to operate the STAESS.

   Response 3: The STAESS worked great. It is very modular and scalable. We used it in a 4kw set up. We did not need that much power but for demonstration purposes it was good to show the potential of the system. We used batteries from the local economy as the battery buffer. I thought this showed great modularity for the system. There were no issues with the STAESS during operation.

2. **Please provide your overall impressions of the REAL operations during AS16.**

   Response 1: The Small REAL was demonstrated during the Science and Engineering Festival. There were thousands of visitors (mostly students) during the events and most visitors were interested in the Small REAL performance. The Small REAL was used during Angkor Sentinel 16 at the UN PKO Base Pond as a security light in the area when the TEC team departed.

Response 2: REAL was deployed at AS16 to show and demonstrate the operation and performance of the LED lighting system. Since we were not at the AS16 sight during the day we made sure we turned on 1 of the LED light before we departed around 3 PM. The 1 LED light would have illuminated the awning and surrounding area but we were not present to witness this. We only had 1 of the 140 watt solar panels deployed because we did not have the proper cable to connect 2 solar panels. With only 1 solar panel we were able to operate 1 LED light from 3 PM continuously until we returned the next day by 8:30 AM. To assess the performance of the REAL we measured the REAL battery voltage when we arrived in the morning, battery voltage was consistent at 15 volts that indicated there was still over 60% battery capacity remaining. Deploying the REAL took less than 10 minutes.

Response 3: During the Science and Engineering Festival the small REAL system was displayed and discussed to students as they came by in groups. There was general interest in the solar technology. The team explained to the students how the system worked and operated off solar. The Small REAL performed as expected during the Angkor Sentinel 16 at the UN PKO Base Pond (location of the TEC technology demonstration and assessment) and was used as security light in the area when the TEC team departs. This small portable system is a great asset to have during emergency relief missions as well as during combat. The team discussed possible improvements, which would include using standard military batteries.

SPM-622 User Survey Feedback

The following provides a summary of responses to survey questions about the technologies that participated in the AS16 power demonstration event. Due to the limited time, and manpower restrictions, only SSG Rose provided feedback on the SPM-622. Responses are taken directly from the user survey with only minor grammatical modifications.

1. Please provide your overall impressions of the SPM system.
    - Small, lightweight, easy to use

2. Please provide your overall impressions of the 100W solar panel used with the SPM system.
    - The 100W solar panel was extremely light weight and durable, easy to fold up

3. Please provide details of how you deployed the system.
    - It was used to charge phones, batteries, and power a fan at night

4. It was easy to move the system across the terrain.
    - Completely Agree

5. SPM was easy to setup and install.
    - Completely Agree

6. SPM was easy to operate.

- Completely Agree

7. I felt confident operating the system on my own after the training.
    - Completely Agree

8. What did you dislike about the SPM capability?
    - None, the system worked excellent

9. What improvements do you recommend?
    - None, the system worked excellent

10. Would you deploy with this system?
    - Yes

Power Summary

The AS16 STAESS, REAL, SPM-622, and eMUBC technology demonstration was conducted under expeditionary conditions, during AS16 in the Kingdom of Cambodia from 12-17 March, 2016. The STAESS served as the central technology for powering the First Response technology during the demonstration. REAL provided area lighting security and power for charging small electronics throughout the event. The SPM-622 was provided to U.S. Army personnel and used to provide power to support operations. The eMUBS was setup as a static display for visitors throughout the event.

The STAESS successfully provided all power required to operate the First Response technology. The system provided 4kw of solar power run time. The REAL was deployed with one 140W solar panel that successfully powered the light overnight to provide area security. Power usage by the system was recorded the following morning and reflected a significant excess. The TEC team trained an AS16 operations cell member who took the SPM-622 technology to help support AS16 battery charging requirements during the demonstration period. Additionally, a comparison of two solar panel technologies was conducted with each technology performing as expected. The defining element was the notable difference in size of the two technologies. No major issues were encountered during the RE/PM TD. All the technologies performed as expected and successfully supported the event.

Overall the AS16 RE/PM TD was an effective event. TEC SMEs demonstrated valuable RE/PM technologies in an expeditionary environment to Cambodian soldiers and demonstrate and collect feedback from U.S. Soldiers. Visitors were very impressed by the technologies and expressed a desire to have the TEC team return to future AS events to provide additional technology demonstrations, assessments, and warfighter capabilities.

ANNEX B: IWPS CV16 REPORT

CRIMSON VIPER 2016

INTEGRATED WATER PURIFICATION SYSTEM (IWPS) ASSESSMENT

AUGUST-SEPTEMBER 2016

SARABURI, THAILAND

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November 2016

This report provides information on the IWPS technology assessment conducted during Crimson Viper 2016. This document provides a summary of activities and observations gathered by the Technology Experimentation Center (TEC) and does not represent the formal position of the U.S. Pacific Command or the Department of the Navy.

Shujie Chang, P.E.
Director, TEC

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ACRONYMS

AS16	Angkor Sentinel 2016
CDRUSPACOM	Commander, U.S. Pacific Command
COI	Critical Operating Issue
CONOP	Concept of Operations
CV	Crimson Viper 2016
DoD	Department of Defense
DPD	N,N Diethyl-1,4 Phenylenediamine Sulfate
DST	Defined Substrate Technology
DSTD	Defence Science and Technology Department
EPA	Environmental Protection Agency
FAC	Free Available Chlorine
FR	First Response
FOB	Forward Operating Base
HA/DR	Humanitarian Assistance / Disaster Relief
IED	Improvised Explosive Device
IWP	Individual Water Purifier
IWPS	Integrated Water Purification System
J85	Science and Technology Office
JOC	Joint Operations Center
LI	Lithium-ion
MILAIR	Military Air
MOE	Measure of Effectiveness
MOD	Ministry of Defence
MOS	Measure of Suitability
MPH	miles per hour
MUG	4-methylumbelliferyl-beta-D-glucuronide
N/A	Not Applicable
NAVAIR	Naval Air Systems Command
NSF	National Sanitation Foundation
ONPG	ortho-Nitrophenyl-β-galactoside
OSHA	Occupational Safety and Health Administration
RCA	Royal Cambodian Army
RTA	Royal Thai Army
SGI	Small Group Instruction
SME	Subject Matter Expert
SPM	Squad Power Manager
S&T	Science and Technology
STAESS	Soldier Transportable Alternative Energy Storage System
SUV	Small Utility Vehicle
SUWP	Small Unit Water Purification
TAC	Thai-American Consultations
TDS	Total Dissolved Solids
TEC	Technology Experimentation Center
TSP	Training Support Package
TTP	Tactics, Techniques, and Procedures

UF	Ultra-filtration
USPACOM	U.S. Pacific Command
TD	Technology Demonstration
TDS	Total Dissolved Solids
VIP	Very Important Person
WPS	Water Purification System

UNITS OF MEASURE

AC	Alternating Current
Ah	ampere hour
Amps	amperage
C	Celsius
cu ft	cubic feet
DC	Direct Current
F	Fahrenheit
ft.	feet
gal	gallons
GPD	gallons per day
gtts	drops
hrs	hours
Hz	hertz
in.	inches
kg	killogram
kW	kilowatt
l	liter
lbs.	pounds
min	minute
mg	milligram
ml	milliliters
mm	millimeter
NTU	Nephelometric Turbidity Unit
oz	ounces
pH	potential for hydrogen
ppb	parts per billion
ppm	parts per million
sq ft	square foot
V	volts
VAC	Voltage AC
VDC	Voltage DC
W	watts
Whrs	watt hours

EXECUTIVE SUMMARY

Crimson Viper (CV16) served as an experimentation venue for the Integrated Water Purification System (IWPS) prototype. The IWPS project was developed to support multiple missions, to include support in austere forward operating bases (FOB) and humanitarian assistance and disaster response (HA/DR). The project specifically seeks to integrate advanced pre-filtration and ultra-filtration membrane technology along with a nanoparticle colloidal silver injector to produce two water purification prototypes with 1000 and 5000 gallon/day capacity using renewable energy to power high efficiency/low maintenance pumping systems.

The Crimson Viper Field Experiment is conducted annually between the Royal Thai Ministry of Defence (MOD) Defence Science and Technology Department (DSTD) and TEC as the executive agent for US Pacific Command Science and Technology Office (USPACOM J85). Crimson Viper 2016 was executed under the ambit of the Thai-American Consultations (TAC) Joint Statement. The purpose of technology experimentation in Crimson Viper 2016 (CV16) was to experiment with leading edge technologies and proposed Concepts of Operation (CONOP) in relevant operational conditions to gather operational data feedback. Additionally, CV16 provided engagement opportunities with Royal Thai Army (RTA) partners. This report covers the Technology Experimentation Center (TEC) activities from August 29-9 September, 2016.

CV16 field experimentation was conducted from August 29-9 September at Fort Adisorn, Calvary Center, Saraburi, Thailand. The IWPS experimentation event assessed and integrated four Water Purification Systems (WPS), two water purification additives, and three energy technologies. The technologies included the First Response (FR), Modus, Guardian, and Roving Blue WPSs, the SilverDYNE and O-Pen additive technologies, and the Soldier Transportable Alternative Energy Storage System (STAESS), Squad Power Manager (SPM), and 1 kW generator.

To assess the utility of the water purification technologies, in relation to IWPS objectives, the TEC developed three Critical Operational Issues (COIs). These COIs focused on potable drinking water, transportability, and renewable energy. Ninety-one total water samples were collected and tested in a field environment during CV16. The samples were tested under three major testing categories; initial testing, contamination testing, and storage testing. The First Response and Modus appeared to show the most promise for meeting the IWPS project objectives. Both systems can produce an adequate amount of product water, and are relatively easy to transport. Both systems did have maintenance issues that impacted overall performance during the event. The issues are being reviewed by the technology developers and should be addressed prior to any future events. The First Response and Modus water sample data showed promise for these systems to effectively purify highly turbid and contaminated source water. It is recommended that additional tests be conducted with the First Response and Modus technologies. The Roving Blue WPS demonstrated promise during initial testing, but the system is unable to produce the threshold level of product water of 1,000 gallons per day. The O-Pen and SilverDYNE additives did not appear to provide any additional value to the product water of the WPSs, and were unable to treat source water on their own. The STAESS and SPM technologies successfully integrated with and supported the WPS power requirements and should be included in future tests.

Overall, the IWPS test event during CV16 was a success. The TEC team identified and mitigated a number of limitations that occurred in the field and successfully collected valuable data on 9 total technologies. The data collected, and the lessons learned, during CV16 will help shape the IWPS prototype and future IWPS project test events.

INTRODUCTION

Purpose

Experimentation conducted during CV16 supported the Integrated Water Purification System (IWPS) project objectives. The purpose of technology experimentation in Crimson Viper 2016 (CV16) was to experiment with leading edge technologies and proposed Concepts of Operation (CONOP) in relevant operational conditions to gather operational data feedback. Additionally, CV16 provided engagement opportunities with Royal Thai Army (RTA) partners. This report covers the Technology Experimentation Center (TEC) activities from August 29-9 September, 2016.

Background

IWPS is a TEC led project, sponsored by the Office of the Secretary of Defense (OSD), Rapid Reaction Technology Office (RRTO). The TEC is a U.S. Government network of technology and operational community subject matter experts working together to enable the warfighter by conducting technology demonstrations, experiments, and assessments in relevant operational venues and environments. . The TEC is responsible for coordinating and executing all aspects of the IWPS project to include prototype design, assessment, logistics, demonstration, experimentation, feedback collection, and reporting. RRTO develops risk-reducing prototypes and demonstrations of land, sea, and air systems that address mission-focused combatant command, joint-Service, and interagency capability needs to counter emerging threats and provide a hedge against technical uncertainty. RRTO provides the flexibility to respond to emergent Defense Department needs and address technology surprises within the years of execution and outside the two-year budget cycle, enabling the fielding of solutions to time-sensitive problems. RRTO is the IWPS project sponsor.

The IWPS project was developed to support multiple missions, to include support in austere forward operating bases (FOB) and humanitarian assistance and disaster response (HA/DR). The project specifically seeks to integrate advanced pre-filtration and ultra-filtration membrane technology along with a nanoparticle colloidal silver injector to produce two water purification prototypes with 1000 and 5000 gallon/day capacity using renewable energy to power high efficiency/low maintenance pumping systems.

The integration of the technologies should provide an odorless and tasteless long lasting cleansing effect, which allows the water to maintain purity even if it is passed to bacteria filled containers. The TEC team will test and assess different parameters to determine if the objectives are achievable including; technical performance, interoperability, and operational environment performance. Testing in the CV16 venue provides an opportunity to continue data collection, in an operationally relevant environment, to help inform the direction of the IWPS project going forward.

The Crimson Viper Field Experiment is conducted annually between the Royal Thai Ministry of Defence (MOD) Defence Science and Technology Department (DSTD) and U.S. Pacific Command Science and Technology Office (USPACOM J85). Crimson Viper is executed under the ambit of the Thai-American Consultations (TAC) Joint Statement. Crimson Viper was discussed during TAC XVI on 9-11 April 2014 under Working Group IV for “Relationship

Building, Coordination and Collaboration at All Levels" under subgroup IV.2 for Science and Technology.

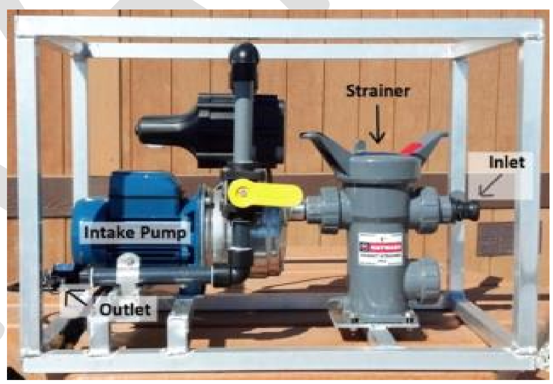
Crimson Viper objectives are to experiment with candidate technologies in a field environment to:

- Support collaboration and promote interoperability between Royal Thai Armed Forces and USPACOM via Science and Technology (S&T) partnership with DSTD
- Assess candidate technologies and provided assessment feedback to the science and technology community
- Confirm technology maturity prior to introducing to warfighters
- Provide candidate technologies for longer term assessment

Water Technology Description

The following section provides a brief description of each of the water technologies that participated in IWPS portion of CV16.

First-Response Freshwater Purifiers (1000 and 5000)
The First-Response systems have Superior Ultra-filtration (UF) membrane capability to remove all microorganisms and virtually all suspended solids and turbidity in one stage. The system includes a unique cleaning capability for the UF membrane that does not require power nor sophisticated instrumentation and control. **Capability**: Produces 1000 and 5000 gallons purified water per day. In addition, the system is easy to transport, set-up and train.



SilverDYNE Water Treatment
SilverDYNE® is a water compound, with a natural silver based, stable suspension, non-toxic, non-chemical and non-hazardous product, that when used as directed not only disinfect water, but can also extend the shelf life of most fruits and vegetables without any taste, odor, color, or toxicity. SilverDYNE® is unique because of the way it is engineered. It uses special clustering de-ionized water and engineering process that keeps the silver particles in suspension, for increased absorption and efficiency as well as guided particle direction for the elimination of bacteria. SilverDYNE® uses true natural silver consisting of both elemental and ionic particles providing the ultimate particle surface area and an extremely high efficiency index.

The Guardian is a single-pass purifier that utilizes ultrafiltration hollow-fiber membrane to remove a broad-range of microbial contaminants. The ergonomic, dual-action pump enables the Guardian™ to produce over 2 liters per minute with minimal user effort. Unlike conventional hollow fiber technology, these advanced medical-grade fibers block viruses, the tiniest waterborne microbiological threats. These fibers are also more durable than others. They're not damaged by freezing, and in the developer's water lab, the purifier withstood drop testing. On every stroke, the purifier uses 10% of its water to flush the contaminants in its filter back into the source. This means, you'll never hassle with backflushing or scrubbing cartridges to maintain its fast flow.

Guardian: Technology Specifications	
Criteria	**Product Specification**
Water Production	2.5 L/min. (150 L/hour)
Efficacy	*Viruses*: > 4 log reduction, *Bacteria*: > 6 log reduction, *Protozoa*: > 3 log reduction
Turbidity Effluent	<1.0 NTU
Filtration Capacity	*Tap Water:* > 10,000 L. *NSF P248 Water:* > 500 L.
Treatment Time	No dwell time required
Temperature Range	Freeze/Thaw resistant.
System Weight	16 oz.
Field Cleaning	Self-cleaning mechanism cleans filter with every pump stroke

The MSR Modus Group Water Purifier is a comprehensive water purification system designed to provide clean water for up to 50 warfighters for 30 days without re-supply. The Modus™ has both human and electric power options, and works effectively on a wide range of fresh water sources.
The filtration kit is built into a custom backpack for portability. The complete Small Unit Water Purification (SUWP) kit fits into a Pelican case for storage and transportation.

Modus : Technology Specifications	
Criteria	**Product Specification**
Water Production	*Electric Pump:* 4.5 L/min., *Manual pump:* 3 L/min., *Gravity:* 1 L/min.
Efficacy	*Viruses*: > 4 log reduction, *Bacteria*: > 6 log reduction, *Protozoa*: > 3 log reduction
Chemical Removal	Removes dissolved organics including VOC, pesticides, herbicides, and industrial solvents. Removes select heavy metals (lead, mercury).
Turbidity Effluent	< 0.1 NTU

System Capacity	> 15,000 liters. [With routine field cleaning].
Voltage	10V DC to 32 VDC or 80VAC to 240V AC. 50/60Hz
Chlorine Residual	Optional chlorine dosing system ensures a 2 mg/L chlorine residual for safe long term storage

The **Roving Blue Water Purification System** is a patent-pending system that utilizes the latest micro-ozone technology for highly effective microbiological control. No other portable water purification system offers all of these benefits: Triple Stage Mechanical Filtration, Dual Stage Biological Filtration: 100% National Sanitation Foundation (NSF) certified materials, No chemicals to buy, No waste water, Effective against dangerous micro-organisms, Eliminates bad tastes and smells, DC power source allows for use in off-grid camps, RV's and boats, Quiet operation, Long filter life and easy filter replacement: change filter every 1,200 gallons (4,542 Liters)

Roving Blue : Technology Specifications	
Criteria	**Product Specification**
Weight	Approx 25 lbs., 11.33 kg
Size	L 18.7" x W 14.8" x H 7" (L 475mm x W 376mm x H 178mm)
Output	Approx. 0.5 liter per minute
Ozone Residual	.1 to .4 mg/l * *.1 to .4mg/l represents FDA required ozone residual levels for bottled water

Roving Blue O-Pen IWP Pocket Water Purifier Lightweight, Individual Water Purifier (IWP) pocket water purifier designed to purify 250 ml (8 oz.) or 500 ml (16 oz.) of water in :30 or :60 seconds. Up to 30 uses per charge. (7.5 litres, or 1.8 gallons). Recharges in 30 minutes via USB. Superior to UV light systems; ozone does not require filtration to purify water. Output water carries cleansing capability. It may be used to sanitize bottles, bladders, etc. No additional chemicals required. Completely silent operation.

O-Pen : Technology Specifications	
Criteria	**Product Specification**
Weight	30 grams, or 1.58 ounces
Size	L 5 3/4” x W .5" x H .5”
Power	Rechargeable lithium-ion (LI) batteries
FDA, EPA, or NSF approved/compliant components	

Power Technology Description

The following section provides a brief description of each of the power technologies that participated in the IWPS portion of CV16.

Soldier Transportable Alternative Energy Storage System (STAESS)
The STAESS consists of efficient foldable photo-voltaic panels and battery packs to provide power. The STAESS is a soldier-portable, rapid-charging photo-voltaic renewable energy system that is modular and expandable to allow for simple set up, transport, and easy operation. The size, efficiency, and power output vary depending on the configuration of modules.

STAESS: Technology Specifications	
System Specifications	System Benefits
32 STORM modules (4kW)	Easily deployable & transportable
24 volt DC (100Ah) battery pack x 4	High energy density, high power, minimal weight
24 volt DC (200Ah) battery pack	Reduces threat of IEDs to fuel supply convoys
4000 watt inverter	Sustained life expectancy of battery technology
Interface: 220/120 VAC, 24/12/5 VDC	Rapid battery charging
MPPT 6kW capacity charge controllers	Modular design for scalability of power demand

1kW Generator

- **Weight:** 31 lbs.
- **Size:** 17.7″ X 12.3″ X 14.9″
- **Operating Temp:** -4°F to 122°F
- **Fuel Capacity:** .66 gal internal fuel tank
- **Noise:** 47-60 dBA @ 7 meters
- **Engine Type:** 4 Stroke, single cylinder
- **Fuel:** All commercial grade or scavenged fuels
- **Power Output:** peak 1000w / nominal 800w
- **System Output:** 120 VAC, 7.5A, 60Hz, 12VDC
- **Reliability:** Up to 100 starts per can starter fluid
- **Fuel Consumption:** 4 to 6 hrs on average
- **Mobility:** Man portable, by a single warfighter

SPM-612
Manages and prioritizes battery usage.
Powers man-worn and man-packable gear.
Recharges military and commercial batteries.
Optimizes solar/alternative power sources.
Monitors power sources and loads, alerting warfighter to problems, dynamically adjusts to changing mission needs, Smart Cable ID configures ports automatically, provides graphical display to show power trends, and permits advanced configuration.

SPM: Technology Specifications	
Characteristic	**Specification**
Size	1.8 h x 4.0 w x 2.3 d inches
Weight	0.9 lbs (0.40 kg)
Color	Desert Sand
Operating Temp	-40 to 60°C
# of Ports	Six Bidirectional
Port Voltage	4–34 VDC
Port Max Power	150 Watts
Mort Max Current	10 Amps
Battery Voltage	11–17 VDC, 14.4 V Nominal
Port Protection	Over-voltage, Over-current, Short-circuit, Reverse Polarity, Surge, EMI
Protection Reset	Automatic Self-reset
Data Interface	Up to Three Batteries
Simultaneous Charge	Up to Three Batteries

Sequential Charge	Up to Five Batteries
Military Battery Support	BB-2590, BB-2557, Li-80, Li-145, 28V Vehicle
Commercial Battery Support	AA, AAA, RCR -123, 12V Vehicle
Smart charging	SMBus 1.1 and SMBus 2.0 Support, All Ports
Harvester Ports	Up to Two
Harvest range	4–34 VDC
Solar Algorithm	Peak Power Point Tracking (PPPT)
Primary Battery Harvesting	Automatic
Fuel Cell Interface/Control	Automatic
Port Charge Indicator	5-Segment Meter for Each Port
Port Status Indicator	3 Status Indicators (Red/Yellow/ Green) for Each Port
Graphical Display	Backlit LCD Interface
Control Keypad	Up, Down, Enter and Escape buttons

MicroCube™ is a nearly Frictionless/Vibrationless power generation system. It is completely safe to people and wildlife, 66% quieter than traditional turbines, 50% more efficient than solar panels (of the same size), 1000% more efficient than other wind turbines. There is no need for expensive poles or large installation teams, and has 95% up time at ground level wind speeds. MicroCube™ generator is certified by Dr. Bill Carswell of Energy Huntsville and the University of Alabama Huntsville energy lab.

IWPS CV16 Objectives

This section provides a summary of the objectives for the IWPS project prior to the execution of CV16, and CV16 specific objectives for IWPS technologies.

IWPS Project Objectives

- Provide a system or set of integrated systems that produces odorless and tasteless product water
- Purified water able to maintain purity even if it is passed to bacteria filled containers
- Test and assess different parameters to include technical performance, interoperability, and operational environment performance
- Develop a system or set of integrated systems able to support multiple missions including austere FOBs and HA/DR

CV16 Specific Objectives

- Conduct water technology testing on the utility of multiple water purification technologies
- Train Thai users to successfully operate the water purification technologies
- Collect user feedback on the utility of the water purification technologies

- Incorporate renewable energy as the power source for the water purification technologies
- Collect SME feedback on the renewable energy technologies
- Promote collaboration and information sharing between the U.S. and Thailand on water purification technology capabilities

General Assessment Approach

To assess the utility of the water purification technologies, in relation to IWPS objectives, the TEC developed two Critical Operational Issues (COIs) (see Table 1). Additionally, one COI was developed to assess the utility of potential power sources for the IWPS. Not all measures were addressed during CV16. The specific Measures of Effectiveness (MOE) and Measures of Suitability (MOS) that were addressed during CV16 are provided in the Findings, Conclusions, and Recommendations section of this report.

The CV16 IWPS event used the following definitions for COI, Objective, and MOE/MOS:

- A **COI** is phrased as a question and must be answered in order to properly evaluate operational effectiveness and operational suitability.
- **Objectives** are statements that break down the COI into clearly defined manageable tasks and are developed to group or organize the measures needed to resolve the COI.
- A **MOE/MOS** is an expression of a quantitative (objective) or qualitative (subjective) "operational" measure that is a key indicator of task accomplishment.

Table 43: CV16 Water Purification COIs, Objectives, and Measures

COI 1: Does the capability provide potable water from local sources for the operators, the local populace, and the local first responders?
Objective 1.1: Assess the quality of the product water
Objective 1.2: Assess water technology component portability
Objective 1.3: Assess water output quantity
Objective 1.4: Assess water technology operations and maintenance training
Objective 1.5: Assess water purity after storage
Objective 1.6: Assess water technology maintenance actions
Objective 1.7: Assess water technology environmental operating conditions
Objective 1.8: Assess operational safety
Objective 1.9: Assess power consumption
Objective 1.10: Assess semi-autonomous operations

Objective 1.1: Assess the quality of the product water		
Measure	**Source**	**Product**
MOE 1-1-1: Presence of fecal coliform bacteria per 100 mL	Event Log	Table
MOE 1-1-2: Count of TDS	Event Log	Table
MOE 1-1-3: Count of NTU	Event Log	Table
MOS 1-1-4: User rating of water smell	Questionnaire	Chart/Text

MOS 1-1-5: User rating of water color	Questionnaire	Chart/Text

Objective 1.2: Assess water technology component portability		
Measure	**Source**	**Product**
MOE 1-2-1: Weight of system	Event Log	Table
MOE 1-2-2: Number of personnel required to lift	Event Log	Table
MOE 1-2-3: Volume of water technology	Event Log	Table
MOS 1-2-4: User rating of portability	Questionnaire	Chart/Text
MOS 1-2-5: SME rating of portability	Questionnaire	Chart/Text

Objective 1.3: Assess water output quantity		
Measure	**Source**	**Product**
MOE 1-3-1: Gallons of purified water per day	Event Log	Table
MOE 1-3-2: Number of personnel supported	Event Log	Table
MOE 1-3-3: Gallons of effluent per day	Event Log	Table

Objective 1.4: Assess water technology operations and maintenance training		
Measure	**Source**	**Product**
MOE 1-4-1: Time to achieve user proficiency	Event Log	Text
MOE 1-4-2: Characterize training requirements	Event Log	Text
MOE 1-4-3: Characterize training materials	Event Log	Text
MOS 1-4-4: User rating of classroom training	Questionnaire	Chart/Text
MOS 1-4-5: User rating of hands-on training	Questionnaire	Chart/Text
MOS 1-4-6: User train the trainer recommendation	Questionnaire	Chart/Text

Objective 1.5: Assess water purity after storage		
Measure	**Source**	**Product**
MOE 1-5-1: Amount of residual chlorine	Event Log	Table

Objective 1.6: Assess water technology maintenance actions		
Measure	**Source**	**Product**
MOE 1-6-1: Time required to perform	Event Log	Text
MOE 1-6-2: Characterize maintenance location	Event Log	Text
MOE 1-6-3: Characterize maintenance as routine	Event Log	Text
MOE 1-6-4 Number and type of proprietary	Event Log	Text
MOE 1-6-5: Number and type of supplies or	Event Log	Text
MOS 1-6-6: User rating of ease to conduct	Questionnaire	Chart/Text
MOS 1-6-7: SME rating of ease to conduct	Questionnaire	Chart/Text

Objective 1.7: Assess water technology environmental operating conditions		
Measure	**Source**	**Product**
MOE 1-7-1: Maximum temperature with system in storage	Event Log	Table
MOE 1-7-2: Maximum temperature with system in operation	Event Log	Table
MOE 1-7-3: Temperature ranges of source water	Event Log	Table
MOE 1-7-4: Characterize ability to operate in rain	Event Log	Table
MOE 1-7-5: Characterize ability to operate in snow	Event Log	Table
MOE 1-7-6: Characterize ability to operate in heat	Event Log	Table
MOE 1-7-7: Characterize ability to operate in cold	Event Log	Table
MOE 1-7-8: Characterize ability to operate in wind	Event Log	Table
MOE 1-7-9: Characterize ability to operate in humidity	Event Log	Table
MOE 1-7-10: Characterize ability to operate in dust	Event Log	Table
MOE 1-7-11: Characterize ability to operate in hail	Event Log	Table

Objective 1.8: Assess operational safety		
Measure	**Source**	**Product**
MOE 1-8-1: Characterize compliance with safety	Event Log	Table
MOS 1-8-2: User rating of safety	Questionnaire	Chart/Text
MOS 1-8-3: SME rating of safety	Questionnaire	Chart/Text

Objective 1.9: Assess power consumption		
Measure	**Source**	**Product**
MOE 1-9-1: Number of watts required to produce 1 gallon of water	Event Log	Table

Objective 1.10: Assess semi-autonomous operations		
Measure	**Source**	**Product**
MOE 1-10-1: Time of unattended operations	Event Log	Text
MOE 1-10-2: Characterize automatic shut off capability	Event Log	Text
MOE 1-10-3: Characterize power performance monitoring capability	Event Log	Text
MOE 1-10-4: Characterize embedded diagnostic capability	Event Log	Text
MOE 1-10-5: Characterize start and stop process	Event Log	Text
MOS 1-10-6: User	Questionnaire	Chart/Text
MOS 1-10-7: SME rating of semi-autonomous capability	Questionnaire	Chart/Text

COI 2: Is the IWPS component transportable to support various missions including austere FOBs and HA/DR?
Objective 2.1: Assess air transportability
Objective 2.2: Assess land transportability

Objective 2.1: Assess air transportability		
Measure	**Source**	**Product**
MOE 2-1-1: Characterize air transportability	Event Log	Text
MOE 2-1-2: Characterize special cargo handling requirements	Event Log	Text

Objective 2.2: Assess land transportability		
Measure	**Source**	**Product**
MOE 2-2-1: Characterize land transport vehicle	Event Log	Text
MOE 2-2-2: Characterize ruggedness	Event Log	Text
MOE 2-2-3: SME rating of system ruggedness	Event Log	Text
MOE 2-2-4: User rating of system ruggedness	Event Log	Text

COI 3: Does the IWPS power source provide reliable power primarily from renewable sources?
Objective 3.1: Assess power type
Objective 3.2: Assess power availability
Objective 3.3: Assess power technology component portability
Objective 3.4: Assess ability to safely operate
Objective 3.5: Assess power technology environmental operating conditions
Objective 3.6: Assess power technology maintenance actions
Objective 3.7: Assess power technology training
Objective 3.8: Assess semi-autonomous operations
Objective 3.9: Assess renewable energy source

Objective 3.1: Assess power type		
Measure	**Source**	**Product**
MOE 3-1-1: Characterize type of power output	Event Log	Table
MOE 3-1-2: Number and type of auxiliary power outlets	Event Log	Table
MOE 3-1-3: Number of international adapter kits	Event Log	Table
MOE 3-1-4: Characterize power inverter	Event Log	Table

Objective 3.2: Assess power availability		
Measure	**Source**	**Product**
MOE 3-2-1: kWh generated per day	Event Log	Table
MOE 3-2-2: Time of power interruptions	Event Log	Table
MOE 3-2-3: Average time operational in 24 hour day	Event Log	Table

Objective 3.3: Assess power technology component portability		
Measure	**Source**	**Product**
MOE 3-3-1: Weight of power source component	Event Log	Table

MOE 3-3-2: Number of personnel required to lift power source	Event Log	Table
MOE 3-3-3: Volume of power source component	Event Log	Table
MOS 3-3-4: User rating of power source portability	Questionnaire	Chart/Text
MOS 3-3-5: SME rating of power source portability	Questionnaire	Chart/Text

Objective 3.4: Assess ability to safely operate

Measure	Source	Product
MOE 3-4-1: Characterize compliance with safety requirements	Event Log	Table
MOS 3-4-2: User rating of safety	Questionnaire	Chart/Text
MOS 3-4-3: SME rating of safety	Questionnaire	Chart/Text

Objective 3.5: Assess power technology environmental operating conditions

Measure	Source	Product
MOE 3-5-1: Maximum temperature with system in storage	Event Log	Table
MOE 3-5-2: Number of storage days	Event Log	Table
MOE 3-5-3: Maximum temperature with system in operation	Event Log	Table
MOE 3-5-4: Number of operational days	Event Log	Table
MOE 3-5-5: Characterize ability to operate in rain	Event Log	Table
MOE 3-5-6: Characterize ability to operate in snow	Event Log	Table
MOE 3-5-7: Characterize ability to operate in heat	Event Log	Table
MOE 3-5-8: Characterize ability to operate in cold	Event Log	Table
MOE 3-5-9: Characterize ability to operate in wind	Event Log	Table
MOE 3-5-10: Characterize ability to operate in humidity	Event Log	Table
MOE 3-5-11: Characterize ability to operate in dust	Event Log	Table
MOE 3-5-12: Characterize ability to operate in hail	Event Log	Table

Objective 3.6: Assess power technology maintenance actions

Measure	Source	Product
MOE 3-6-1: Time required to perform routine maintenance	Event Log	Text
MOE 3-6-2: Characterize maintenance location	Event Log	Text
MOE 3-6-3: Number and type of proprietary components required	Event Log	Text
MOE 3-6-4: Number and type of special tools required	Event Log	Text
MOS 3-6-5: User rating of ease to conduct maintenance	Questionnair	Chart/Text
MOS 3-6-6: SME rating of ease to conduct maintenance	Questionnair	Chart/Text

Objective 3.7: Assess power technology training

Measure	Source	Product
MOE 3-7-1: Time to achieve user proficiency	Event Log	Text

MOE 3-7-2: Characterize training requirements	Event Log	Text
MOE 3-7-3: Characterize training materials	Event Log	Text
MOS 3-7-4: User rating of classroom training	Questionnaire	Chart/Text
MOS 3-7-5: User rating of hands-on training	Questionnaire	Chart/Text
MOS 3-7-6: User rating of documentation	Questionnaire	Chart/Text
MOS 3-7-7: User train the trainer recommendation	Questionnaire	Chart/Text

Objective 3.8: Assess semi-autonomous operations		
Measure	**Source**	**Product**
MOE 3-8-1: Time of unattended operations	Event Log	Text
MOE 3-8-2: Characterize automatic shut off capability	Event Log	Text
MOE 3-8-3: Characterize power performance monitoring capability	Event Log	Text
MOE 3-8-4: Characterize embedded diagnostic capability	Event Log	Text
MOE 3-8-5: Characterize start and stop process	Event Log	Text
MOS 3-8-6: User rating of power performance monitoring capability	Questionnaire	Chart/Text
MOS 3-8-7: User rating of embedded diagnostic capability	Questionnaire	Chart/Text

Objective 3.9: Assess renewable energy source		
Measure	**Source**	**Product**
MOE 3-9-1: Characterize type of energy source	Event Log	Text
MOS 3-9-2: User rating on ruggedness of component	Questionnaire	Chart/Text
MOS 3-9-3: SME rating on ruggedness of component	Questionnaire	Chart/Text
MOS 3-9-4: User rating of ease to clean	Questionnaire	Chart/Text
MOS 3-9-5: SME rating of ease to clean	Questionnaire	Chart/Text

Metrics

The CV16 water purification assessment does not have go/no-go criteria. Instead, the intent is to determine the operational utility of the capabilities in relation to the IWPS objectives by determining if each technology can meet the threshold or objective level parameters established by the TEC team (Table 2 and 3). If the threshold level is not met, the capability might still demonstrate some operational utility if the users and/or Subject Matter Experts (SME) have a positive opinion of the system. Thresholds and objectives for power sources will be developed and assessed later.

Table 44: Water Metrics

Parameter	Threshold	Objective	Comments
Purification	Coliforms/E. coli: 0	Coliforms/E. coli: 0	Technical Bulletin Med 577
	TDS: 1,000 mg/L	TDS: 1,000 mg/L	Humanitarian Charter and Minimum Standards in Disaster Response (Chapter 2)
	Turbidity: 1 NTU	Turbidity: 1 NTU	

Component Portability	< 300 lbs	< 200 lbs	
	6 person lift	4 person lift	
	<54 cu ft	<27 cu ft	
Water Production Quantity	1000 gallons 5000 gallons	1000 gallons 5000 gallons	Gallons in a 24 hour day
Training for operation and routine maintenance	2 hours	< 1 hour	Local population to set-up, operate and maintain
Water Storage (1 week)	≥0.2 mg/L ≤ 0.6 mg/L	≥0.2 mg/L ≤ 0.6 mg/L	0.2 mg/L indicates that essentially all bacteria and viruses have been killed 0.6 mg/L so the taste of the chorine is acceptable

The following Parameters apply to the water purification technologies. The intent is to determine if each technology is transportable via military and commercial air and ground transport systems.

Table 45: Transportability Metrics

Parameter	Threshold	Objective	Comments
Air Transportable	Transported via MILAIR or Commercial	Transported via MILAIR or Commercial	
Ground Transportable	Light truck or trailer	Light truck or trailer	

TEST METHODOLOGY

This section provides insight into the test schedule, location, and data sources required to assess the operational utility of the IWPS prototype water purification and energy technologies.

CV16 IWPS Schedule

The following table provides a summary of the CV16 IWPS technology experimentation team's schedule of events.

Table 46: CV16 IWPS Schedule

Date	Events
23 Aug	TEC Logistics Lead arrives at BKK
24-26 Aug	TEC Logistics Lead coordinates and conducts cargo and transportation requirements.
27 Aug	Rest day. 1000 meeting at the Intercontinental Hotel Lounge for the in country "Liberty/safety brief"
28 Aug	CV16 team travel to the Saraburi Receive cargo at Fort Adisorn Cavalry Center
29 Aug	Source water sample testing
29 Aug-6 Sept	IWPS Main Operating Window • Water Sample Testing • Water Production Data Collection • Power Integration
7 Sept	Backup Data Collection Day
8 Sept	VIP Day and Pack Out
9 Sept	Cargo Shipment

Evaluation Data Sources

This section identifies the data requirements and sources for determining the operational utility of the water purification technologies.

Surveys

SMEs completed surveys designed to gather subjective feedback on the utility of the water purification technologies. Questions used a six-point Likert rating scale ranging from Completely Disagree to Completely Agree and provided space for comments to allow users to explain their ratings or to comment further. In addition, a Not Applicable (N/A) choice was available to those who felt a question did not apply to them. A separate page of the questionnaire was devoted to demographic information.

Event Logs

Event Logs were used to capture subjective and objective data during CV16 events. The data captured included performance data, user impressions, subject matter expert observations, and the data collectors' independent view.

Instrumentation
Instrumentation includes the equipment used to test the quality of the water. Instrumentation does not need to be operated by TEC personnel. Instrumentation results were noted on water testing event logs.

Photographs
Data collectors captured photographs to support the assessment. Data collectors ensured photographs remain unclassified and are approved for release by the appropriate agencies.

Locations

The CV16 events were conducted at Fort Adisorn, Calvary Center, Saraburi, Thailand. Saraburi, Thailand is located 113 kilometers northeast of Bangkok.

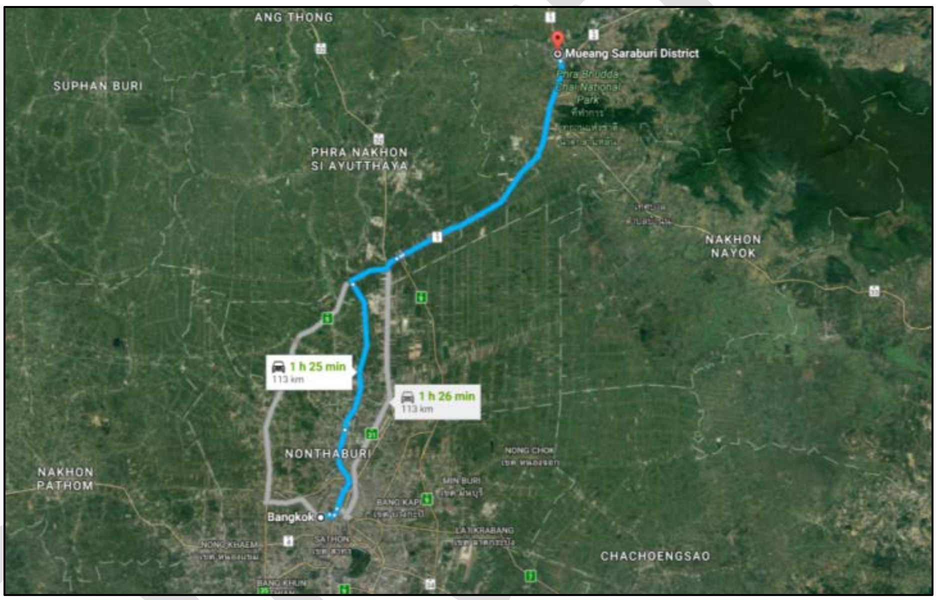


Figure 25: CV16 Locations

Figure 26. Fort Adisorn, Calvary Center, Saraburi

Source Water Selection

During source water baseline sample testing, the corpsman found that the source water from the identified source water location was chlorinated. It was confirmed that samples had not been taken during site surveys due to time constraints and limited access to lab facilities, so the corpsman took two samples at different banks of the selected pond:

- Sample 1: 0950 from manmade pond Eastern bank near Joint Operations Center (JOC)
  - Source water temperature: 87.1°F
  - TDS: 250 mg/l
  - pH: 8.4
  - Turbidity: 76.4 NTU
  - DPD Chlorine Detection powder: Pink (chlorine present)
  - Chlorine: 0.54 PPM Free Available Chlorine (FAC) (0.2-2.0 PPM FAC is desired chlorination level for potable water to effectively kill bacteria while maintaining safe drinking water)
- Sample 2: 1040 from manmade pond Southern bank near JOC
  - N,N Diethyl-1,4 Phenylenediamine Sulfate (DPD) Chlorine Detection Powder: Pink
  - Chlorine: 0.5 PPM FAC

Ideally source water with no, or a negligible amount of chlorine would be desired for WPS testing. To help ensure the best source location for the test, the team took a total of 13 samples at different locations around base to include manmade ponds, irrigation ditches, natural pond, rain accumulated puddles, and stagnant water. Only two locations tested had <0.2 PPM FAC chlorination levels and the lowest was 0.13 PPM FAC. All locations ranged from 0.13 – 2.2 PPM FAC. The corpsman periodically conducted troubleshooting methods to ensure that the chlorine measurement device was correctly calibrated, which it always was. In addition, the corpsman sampled bottled drinking water two times with results of .007 PPM FAC.

Figure 27. Other Potential Source Water Sites

Finding source water that was not already chlorinated proved difficult. Based on the chlorination test method, all tested sources contained chlorine. The team initially chose the least chlorinated water source to conduct the test, the Parade Field West Pond. Potable water contains .2-2.0 chlorine to effectively kill bacteria while remaining safe to drink. The source water used measured 0.13, which is below the minimum recommended chlorination level. However, the water tested negative for coliform and E. coli.

Figure 28. Parade Field West Pond

As a result, the team moved the test site to the Joint Operations Command (JOC) pond. The JOC pond measured 0.54 ppm FAC, but tested positive for coliform and E. coli.

Source Water Test Results	
Total Dissolved Solids (mg/l)	250 mg/l
pH	8.4
Turbidity (NTU)	76.4 NTU
Chlorine (PPM FAC)	0.54 PPM FAC
Temperature (°F)	87.1 °F
Coliform	Yes
E. coli	Yes

Additional source water characteristics included an estimated depth of 10 ft., a medium grade of sediment, low level of color, and potential pollution sources of animals, plants/algae, laundry, and other human influenced runoff.

Figure 29. JOC Pond Test Site and Source Water Sample

Water Sample Testing Process

CV16 provided an opportunity to conduct water sample testing, in a field environment, utilizing a single contaminated water source, four different WPSs, and two different additives.

Testing was conducted on the source water to determine the baseline levels of pH, turbidity, TDS, chlorine, coliform, and E. coli. The Navy Corpsman collected samples via plastic beaker from the water source.

Figure 30. Corpsman Collecting Source Water Samples

Samples were categorized as part of; initial testing, contamination testing, or storage testing. Each type of category is described as follows:

Initial Testing: Initial testing included water level testing of temperature, pH level, turbidity, TDS, and chlorine followed by an 18-22 hour incubation period to test for coliform, and E. coli. Initial testing was conducted on the source water and samples of product water from each of the WPS, to determine the baseline for the source water and the ability of each system to produce safe product water.

Contamination Testing: Contamination testing was conducted to determine if product water that contained chlorine or ozone injected as part of the purification process, or product water that had additives instead of the chlorine or ozone injected as part of the purification process could withstand 2 gtts of dirty source water per 100ml, and remain safe. Any sample that received the SilverDYNE additive was given a 30 min wait period before testing commenced.

Storage Testing: Storage testing was conducted to determine if product water directly from the WPSs, or with one of the additive technologies would remain safe after a minimum of 2-10 days of storage.

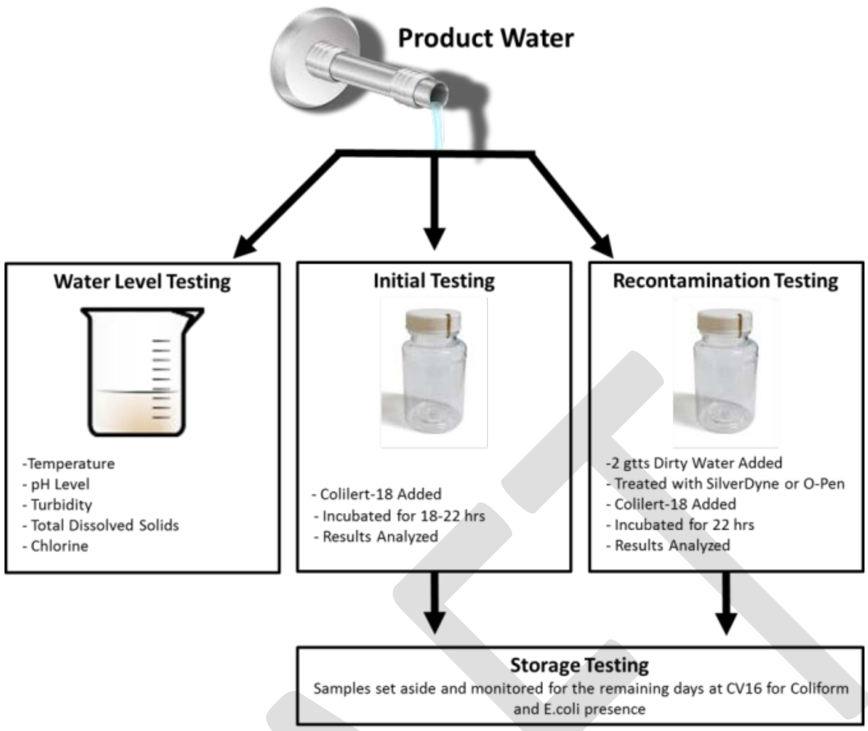


Figure 31. Water Sample Testing Summary

The CV16 team processed 91 total water samples during the event. Each sample was tested for temperature, total dissolved solids (TDS), pH level, turbidity, chlorination, E. coli, and coliform. The following section provides more detailed information on how each sample was processed during the event.

Each of the 91 samples processed during CV16 was tested by a Navy Corpsman specializing in water safety. The Corpsman collected product water samples from the WPSs, as outlined in the CV16 test plan, and tested each batch of water for temperature, pH level, TDS, turbidity, and chlorination prior to incubation. The approach for each attribute included:

Temperature: The Corpsman measured the temperature of the product water at the time of testing with an off-the-shelf COTS digital thermometer.

Total Dissolved Solids (TDS): The Corpsman measured the TDS with the Environmental Protection Agency (EPA) compliant Oakton EcoTestr TDS Low pocket TDS tester, which provided a digital readout of the TDS level when the probe was submerged into the product water.

pH Level: The Corpsman measured the product water pH level with the EPA compliant Oakton EcoTestr 2 Pocket pH Tester, which provided a digital readout of the pH level when the probe was submerged into the product water.

Turbidity: The Corpsman placed the product water in a sanitized vial and measured the turbidity with the EPA compliant Hach 2100Q Handheld Turbidimeter, which provided a digital readout. The turbidimeter incorporated an innovative Rapidly Settling Turbidity™

(RST) mode to provide accurate, repeatable measurements for difficult to measure, rapidly settling samples.

Chlorination: The Corpsman added the DPD reagent, which stands for N,N Diethyl-1,4 Phenylenediamine Sulfate, to a vial of the product water. The addition of DPD to water samples containing oxidizers such as free chlorine, bromine, iodine, chlorine dioxide and/or permanganate results in the formation of a reddish/pink tint to the water. The intensity directly relates to the amount of oxidizer(s) present in the water sample. The DPD reagent provided a general chlorine mg/l range in accordance with the chart in Figure 7. The Corpsman then placed the vial into the Hach Chlorine Pocket Colorimeter II for a digital reading.

Figure 32. Oakton EcoTestr TDS Low Pocket TDS Tester (left) Oakton EcoTestr 2 Pocket pH Tester (center) Hach 2100Q Handheld Turbidity Meter (right)

Figure 33. DPD Reagent, Scale, and Hach Chlorine Pocket Colorimeter II

Once the sample product water was tested for temperature, turbidity, TDS, pH level, and chlorine 100ml samples were placed into sterile sample bags (Whirl-Paks), or sample storage bottles for further testing. The test plan called for samples to be incubated 18-22 hours and observed for presence of E. coli and coliform. This was accomplished by placing Colillert-18 in the sample water. The Colilert-18 uses a proprietary Defined Substrate Technology (DST) nutrient indicators ortho-Nitrophenyl-β-galactoside (ONPG) and 4-methylumbelliferyl-beta-D-glucuronide (MUG) to detect coliforms and E. coli. Coliforms use the β-galactosidase enzyme to metabolize ONPG and change it from colorless to yellow. An example of the difference can be seen in Figure 9 where the negative coliform sample is depicted as clear and the positive coliform sample is depicted yellow.

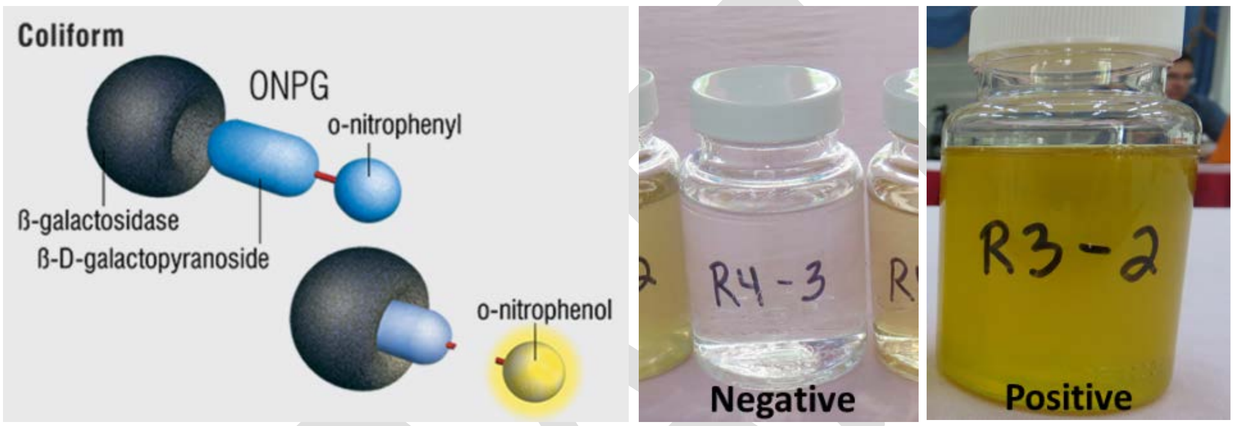


Figure 34. Coliform Testing Process

E. coli use *β*-glucuronidase to metabolize MUG and create fluorescence. An example of the difference can be seen in Figure 7 where the negative E. coli sample is depicted translucent on the left and the positive E. coli sample is depicted fluorescent on the right.

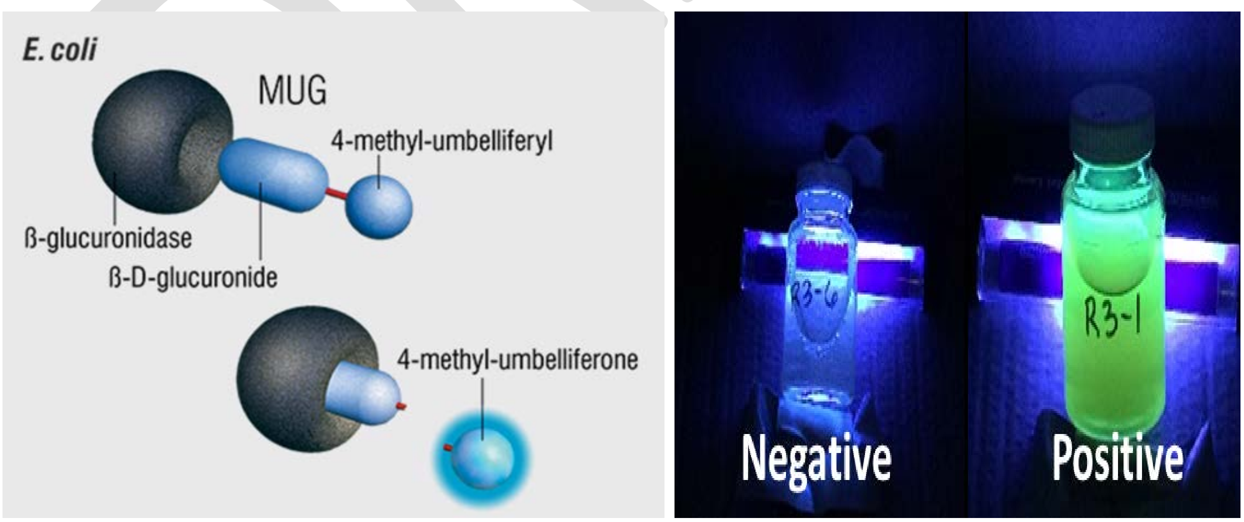


Figure 35. E. coli Testing Process

The outcome of the coliform and E. coli testing determined if the tested batch of product water would go through contamination testing and/or storage testing. If the initial test showed that the WPS had not produced clean product water, negative for coliform and E. coli, that batch of product water would not go through additional testing. If the initial testing showed the WPS had produced product water free of coliform and E. coli, that batch of product water would be used to collect samples for contamination and storage testing. Separate samples had to be collected for contamination and storage testing because the Colliller-18 could only be incubated once with a sample. However, the separate samples were collected from the same batch of product water to ensure an accurate representation of the batch.

During contamination testing, the product water received 2 drops (gtts) of dirty source water and was treated with the test plan specified products (O-Pen or SilverDyne) and incubated 18-22 hours, and observed again for presence of E. coli and coliform. During storage testing, product water was stored for 2-9 days to determine if coliform and E. coli would be detected in the sample. All sample data was collected and recorded for future analysis.

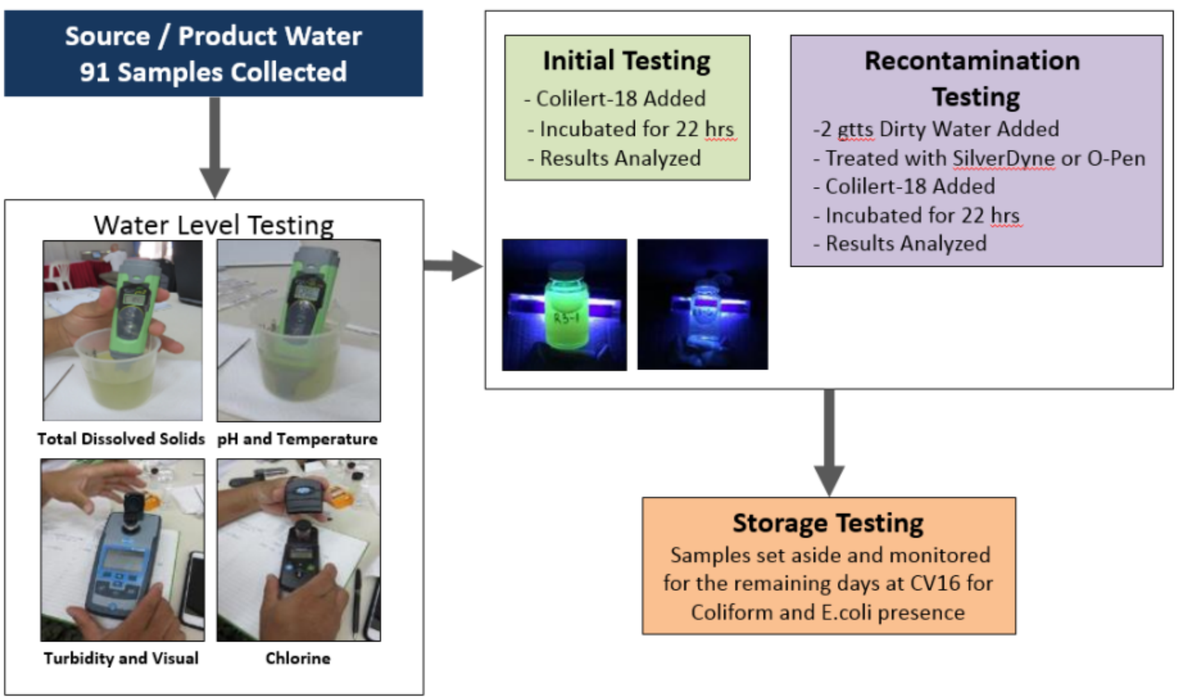


Figure 36. Water Sample Process Summary

Source Water Composition

The results of some sample testing during CV16 demonstrated there might be an unforeseen issue with the source water that was impacting test results. Specifically, the chlorine results were not in line with expected outcomes. Coliform and E. coli. were present in samples with chlorine levels high enough to treat them. Due to the compressed nature of the test schedule, more in-depth testing of the source water was not possible during the event. However, after the completion of CV16, separate tests were conducted in a lab to determine the composition and any impact that composition might have on sample data. The following is a summary of the source water composition test and findings:

Source Water Lab Test Results

- 4600 mg/m^3 Chlorophyll a – indicating significant algae presence
- 11.9 mg/L Sulphate
- Little to no Hexavalent Chromium
- 79 ppb Copper
- 16.9 mg/L Manganese

The manganese level is particularly important because it was more than enough to cause false positive readings when using the DPD method for chlorine. The DPD method was the method used during CV16. This method is vulnerable to false positives when there are high levels of metals in the water. The lab that conducted the composition test only had the capability of using the DPD method to test for chlorine so the following steps were taken to determine the presence, if any, of chlorine in the source water

Free Available Chlorine (FAC) Investigation:

1. The source water was evaluated for FAC as follows:
    a. Simple read of the water according to spectrophotometer instructions using standard DPD method– 0.41 mg/L Chlorine (this was very similar to the readings recorded in CV16 which varied between 0.4 and 0.8)
    b. Using the same DPD method but using bottled water to zero the spectrophotometer - 1.41 mg/L Chlorine
    c. Free chlorine evaluated using 3 different test strip brands and at least two different chemistries - 0.0 mg/L Chlorine in all cases
    d. Chlorine was added to the water to determine the Chlorine background demand - >6 ppm of chlorine was consumed in < 10 minutes (indicating a very high level of Chlorine background demand making it very unlikely that a chlorine residual would exist for any length of time in the source water).
    e. If any chlorine existed in the source water, then adding sodium thiosulfate to the sample would instantly neutralize it. A sample was taken of the raw water, more than enough sodium thiosulfate was added to neutralize that much Chlorine, the sample was read using the standard DPD method on a spectrophotometer. This produced a very similar reading to the raw water without the added sodium thiosulfate (~0.4 mg/L Chlorine). This clearly demonstrates that something else in the raw water sample is giving a false positive reading for Chlorine where none exists (most probably the Manganese and perhaps other contributors as well). This explains the existence of the bacteria in the water, which would normally not be able to survive in that level of Chlorine, because that level of Chlorine, in fact, did not exist.

Because of this new data, the water sample data was analyzed while giving consideration for the impact of the inaccurate chlorine readings. The inaccurate chlorine data was removed from Appendix A.

Power Source Integration Approach

The STAESS provided the majority of power to the water purification systems. The STAESS includes 32 solar panels each rated at 125 watts, for a total combined rate of 4,000 watts. The DC to AC inverter is rated at 4,000 watts 120/240 VAC with 100% duty cycle. The TEC team purchased local sealed lead acid 12 volts 90 amp hour car batteries, using 2 batteries in series for 24 volts. This was the second demonstration, the first being in Angkor Sentinel (AS16) in Cambodia, where the team successfully demonstrated that the STAESS can incorporate locally acquired car batteries to create an effective, although lower capacity, storage system.

The STAESS Power SME conducted a test to see if the solar panels could power the First Response without the storage battery connected. STAESS successfully ran the First Response with no storage battery at 30amps (36 amps with battery connected), 4.5 flow rate, and 52% irradiance. At this configuration (52% irradiance), STAESS can provide 2080 W and the system was drawing approximately 830 W.

Table 47. STAESS Daily Power Summary

Date	Time	Average Solar Irradiance	Available power in W per hour
08/29/16	14:17 – 16:08	23%	920
08/30/2016	15:07 – 17:17	34%	1356
08/31/2016	14:20 – 16:00	49%	1956
09/01/2016	10:35 – 14:10	72%	2880
09/02/2016	11:03 – 13:42	60%	2400
09/03/2016	9:37 – 14:22	81%	3240
09/05/2016	8:56 – 16:00	70%	2800
09/06/2016	9:44 – 15:55	64%	2560

STAESS successfully powered the First Response with and without the storage battery connected, and served as the only power source for the system throughout CV16. The STAESS also successfully powered the Modus throughout the event, and demonstrated the capability to charge the Roving Blue WPS battery.

The STAESS inverter is designed to be able to charge the external batteries when it is connected to a 120 VAC source via generator or shore power, the inverter has a built in 24 VDC charger. The power SMEs were unable to get the STAESS and 1 KW flex generator to work properly during CV16. The STAESS kept trying to seek the input power source. The STAESS has connected to a generator and shore power in the past and functioned properly. Additional testing will need to be conducted to determine why the STAESS and 1 kW are not interoperable.

The SPM w/ 100W Solar Blanket demonstrated the capability to charge the Roving Blue WPS Battery as an UPS system. The SPM can manage power for the smaller pumps like the one used in the Modus, but that was not demonstrated during CV16. Additionally, the 1KW generator can power the pumps, but that was not demonstrated with the STAESS due to some integration issues with the STAESS.

The American Wind Microcube wind turbine system was not able to integrate into the WPS technologies and power the systems due to a lack of power production. Thus, no additional data was collected on the system.

ASSESSMENT FINDINGS, OBSERVATIONS, AND RECOMMENDATIONS

This section provides the data collected during the CV16 IWPS event, along with any observations and recommendations based on that data. The overall assessment strategy for CV16 was to evaluate the utility and transportability of the technologies to support various missions, including austere FOBs and HA/DR response. Toward that end, the TEC identified the measures and data sources needed to address the COIs, Objectives, MOEs and MOSs. No users were provided for the CV16 IWPS event, so all feedback was collected from SMEs and observers. Only the measures assessed during CV16 are included below. A complete list of COIs, Objectives, and Measures can be found in the General Assessment Approach section.

The Roving Blue WPS did not function as expected. The system repeatedly switched off minutes after being turned on. Thus, limited performance data was collected on the system. Due to the MicroCube not performing as expected, no data was collected in relation to the IWPS COIs, objectives, and measures. Based on SME observations, the MicroCube in its current form would not be a good fit for the IWPS prototype.

Overview

To evaluate the utility of the water purification capabilities, the TEC gathered objective data via water sample testing and observation of event activities, and subjective data in the form of SME feedback. The TEC relied upon surveys, interviews, data collection forms, event logs and data collector observations during the assessment events to support any recommendations or conclusions.

COI 1: Does the capability provide potable water from local sources for the operators, the local populace, and the local first responders?

The goal of this COI was to evaluate the effectiveness and suitability of the water technologies to provided potable water from local sources.

Objective 1.1: Assess the quality of the product water
This objective seeked to characterize the quality of the purified water produced. The measures determined if fecal coliform is present in the product water, both threshold and objective level is "No" coliforms. The threshold and objective levels for TDS and NTU are provided in Table 2. In addition to the objective data, the TEC gathered subjective data, via questionnaires, regarding the quality of the water. SMEs rated the smell and color of the product water.

MOE 1-1-1: Presence of Fecal Coliform Bacteria per 100 mL
MOE 1-1-1 covered testing for the presence of general coliform and E. coli. More detailed data on individual samples is included in Appendix A of this report. It is important to note, that the chlorine readings throughout the event were incorrect, likely due to the metal content in the source water and the chlorine testing method. More detailed information about the source water composition can be found the Source Water Composition section of this report.

Source Water Observations

The SilverDYNE and O-Pen were unable to successfully treat the source water alone. There was a 0% success rate of either system treating for coliform. Two SilverDYNE samples and two O-Pen samples tested negative for E. coli after initial treatment. The samples were not part of contamination testing, but all four samples tested positive for E. coli after being stored for <9 days. Other samples treated in the same manner as those negative for E. coli tested positive for E. coli suggesting the additives did not reliably treat source water. All 6 samples that were part of contamination testing tested positive for coliform and E. coli. The number of SilverDYNE drops added, 2 or 4, or the amount of time samples were treated with the O-pen, 30 seconds or 60 seconds, had no impact.

Recommendations

SilverDYNE did not treat source water as expected during multiple events and is recommended to be removed as a potential component of the IWPS prototype.

The O-Pen was unable to successfully treat the source water at CV16. Given the small amount of water that can be treated per pen and the inability to perform as expected, the O-Pen is recommended to be removed as a potential component of the IWPS prototype.

First Response Observations

The FR uses ultrafiltration to remove bacteria, viruses, and sediments from source water. However, this process does not remove metals such as copper or manganese. As previously stated in the water purification process portion of this report, this would account for FR samples that did not have chlorine showing positive results for chlorine during sample testing. During CV16 between 2 and 5 ppm were added to the FR product water for FR with chlorine samples. The addition of chlorine adds both a second level of purification after filtration, and the ability to store the water for a period of time. However, that chlorine was neutralized by the sodium thiosulfate tablets in the Whirl-Pak test bags and sample bottles immediately based on the source water pH. Assuming the ultrafiltration system removed all viruses and bacteria during the filtration process, the FR samples without chlorine samples that were not contaminated should test negative for coliform and E. coli initially and after storage. Additionally, the FR with chlorine should be less likely to test positive for coliform and E. coli than FR without chlorine when not contaminated. It should be noted that samples that were part of contamination testing received source water with a background demand of >6ppm of chlorine, and only 2-5ppm was ever added to the samples based on the chlorine results from the DSD testing. Additionally, the samples were contaminated after being added to the Whirl-Pak bags that neutralized the chlorine.

Overall 100% of the 21 FR samples tested negative for coliform and E. coli after initial filtration. This is an important piece of data as it shows the FR can effectively treat the source water for immediate consumption.

20 samples were collected for storage testing, 6 out of 20 samples tested positive for either coliform and E. coli, or both, after the samples were stored for <9 days. Only 2 of the 6 samples tested positive after storage were treated with chlorine during the filtration process, but only 1 of these was part of contamination testing. Because this sample was recontaminated the chlorine should have protected it against the regrowth of coliform and E. coli. However, given that the

chlorine readings were incorrect it is possible the amount of chlorine in the sample might not have been high enough to ensure there was no regrowth. Also, the sodium thiosulfate tablets in the storage bottles would have neutralized the chlorine before recontamination.   Of the remaining 4 samples, 3 samples were not treated with chlorine and not contaminated and 1 sample was not treated with chlorine and was contaminated.

Recommendations

The data suggests that the FR system effectively treated source water for immediate consumption. However, due to the presence of coliform and E. coli after storage not all bacteria were eliminated during filtration and/or chlorination. 3 of the 4 samples that tested positive during storage testing were FR product without chlorine so it is also possible that the water was filtered to safe levels, but then the bacteria had time to grow during storage. Additional testing should be conducted to determine the cause of the positive samples.

The FR product water should maintain some level of chlorine if it is not consumed immediately. The SilverDYNE and O-Pen appeared to provide no value added to samples whether contaminated or not.

Additional testing of FR water must be conducted in a lab and in the field to identify why samples test positive for coliform and E. coli after short term storage. Additional information needs to be collected on the ultrafiltration filter to determine if it should be eliminating 100% of bacteria.

Recommend the SilverDYNE and O-Pen no longer be tested as an additional additive to the FR product water as both appear to have no impact on the outcome on the product water beyond what the FR has already accomplished.

Modus Observations

The Modus operated with and without a chlorine additive. The unchlorinated Modus samples had a much higher average turbidity, which is expected given the high amount of plant matter in the source water. 1 of 14 unchlorinated Modus samples tested positive for coliform and E. coli after the storage period. Fewer samples were collected of the Modus water with chlorine, 2 samples tested positive for both coliform and E. coli, one during initial testing and one during storage testing. Each of the samples were part of the contamination testing. Both chlorinated samples were part of contamination testing so it is possible that the Whirl-Pak neutralized the chlorine and allowed bacteria that remained in the product water to grow. SilverDYNE was added to the Modus with chlorine water after contamination. That sample still tested positive for coliform during storage testing. SilverDYNE was added to two samples of Modus without chlorine prior to contamination, and 1 sample after contamination. The O-Pen was added to two samples of Modus without chlorine. Each of these 4 samples tested negative for coliform and E. coli. However, multiple samples of the Modus without any additive also tested negative suggesting the additives might have had little to no effect.

Recommendations

These results are somewhat inconclusive. The mix of presence and absence of coliform and E. coli are mixed across almost all combinations of additives and test types. This might be due to the Modus filter reaching end of life much quicker than expected due to the composition of the source water. More testing should be conducted to determine why the Modus filter had repeated issues, and if that issue can be addressed.

The SilverDYNE and O-Pen did not appear to have any value added for the Modus.

Guardian Observations

Three of 14 samples of the Guardian purifier product water tested positive for coliform and E. coli during initial testing and 8 of 12 during storage testing. Of those 26 samples, 10 were contaminated, half tested positive for coliform and/or E. coli during contamination and/or storage testing. Eight out of 12 stored samples, whether contaminated or not, tested positive for coliform and E. coli.

Recommendations

The results for the Guardian system were mixed. Based on the collected data, the Guardian purifier would not effectively purify water like the source water in CV16. If this system is considered for inclusion in the IWPS prototype, additional sample testing in relevant environments should be conducted to determine the system applications and limitations.

Roving Blue Observations

The Roving Blue consistently handled turbidity better than any other system. All samples tested negative for coliform and E. coli during initial testing. Three out of 3 samples, that were stored and not contaminated, tested negative for coliform and E. coli. Two of 3 contaminated samples tested positive for coliform and E. coli after storage.

Recommendations

Roving Blue product water can be consumed immediately after filtration. Because the Roving Blue was a late addition to the test, only 7 total samples were collected. Additional testing is needed to determine if it is a good fit for the IWPS prototype

O-Pen Observations

The O-Pen is still in development and it is intended to be used by business travelers who wish to treat hotel faucet water to brush teeth, wash face, etc. The test pushed the O-Pen beyond the limits of what the O-Pen was expected to achieve. Six of 6 source water samples, treated only with the O-Pen tested positive for coliform and/or E. coli during initial testing. Two of these 6 samples tested negative for E. coli during initial testing, but positive during storage testing.

Recommendations

Determine what the log reduction is for bacteria with one treatment from the O-Pen. If the O-Pen is considered for future testing, the treatment time to effectively eliminate all bacteria must be determined prior to the event.

SilverDYNE Observations
The test pushed the SilverDYNE additive to determine if it provided value to the purification or water storage process. Six of 6 source water samples, treated only with SilverDYNE tested positive for coliform and/or E. coli during initial testing. Two of these 6 samples tested negative for E. coli during initial testing, but positive during storage testing. Eight out of 8 samples of source water treated only with SilverDYNE tested positive for coliform and/or E. coli. Two of these 8 samples tested negative for E. coli during initial testing, but positive during storage testing. The SilverDYNE additive appeared to have no impact as an additive to product water from any system.

Recommendations
The SilverDYNE additive should not be included in future testing. Results have shown no value as a first step for water treatment, or to support water storage.

Table 48. Obj. 1.1, MOE 1-1-2 and 1-1-3 Data

Objective 1.1: Assess the quality of the product water MOE 1-1-2 and 1-1-3		
System	**Average TDS (<1000 mg/L)**	**Average Turbidity (<1 NTU)**
Source Water	294 mg/L	39.5 NTU
First Response w/out Chlorine	275 mg/L	4.6 NTU
First Response w/ Chlorine	284 mg/L	.21 NTU
Modus	293 mg/L	2.3 NTU
Guardian	277 mg/L	3.3 NTU
Roving Blue	270 mg/L	.19 NTU

Observations
All systems stayed under the target objective of TDS less than 1,000 mg/L. Only the First Response with chlorine and the Roving Blue consistently stay under the less than 1 NTU turbidity objective, with the Roving Blue outperforming all other systems in that area.

Recommendations
The filtration system of any WPS considered for the IWPS prototype need to be reviewed ensuring they meet basic TDS and turbidity standards for water purification.

Objective 1.2: Assess water technology component portability
This objective seeked to characterize the portability of the water purification technology. Portability is the weight, number of personnel required to lift, volume of the technology. The number of personnel required was reported by the least number required which was determined by dividing the component’s weight by 50 lbs., and the maximum number required which was determined by dividing the component’s weight by 35 lbs.

Table 49. Obj. 1.2, MOE 1-2-1 through 1-2-3 Data

Objective 1.2: Assess water technology component portability MOE 1-2-1 through 1-2-3				
System	**Weight**	**Min # of personnel to lift**	**Max # of personnel to lift**	**Volume**
First Response	Filter 99 lbs.	2	3	24"L x 24"Wx 26"H
	Pump 44 lbs.	1	2	20"L x 14"W x 20"H
	Accessories 84lbs.	2	3	24"L x 24"Wx 26"H
Guardian	16 oz.	1	1	8.2" x 4.5" x 2.8"
Modus	110 lbs	3	4	33" x 28" x 18"
Roving Blue	25 lbs.	1	1	L 18.7" x W 14.8" x H 7"
O-Pen	1.58 oz.	1	1	L 5 3/4" x W .5" x H .5"

Observations

Ideally each component of the IWPS prototype would only require a 2-man lift, requiring each component to weigh 100 lbs. or less. All WPS technologies meet this requirement except for the Modus that weighs 110 lbs.

Recommendations

Given that the Modus shows promise as the WPS component of the IWPS prototype it should still be considered even with its slightly higher weight. If possible, identifying ways to lighten the system would add value.

MOS 1-2-5: SME Rating of Portability

Observations

All SMEs felt the WPS technologies were adequately portable, but acknowledged that there would be value in lightening the First Response and Modus if possible.

Recommendations

If possible, identify ways to lighten the First Response components and the Modus system.

Objective 1.3 Assess water output quantity

This objective seeked to characterize the amount of purified water produced (in gallons per day), number of people the water support per day and the amount of liquid waste (effluent) created though the purification process. Gallons per day was the determined by multiplying the average number of gallons of product water produced in an hour by the number of operating hours. It is important to note that the results do not account for system downtime for maintenance and repairs. The number of personnel supported was determined by dividing the gallons produced in one operational day by the standard of 2 gallons per day. The effluent produced by each technology will also be reported as gallons per day and calculated using the same formula as gallons produced per day.

Table 50. Obj. 1.3, MOE 1-3-1 through 1-3-3 Data

Objective 1.3 Assess water output quantity MOE 1-3-1 through 1-3-3			
System	**Average gallons per day**	**Number of personnel supported**	**Gallons of effluent per day**
First Response	3652.8	1826	0
Modus	1267.2	633	0
Roving Blue	211	105	0

Observations
The Guardian water purifier is not designed for mass production of water and is instead intended for personal use. The manual hand pump design and individual nature of the system resulted in no data being collected on average gallons produced per day. Both the First Response 5000 and the Modus easily produced the targeted 1,000 gallons per day, while the Roving Blue WPS fell short of the objective 1,000 gallons per day and threshold of 1,000 liters per day. No data was collected on effluent as none of the tested systems produce effluent during the purification process.

Recommendations
The First Response 5000 might provide more capacity than needed for the IWPS prototype, recommend using the FR 1000. Additional testing should be conducted with both the Modus and FR 1000 to determine the right system for the IWPS prototype.

Objective 1.4: Assess water technology training
The TEC will gather objective and subjective data to assess the water technology training. Objective data includes the time required for operators to become proficient with the system, training requirements (i.e., slide and projectors or on-site) and training materials. Users will rate the adequacy and time allocated for classroom and hands-on training.

Table 51. Obj. 1.4, MOE 1-4-1 Data

Objective 1.4 Assess water technology training MOE 1-4-1	
System	**Est. Time to Achieve User Proficiency**
First Response	1 hour to operate, 8 hours including full maintenance training
Modus	1 hour
Roving Blue	1 hour
Guardian	15 minutes
O-Pen	15 minutes
SilverDyne	30 minutes

Observations
The IWPS team did not have users during CV16. The times listed for MOE 1-4-1 are estimated times by the developers.

Recommendations
Future tests should include users. Data should be collected on actual training time required with various user group types.

Table 52. Obj. 1.4, MOE 1-4-2 and 1-4-3 Data

Objective 1.4: Assess water technology training MOE 1-4-2 and 1-4-3	
Characterize the training requirements and materials for each system	
First Response	Hands-on training is required for the operation and maintenance procedure of the First Response. Training materials do not currently exist for this system
Modus	System includes pictorial Quick Start Guide and full length instructions. Approximately one hour required to familiarize user with system components.
Guardian	Device includes pictorial quick start guide and full length instructions with troubleshooting guide. Approximately 15 minutes required to learn system.
Roving Blue	Roving Blue has an online training course about ozone and best practices, however, absent that, the system comes with complete operating instructions printed on the unit that should allow any English-reading user to operate the unit safely without instruction
O-Pen	Roving Blue has an online training course about ozone and best practices, however, absent that, the system comes with complete operating instructions printed on the unit that should allow any English-reading user to operate the unit safely without instruction
SilverDyne	None, just verbal

Observations

Each of the WPS technologies and additive technologies are simple to operate and use. Each system is estimated to require an hour or less to train a user to operate the system or administer the additive. The FR, having more maintenance requirements, can take up to one full work day to fully train users on how to operate, maintain, and troubleshoot the system. It is important to note that many HA/DR missions occur in areas where English is not the native language. This would likely impact training time to reach user proficiency.

Recommendations

All IWPS prototype technology components should come with a simple picture only training and operations manual to ensure users at various skill levels, and who speak various languages, can learn to operate and maintain the system.

Objective 1.6: Assess water technology maintenance actions

A formal reliability, availability, and maintainability assessment was not conducted since it is beyond the scope of the IWPS project. However, the TEC gathered any routine maintenance on event logs conducted during CV16. The TEC recorded maintenance actions taken, where the maintenance occurred, required supplies, and any other relevant details about the maintenance event.

The SMEs performed all troubleshooting, repairs and maintenance actions for the respective IWPS systems at the CV16 execution site near the JOC pond. It is important to note the systems did not operate for equal amounts of time during CV16 due to system availability and suitability. Each incident was rated as catastrophic, critical, marginal, or negligible. The rating system is described in Table 11. Table 12 identifies the incidents and any impact on CV16 execution.

Issues listed in the table are ordered by system chronologically as they occurred throughout CV16.

Table 53. Maintenance Actions Rating System Description

Category	Description	Definition
I	**Catastrophic**	Operations not possible IAW processes & procedures
II	**Critical**	Operations possible with major changes to existing processes & procedures.
III	**Marginal**	Operations possible with minor changes to existing processes & procedures.
IV	**Negligible**	Operations possible with relatively simple changes to existing processes & procedures.

Table 54. Obj. 1.6, MOE 1-6-1 through 1-6-5 First Response Data

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Impact**	**Mission Impact**	**Repair Location**	**Proprietary Components/ Special Tools**
First Response					
Pump Motor The pump motor is rusty and corroded. The SME removed the motor fan cap and kick started the motor with a screwdriver to operate.	6 min	IV	None. Issue discovered during initial set-up procedures.	JOC Pond	None
Pump The pump was not a self-priming pump and proved difficult to prime. The SMEs continued to refine the start up TTPs to address the issue of priming the pump.	12 min	IV	None. Issue discovered during initial set-up procedures.	JOC Pond	None
Pump Motor The pump motor overheated and the circuit tripped continuously upon restart. Additionally, the motor was too hot to touch. The SMEs recommended cooling the pump motor before restarting.	30 min	II	Delayed operations for 30 min.	JOC Pond	None
Pump Motor The pump motor overheated and the circuit tripped. The SME was able to reset the circuit breaker and restart the system.	2 min	III	Delayed operations for 2 min.	JOC Pond	None
Pump Motor The pump motor overheated and the circuit tripped. The SME was able to reset the circuit breaker and restart the system.	2 min	III	Delayed operations for 2 min.	JOC Pond	None
Pump Motor The pump motor overheated and the circuit tripped. The SME was able to reset the circuit breaker and restart the system.	3 min	III	Delayed operations for 3 min.	JOC Pond	None
Pump The pump was not a self-priming pump and proved difficult to prime. The SMEs followed re-priming procedures twice before restarting.	14 min	IV	None. Issue discovered during initial set-up	JOC Pond	None

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Impact**	**Mission Impact**	**Repair Location**	**Proprietary Components/ Special Tools**
			procedures.		
Backwash The flow rate decreased to 1.5 g/min. at 10 min. into operations. The SME backwashed and restarted the system. The flow rate increased to 4.5 g/min.	9 min	III	Delayed operations for 9 min.	JOC Pond	None
Pump Motor The pump motor overheated and the circuit tripped. The SME was able to reset the circuit breaker and restart the system.	2 min	III	Delayed operations for 2 min.	JOC Pond	None
Pump The pump proved difficult to prime. The SMEs followed re-priming procedures three times before restarting.	18 min	IV	None. Issue discovered during initial set-up procedures.	JOC Pond	None
Backwash The flow rate decreased significantly at 48 min. into operations. The SME backwashed and restarted the system. The flow rate increased.	9 min	III	Delayed operations for 9 min.	JOC Pond	None
Restarting After backwashing the system, the SMEs had to restart the system 8 times before it continuously ran for more than 20 sec. without shutting down.	4 min	III	Delayed operations for 4 min.	JOC Pond	None
Pump Motor The pump motor overheated and the circuit tripped. The SME was able to reset the circuit breaker and restart the system.	1 min	III	Delayed operations for 1 min.	JOC Pond	None
Pump The pump was not a self-priming pumped and proved difficult to prime. The SMEs followed re-priming procedures four before restarting.	22 min	IV	None. Issue discovered during initial set-up procedures.	JOC Pond	None
Backwash The flow rate decreased significantly at 43 min. into operations. The SME backwashed and restarted the system. The flow rate increased.	11 min	III	Delayed operations for 11 min.	JOC Pond	None
Pump Motor The pump motor overheated and the circuit tripped. The SME was able to reset the circuit breaker and restart the system.	1 min	III	Delayed operations for 1 min.	JOC Pond	None
Pump Motor The pump motor overheated and the circuit tripped. The SME was able to reset the circuit breaker and restart the system.	1 min	III	Delayed operations for 1 min.	JOC Pond	None
Pump Motor The pump motor overheated and the circuit tripped. The SME reset the circuit breaker and restarted the system; however, the system continued to trip and shut off. The SMEs	Rest of the day	I	Did not operate the First Response for the rest of the	JOC Pond	None

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Impact**	**Mission Impact**	**Repair Location**	**Proprietary Components/ Special Tools**
decided to stop testing at this point in the day (46 min into operations).			day.		

Observations

All First Response maintenance, repairs and troubleshooting actions were easily conducted by the SMEs at the JOC pond test site. The only tool required was a screw driver to remove the pump motor fan cap and kick start the motor.

The pump motor overheated and the circuit breaker tripped 11 times. The SMEs spent 52 min. total on the pump motor to restore operations. During one occurrence, the SMEs decided to let the motor cool for 30 min. During another instance, the SMEs decided to end the test event for the day. The SMEs were unsure if the circuit was defective or improperly rated for the system (Figure 12). To continue operations, the SME removed the circuit breaker on 2 Sep 2016. The system did not shut off at all during operations once the circuit breaker was removed and the pump, although too hot to touch, continued to operate consistently.

The First Response pump is not self-priming or submersible. The SMEs had difficulty priming the pump when the system would initially turn on. The SMEs experienced difficulty priming the system four times and spent a total of 1 hr 6 min. priming the pump. The process became easier throughout the CV16 exercise because the SMEs continued to modify and adapt new Tactics, Techniques, and Procedures (TTPs) and rules of thumb to minimize the amount of time spent on priming the pump. The final TTP used included: taking the lid off, filling the pump with water, continuously pouring water over the pump while starting the motor and closing the pump lid once the system was operational. This TTP took two SMEs to conduct.

The First Response system needed to be backwashed during operations three times due to decreased flow rates. The SME spent 29 min. total backwashing the system during operations outside of normal setup/teardown backwashing procedures. The SMEs added additional steps to the setup and teardown procedures. SMEs decided to backwash the system at the end of each use and before each use. The SME also soaked the filters in chlorinated water overnight. These procedures were put into place to counter the high organics and sediment in the source water (Figure 12).

Figure 37. First Response Pump Motor Circuit Breaker (left) Backwash Output (right)

Recommendation 1
The FR in its current form is easy to maintain due to its simple design and lack of a requirement for special tools or proprietary parts. Future iterations of the system should continue to focus on easy to maintain designs.

Recommendation 2
The current motor/circuit system for the FR should be reviewed and a more efficient and reliable motor installed.

Recommendation 3
The current requirement to manually prime the FR pump impacts various characteristics of the system including man power requirement, total water production, and the reliability of the system. Future system designs should incorporate a self-priming pump.

Recommendation 4
The need to repeatedly backwash the system impacted operational time and water production. TTPs should be developed and recorded in an operations handbook, based on estimated organics and sediment levels in source water, to provide operators a way to gage backwash procedure requirements including how to and how often. Alternately, a mechanism for the FR to automatically backwash when necessary would significantly impact the semi-autonomous nature of the system, causing it to be more reliable when operating autonomously.

Table 55. Obj. 1.6, MOE 1-6-1 through 1-6-5 Modus Data

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Impact**	**Mission Impact**	**Repair Location**	**Proprietary Components /Special Tools**
Modus					
<u>Relief Valve Activated</u> Approximately 1 min. into operations, the relief valve activated due to the differential	6 min	III	Delayed operations for 6 min.	JOC Pond	None

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Impact**	**Mission Impact**	**Repair Location**	**Proprietary Components /Special Tools**
pressure exceeding 50 psi. The SME checked all hoses and connections and restarted the system.					
<u>Filter #2 – 0.2 micron</u> The filter life indicator was 100% red 16 min. into operations. The SME removed and cleaned the filter, returned the filter to the cartridge and restarted the system.	3 min	III	Delayed operations for 3 min.	JOC Pond	None
<u>Filter #3 – Carbon</u> The filter life indicator was 100% red at 29 min. into operations. The SME stated that the system could continue to run, but the flow rate would decrease.	0	III	Decreased flow rate.	JOC Pond	None
<u>Filter #3 – Carbon / Relief Valve Activated</u> The relief valve activated 43 min. into operations. The SME replaced the carbon filter and added an extension hose to the source water hose to push the source water extraction point further away from the bank in hopes that less sediment/organics/particulates would be extracted. The SME restarted the system.	11 min	III	Delayed operations for 11 min.	JOC Pond	None (Carbon Filter is off the shelf COTS pool filter and hose is in the kit with standard fittings)
<u>Filter #2 – 0.2 micron and Filter #4 – Carbon</u> Both Filter #2 and Filter #3 were 100% red 19 min. into operations.	0	III	Decreased flow rate.	JOC Pond	None
<u>Filter #4</u> Filter #4 was 70% red 23 min. into operations.	0	III	Decreased flow rate.	JOC Pond	None
<u>Filter #2 – 0.2 micron and Filter #4 – Carbon</u> Both Filter #2 and Filter #3 were 100% red 11 min. into operations. The differential pressure increased to 36 psi.	0	III	Decreased flow rate.	JOC Pond	None
<u>Filter #2 – 0.2 micron</u> The SME removed and washed Filter #2.at 12 min. into operations. The SME restarted the system.	5 min.	III	Delayed operations for 5 min.	JOC Pond	None
<u>Filter #2 – 0.2 micron</u> At restart (12 min. operational), Filter #2 turned 50% red.	0	III	Decreased flow rate.	JOC Pond	None
<u>Filter #2 – 0.2 micron and Relief Valve</u> The relief valve activated 18 min. into operations. The SME cleaned Filter #2 and restarted the system.	6 min.	III	Delayed operations for 6 min.	JOC Pond	None

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Impact**	**Mission Impact**	**Repair Location**	**Proprietary Components /Special Tools**
Filter #2 – 0.2 micron and Relief Valve The relief valve activated 20 min. into operations. The SME cleaned Filter #2 and restarted the system at 22 min. into operations. At restart, Filter #2 was still 100% red. The SME turned the system on/off with no change. At 23 min. into operations, the relief valve activated.	4 min.	III	Decreased flow rate. (note: the team decided to operate the system for 2 min. with the relief valve activated to get flow rate data). Delayed operations for 4 min.	JOC Pond	None
Filters #1, #2 and Relief Valve At 27 min. into operations the SME shut down the system to clean Filters #1 and #2. The SME restarted the system.	3 min.	III	Delayed operations for 3 min.	JOC Pond	None
Filters - Modus #1 At restart (27 min.into operations), the SME decided to operate the spare Modus onsite to see if the filter issue could be replicated.	14 min. to switch to spare (rest of day)	II	Delayed operations for 14 min. Modus #1 not used.	JOC Pond	None
Filter #2 – 0.2 micron (Modus #2) At 9 min. into operations, Filter #2 turned 100% red.	0	III	Decreased flow rate.	JOC Pond	None
Relief Valve (Modus #2) At 16 min. into operations, the relief valve activated and the SME turned the system off.	Rest of the test day	I	Did not operate the Modus for the rest of the day.	JOC Pond	None

Observations

All Modus maintenance, repairs and troubleshooting actions were easily conducted by the SME at the JOC pond test site. The Modus is specifically engineered to ensure all maintenance and repairs can occur without special tools. All canister knobs are hand-tightened and hoses have barbed quick release hose fittings. The Modus does contain a hose connector tool that makes it easier to disconnect hoses, but it is not necessary. All the Modus parts are quick release and interchangeable. When the team switched from using the Modus #1 (backpack configuration) to the spare Modus #2 (pelican case configuration), the relief valve from the Modus #1 was removed and placed onto Modus #2 quickly and easily.

The Modus relief valve experienced some issues during the event. The differential pressure increased to above 50 psi, which; in turn, activates the relief valve. The issue occurred one time at the start of operations and took 6 min. to resolve. Once the SME checked and reconnected all hoses to the cartridges, the psi decreased and operated without the relief valve engaged.

The Modus filters experienced buildup, which decreased the flow rate 13 times. The SME spent a total of 52 minutes troubleshooting, cleaning, or swapping out the filters during operations outside of normal teardown procedures. The SME decided to continue operations six times when the filter indicators were ≥70% red with a decreased flow rate to continue operations (Figure 13). In one instance, the team decided to stop testing for the remainder of the day. The SME washed filters #1 and #2 as a maintenance action to prepare for the next day. The SMEs discussed developing a filter maintenance cycle. Initial thoughts were to wash the filter every 10 min. the system is operational when functioning in an environment with high organics and sediment as observed at CV16.

Figure 38. Modus Filter Indicators

Recommendation 1
The Modus in its current form is easy to maintain due to its simple design and lack of a requirement for special tools. Future iterations of the system should continue to focus on easy to maintain designs.

Recommendation 2
It is likely not realistic to operate a system that has a filter that requires cleaning every 10 minutes in environments with high organics and sediments. New filters should be considered and integrated into the Modus system to allow it to successfully operate in these environments.

Table 56. Obj. 1.6, MOE 1-6-1 through 1-6-5 Guardian Data

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Impact**	**Mission Impact**	**Repair Location**	**Proprietary Components/ Special Tools**
Guardian					
<u>Filter Overtightened</u> The filter was overtightened by the user. As a result, the Guardian leaked water. The SME explained how to hand-tighten the filter and fixed the issue.	2 min.	IV	Training mitigated issue.	JOC Pond	None

Observations
The Guardian experienced only one issue. The operator overtightened the filter, which caused the Guardian to leak water. There was no visual or audible que to indicate when the filter is appropriately tightened. This issue was easily resolved by the SME by removing and reattaching the filter.

Recommendation
Incorporate some indicator to let the user know if the filter is overtightened.

Table 57. Obj. 1.6, MOE 1-6-1 through 1-6-5 Roving Blue with Filtration Data

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Impact**	**Mission Impact**	**Repair Location**	**Proprietary Components/ Special Tools**
Roving Blue WPS with Filtration					
Backwash End Cap Valve The backwash end cap valve detached from the hose due to pressure buildup. SMEs used zip ties to reattach the valve to the hose and hold in place.	3 min.	III	Delayed operations for 3 min.	JOC Pond	None
Hose The hose attached to the filter detached during operations. The SME reattached the hose, backwashed the system, and restarted the system.	2 min.	III	Delayed operations for 2 min.	JOC Pond	None
Shut Off The system shut off for no apparent reason. The SME restarted the system.	3 min.	III	Delayed operations for 3 min.	JOC Pond	None
Hose The red hose leading to the .10 micron filter detached during operations. The SME reattached the hose and restarted the system.	1 min.	III	Delayed operations for 1 min.	JOC Pond	None
Shut Off The system shut off for no apparent reason. The SME restarted the system.	2 min.	III	Delayed operations for 2 min.	JOC Pond	None
Shut Off The system shut off for no apparent reason. The SME backwashed and restarted the system.	3 min.	III	Delayed operations for 3 min.	JOC Pond	None
Shut Off The system shut off for no apparent reason. The SME backwashed and restarted the system.	3 min.	III	Delayed operations for 3 min.	JOC Pond	None
Battery The battery died. The battery cannot be charged while operating. The SME used the Squad Power Manager with 100W solar blanket to recharge.	Rest of the test day	I	Did not operate the system that day while battery	JOC Pond	Battery

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Imp act**	**Mission Impact**	**Repair Location**	**Proprietary Components/ Special Tools**
			recharged. A spare battery was not available.		
Battery The battery died again. The battery cannot be charged while operating.	Rest of the test day	I	Did not operate the system that day while battery recharged. A spare battery was not available.	JOC Pond	Battery

Observations

All Roving Blue WPS with Filtration maintenance, repairs and troubleshooting actions were easily conducted by the SMEs at the JOC pond test site. The only tool required was a zip tie to affix the hose to the system.

Hoses detached from the system three times during operations due to pressure buildup. Reattaching the hoses took a total of 6 min. and in one instance the SME needed to use a zip tie to affix the hose to the system (Figure 14).

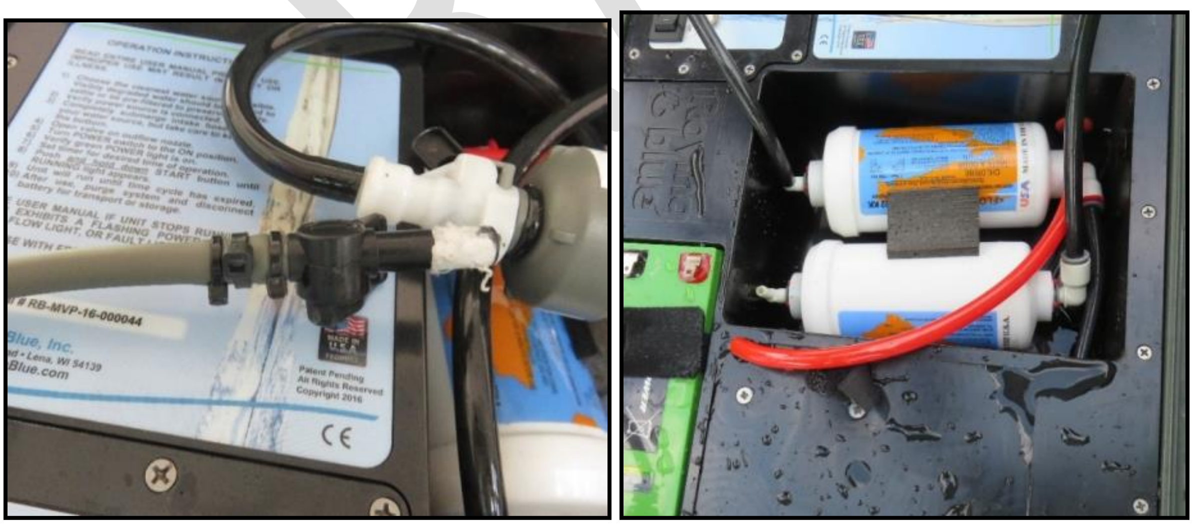


Figure 39. Filtration Hose Zip Tied to Backwash Valve (left) Filtration Hose Detached from Filter (right)

The system inadvertently shut off four times during operations. The total downtime to troubleshoot and restart the system was 11 min. The SMEs did not know exactly why the system was inadvertently powering off.

Twice, the battery was completely dead at the start of operations although the SME remembered powering down the system at the end of the previous day. In both cases, the system was not used that test day because there was no spare battery and the system could not operate while charging the battery (Figure 15).

Figure 40. Charging the Roving Blue WPS with Filtration Battery with the Squad Power Manager with 100W Solar Blanket

Recommendation 1
The Roving Blue in its current form is easy to maintain due to its simple design and lack of a requirement for special tools. Future iterations of the system should continue to focus on easy to maintain designs.

Recommendation 2
The system needs a better method for attaching hoses that ensures they do not detached unless there is a safety related issue, or if the operator is intentionally trying to detach them.

Recommendation 3
The system needs to undergo further testing by the developer to determine why it would inadvertently power off.

Recommendation 4
The system needs to undergo further testing by the developer to determine why the battery continued to drain even when shutdown.

Table 58. Obj. 1.6, MOE 1-6-1 through 1-6-5 Roving Blue without Filtration Data

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Impact**	**Mission Impact**	**Repair Location**	**Proprietary Components/ Special Tools**
Roving Blue WPS without Filtration					
System Shut Off The system was powering off after approximately 7 sec. of operations, which is not a long enough treatment time to be effective.	NA	I	The O-Zone WPS without filtration was not used.	JOC Pond	None

Observations

The system powered off after approximately 7 sec. of operations, which is not a long enough for a treatment cycle to be effective. The SMEs believed it was a coding error that could not be fixed in the field. Due to this, the system was not used but was available for display purposes.

Recommendation

Further testing by the developer should be conducted on the Roving Blue without filtration to determine why the system would not operate effectively.

Table 59. Obj. 1.6, MOE 1-6-1 through 1-6-5 O-Pen Data

Objective 1.6: Assess water technology maintenance action MOE 1-6-1 through 1-6-5					
Incident / Remedy	**Down Time**	**Impact**	**Mission Impact**	**Repair Location**	**Proprietary Components/ Special Tools**
O-Pen					
Cleaning and Maintenance The O-Pen did not have clear guidance on cleaning the system. The O-Pen had a foul odor hours after use from the source water.	NA	I	The O-Pen may have had coliform and E. coli present and contaminated other water samples.	JOC Pond	None

Observations

The O-Pen did not have clear guidance on cleaning the system. The O-Pen had a foul odor hours after use from the source water. The O-Pen may have had coliform and E. coli present and contaminated other water samples.

Recommendations

Better guidance and training materials should be created by the developer to ensure operators effectively use the O-Pen. Further testing by the developer should be conducted to ensure the O-Pen is not contaminating samples when passed from one sample to another.

MOS 1-6-7: SME rating of ease to conduct maintenance

The CV16 SMEs felt they easily conducted maintenance on the FR, Modus, Guardian, and Roving Blue with filtration. Due to the Roving Blue without filtration not operating no observations could be made about the ease of maintenance. Additionally, the lack of good guidance on how to clean the O-Pen left the SMEs unsure about the overall ease or difficulty of maintenance for the technology.

Objective 1.7: Assess water technology environmental operating conditions

The environmental conditions include the time and temperature the technology can be stored, the operating temperature and time and the temperature of the source water that can be purified. The temperature was reported in degrees, time in days, and the maximum and minimum temperature range of the water source. During CV16 a TEC SME will characterize the ability of the technology to operate in rain, snow, heat, cold, wind, humidity, dust, and hail.

Table 60. Obj. 1.7, MOE 1-7-1 through 1-7-3 Data

Objective 1.7: Assess water technology environmental operating conditions MOE 1-7-1 through 1-7-3			
System	**Max Temp in Storage**	**Max Temp in Operation**	**Temp Ranges for Source Water**
First Response	Unknown	100°F	Est. 40-90°F
Guardian	160°F	120°F	34F to 120°F
Modus	160°F	115°F	34F to 120°F
Roving Blue	125 °C for the electronics, unknown for the entire system	unknown	unknown

Table 61. Obj. 1.7, MOE 1-7-4 through 1-7-11 FR Data

Objective 1.7: Assess water technology environmental operating conditions MOE 1-7-4 through 1-7-11	
Characterize the ability of the First Response system to operate in these conditions	
Rain	Can be operated in rain but the electric pump would need to be covered to protect from rain damage
Snow	Not tested
Heat	Will operate under hot conditions but the pump will automatically turn off when the pump is too hot
Cold	Not tested
Wind	Wind has no effect on the operation of the First Response
Humidity	Humidity has no effect on the operation of the First Response
Dust	Not tested
Hail	Not tested

Observations

The FR system has been demonstrated multiple times under hot and humid conditions and has been found to function well in these conditions. However, it has not been tested in snow, excessive cold, dust, or during hail. The pump does need to be covered during rain which might pose an issue if left unmanned.

Recommendations
The FR should undergo additional testing to ensure it can operate in various environmental conditions. Additionally, consideration should be given to developing a way to protect the system from elements such as rain, snow, and dust that is inherent to the system and allows it to remain unmanned if needed.

Table 62. Obj. 1.7, MOE 1-7-4 through 1-7-11 Modus Data

Objective 1.7: Assess water technology environmental operating conditions MOE 1-7-4 through 1-7-11	
Characterize the ability of the Modus system to operate in these conditions	
Rain	Fully functional
Snow	Fully functional if unit is not frozen. Freeze/thaw will not damage unit if properly drained. System must be thawed before use.
Heat	Fully functional, if extreme heat (>115 ^{o}F) electric pump will turn off automatically before overheating
Cold	Prevent system from freezing, otherwise fully functional. Freeze/thaw will not damage unit if properly drained. System must be thawed before use.
Wind	Fully functional
Humidity	Fully functional
Dust	Fully functional, protecting motor from excessive dust is ideal
Hail	Fully functional

Observations
The Modus has undergone testing in various environmental conditions and was found to be fully functional under each condition with some special consideration for excessive cold.

Recommendations
Considerations should be given to developing a method of protecting the Modus motor from excessive dust that is inherent to the system.

Table 63. Obj. 1.7, MOE 1-7-4 through 1-7-11 Guardian Data

Objective 1.7: Assess water technology environmental operating conditions MOE 1-7-4 through 1-7-11	
Characterize the ability of the Guardian system to operate in these conditions	
Rain	Fully functional
Snow	Fully functional if unit is not frozen. Freeze/thaw will not damage unit if properly drained. System must be thawed before use.
Heat	Max tested operational water temperature is 120F; storage temp 160F
Cold	Fully functional if unit is not frozen. Freeze/thaw will not damage unit if properly drained. System must be thawed before use.
Wind	Fully functional
Humidity	Fully functional
Dust	Fully functional; moving parts must be cleaned and serviced to prevent accelerated wear
Hail	Fully functional

Observations
The Guardian has undergone testing in various environmental conditions and has found to be fully functional under each condition with some special considerations for excessive cold and dusty conditions.

Recommendations
None at this time

Table 64. Obj. 1.7, MOE 1-7-4 through 1-7-11 Roving Blue Data

Objective 1.7: Assess water technology environmental operating conditions MOE 1-7-4 through 1-7-11	
Characterize the ability of the Roving Blue system to operate in these conditions	
Rain	Case is IP67 rated, no other detailed were provided
Snow	Case is IP67 rated, no other detailed were provided
Heat	Case is IP67 rated, no other detailed were provided
Cold	Case is IP67 rated, no other detailed were provided
Wind	Case is IP67 rated, no other detailed were provided
Humidity	Case is IP67 rated, no other detailed were provided
Dust	Case is IP67 rated, no other detailed were provided
Hail	Case is IP67 rated, no other detailed were provided

Observations
The case for the Roving Blue WPS is rated IP67, but no information was provided on how the system would operate in various conditions.

Objective 1.8: Assess ability to safely operate
A TEC SME will provide information on whether each water technology complies with Department of Defense (DoD) and Occupational Safety and Health Administration (OSHA) standards. Users will provide a rating regarding the ability to safely operate the technology.

Table 65. Obj. 1.8, MOE 1-8-1 Data

Objective 1.8: Assess ability to safely operate MOE 1-8-1	
Characterize the compliance of each system with safety regulations	
First Response	First Response is still in prototype form
Modus	Modus was developed to meet the military’s drinking water disinfection standard, the NSF/ANSI P248. The P248 is the definitive standard across the entire DoD (all branches of the military) for microbial disinfection of drinking water.
Guardian	Guardian was developed to meet the military’s drinking water disinfection standard, the NSF/ANSI P248. The P248 is the definitive standard across the entire DoD (all branches of the military) for microbial disinfection of drinking water.
Roving Blue	This system was designed to all EPA, NSF, UL and CE requirements
O-Pen	This system was designed to all EPA, NSF, UL and CE requirements
SilverDyne	Testing with water organizations have shown adequacy. The amount of silver is below EU recommendations, even long range.

Observations
Operating safety and the safety of the product water are of the highest importance for the IWPS prototype. Some of the tested WPS technologies have been developed with certain DoD and industry standards in mind, others are still in the prototype phase of development.

Recommendations
Safety requirements should be identified and tested for each component of the IWPS prototype once the final configuration is identified.

MOS 1-8-3: SME rating of safety
All SMEs surveyed felt the FR, Guardian, and Modus would be safe to operate to support multiple mission types. The group was less certain of the safety of the Roving Blue WPS, but with the system not operating as expected more operating time would be required for the SMEs to provide good feedback on the system. Finally, all SMEs agreed they were not comfortable with the safety level of the SilverDyne and O-Pen technologies.

Objective 1.9: Assess power consumption
Power consumption was recorded as the average number of watts required to produce a gallon of water.

Table 66. Obj. 1.9, MOE 1-9-1 Data

Objective 1.9: Assess power consumption MOE 1-9-1				
System	**Average Watts per hour**	**Average Watts per day**	**Average Gallons per hour**	**Average Watts per gallon**
First Response	832.2	19972.8	152.2	5.5
Modus	71.6	1704	52.8	1.35
Roving Blue	NA	NA	8.8	NA

Observations
The Modus WPS produces each gallon using significantly less power than the FR. No data was collected on the power requirements for the Roving Blue WPS due to the system shutting down each time a watt meter was connected. The team tried two separate watt meters, but the system shut down when connecting either meter.

Recommendations
The FR 1000 should be considered instead of the 5000 to determine if the W per hour are more efficient. Additionally, a review of the current FR pump and motor should be conducted to determine if a more efficient part could be integrated.

Objective 1.10: Assess semi-autonomous operations
The semi-autonomous capability ensures the water purification technology does not have to be constantly manned and will automatically shut off prior to a system failure.

Table 67. Obj. 1.10, MOE 1-10-2 Data

Objective 1.10: Assess semi-autonomous operations MOE 1-10-2	
Characterize the automatic shut off capability of each system	
First Response	A manual procedure is required to start and stop the operation. Although the current pump caused the system to shut off when it overheated, that was not a mechanism built into the system for safety. It was a previously unknown issue.
Modus	The pump system will internally bypass if system goes over 50 psi and will turn off if the motor overheats. The filtration system will vent water if it goes over 50 psi.
Guardian	N/A. Manually operated. Fully automated pressure relief valve protects system from over pressurization. Guardian is also self-cleaning.
Roving Blue	This system will shut itself off if any safety parameters are missing.

Observations

The FR system does not have an automatic shut off capability incorporated into the system. This could pose problems impacting system maintenance, and the ability to leave the system running unattended.

Recommendation

The final version of the FR should include safety measures that cause the system to shut off under any unsafe conditions. These conditions should be identified and requirements developed to inform future development of the FR.

Table 68. Obj. 1.10, MOE 1-10-3 Data

Objective 1.10: Assess semi-autonomous operations MOE 1-10-3	
Characterize power performance monitoring capability of each system	
First Response	None
Modus	There is no electrical power performance monitoring.
Guardian	N/A. System is manually operated.
Roving Blue	The Roving Blue MVP unit has a graphic display that shows the power left in the batteries.
O-Pen	The O-Pen will not light a green operational light and will not operate if the batteries are drained. However a portable charge bank can display the battery state.

Observation

The FR and Modus do not currently have any power performance monitoring capability.

Recommendation

Future FR and Modus prototypes should include power performance monitoring to improve the efficiency, maintenance, and operations of the systems.

Table 69. Obj. 1.10, MOE 1-10-4 Data

Objective 1.10: Assess semi-autonomous operations MOE 1-10-4	
Characterize embedded diagnostic capability of each system	
First Response	First Response has a gauge for the pre-filter monitoring and another gauge to monitor the Ultra-Filtration. These gauges will determine if the pre-filters and Ultra-Filtration require maintenance prior to proceeding with the operation.
Modus	There is a complete system pressure gauge and differential pressure gauges mounted on each filter to allow the user to visually diagnose the system performance. Manual field test can be performed to test integrity of system.
Guardian	N/A. System is manually operated. Manual field test can be performed to test integrity of system.
Roving Blue	The MVP unit has fully capable diagnostics which will display whether a filter needs servicing, changing or if the ozone unit needs replacing.

Observations

The WPS technologies have a range of diagnostic capabilities. The Guardian has no diagnostic capability, the Modus and FR have some basic diagnostic mechanisms, and the Roving Blue has a fully capable diagnostic system.

Recommendations

Any WPS chosen for the IWPS prototype should include embedded diagnostic capabilities to help ensure maximum operating time during missions.

Table 70. Obj. 1.10, MOE 1-10-5 Data

Objective 1.10: Assess semi-autonomous operations MOE 1-10-5	
Characterize start and stop process of each system	
First Response	The pump must be primed prior to starting the system. The system is turned off and on with a simple switch.
Modus	In electrically powered operation, start/stop entails only toggling a switch and venting. In other use modes, gravity, municipal supply, hand pump, hand pump floor mode the system requires manual operation. To initially setup system, use the Quick Start Guide to connect the appropriate plumbing. Estimated time is 5 minutes. Once completed, system is drained and packed. Estimated time is 10 minutes.
Guardian	Uncoil hose, remove outlet cap, attach water bottle, and manually pump desired amount of water from a freshwater source. Then remove hose from source, pump excess water out of system, coil hose, attach outlet cap, and store.
Roving Blue	The MVP unit features a 2-stage On and Start function.

Observations

Each of the WPS technologies uses a relatively simple start and stop process.

MOS 1-10-7: SME rating of semi-autonomous capability

SMEs felt most comfortable rating the FR as semi-autonomous, with both the Modus and Roving Blue also receiving positive feedback. Due to the manual operation of the Guardian, it was not considered in relation to MOS 1-10-7.

COI 2: Is IWPS transportable to effectively support various missions including austere FOBs and HA/DR missions?

The goal of this COI is to determine whether the water purification technologies are transportable via commercial and military air and ground.

Objective 2.1: Assess air transportability
This objective assessed the transportability of the water purification technologies by commercial or military aircraft. The system should not require any special cargo handling equipment.

Table 71. Obj. 2.1, MOE 2-1-1 and 2-1-2 Data

Objective 2.1: Assess air transportability MOE 2-1-1 and 2-1-2		
System	**Is the system transportable by commercial air**	**Does the system require any special cargo handling**
First Response	Yes	No
Modus	Yes	No
Roving Blue	Yes	No
Guardian	Yes	No
O-Pen	Yes	No
SilverDyne	Yes	No

Observations
All tested technologies are transportable by commercial air. Some require additional charges for overweight baggage, but no special cargo handling.

Recommendations
Ensure all components of the IWPS prototype continue to be transportable by commercial air, with no special handling requirements.

Objective 2.2: Assess land transportability
This objective assessed the transportability of the water purification technologies by land. The land transport vehicle could be either a light truck or trailer. The system should be rugged enough to operate after being transported by the vehicle. SMEs provided feedback on the ruggedness of each system

MOE 2-2-1 and 2-2-2 Land Vehicle Requirements and System Ruggedness after Transport
All of the WPS technologies and additives can be easily transported. The larger systems like the FR and Modus require a small truck, or Small Utility Vehicle (SUV), while the smaller units can be transported in a backpack. The packaging of the systems for transport varies greatly. The first response uses crates, the Modus a backpack and/or pelican case, the Roving Blue a pelican case, and the remaining technologies into any personal backpack.

Observations
Not all systems are ruggedizing adequately for transportation.

Recommendation
All IWPS prototype components should include a ruggedized shipping method.

MOE 2-2-3: SME Rating of System Ruggedness
The consensus among the CV16 SMEs was that the FR, Modus, Guardian, and Roving Blue were all adequately ruggedized. However, any system included as part of the IWPS prototype would need to be further ruggedized to ensure it could support multiple mission types.

COI 3: Does the IWPS power source provide reliable power from primarily renewable sources?

The goal of this COI was to determine whether the power capability generates enough power, primarily from renewable sources, to operate the water purification technology.

Objective 3.1: Assess power type
The power output should facilitate running the water purification technology, operating on 110/220 VAC DC. The power source should include additional auxiliary outlets. To ensure local power needs are met if necessary, the power source should include international adapter kits and a power inverter with true sine wave output.

Table 72. Obj. 3.1, MOE 3-1-1 through 3-1-4 Data

Objective 3.1: Assess power type MOE 3-1-1 through 3-1-4				
System	**Type of Power Output**	**# of Auxiliary Power Outlets**	**Adapter kits (International)**	**Characterize Power Inverter**
STAESS	24 VDC and 120/240 VAC	2-120VAC 1-240 VAC 24 VDC	1 Universal AC kit	Magnum inverter 120/240 VAC 50/60 HZ. 4000 watts continuous, 5500 watts intermittent. Programmable auto on and low voltage disconnect
SPM w/100W Solar	4-34 VDC 120 AC/DC converter in the kit to be used with "wall power"	4-34 VDC 120 AC/DC converter in the kit to be used with "wall power"	1	NA
1 kW Generator	120 AC and 12CDC	1 AC and 1 DC	0	NA

Observations
The three power technologies tested provided a variety of power sources, and auxiliary outlet options. The STAESS and SPM include universal adapter kits.

Recommendations
Continue power integration testing in future events to confirm the right energy technology to support the final IWPS prototype components. Collect data on the ideal number and type of auxiliary outlets, adapter kits, and any other system requirements.

Objective 3.2: Assess power availability
This objective seeked to characterize the amount of power output in a day, the down time due to power interruptions. While the power should be available 24/7, power interruptions should not exceed 60 minutes.

Table 73. Obj. 3.1, MOE 3-2-1 through 3-2-3 Data

Objective 3.2: Assess power type MOE 3-2-1 through 3-2-3			
System	**kWh per day**	**Power Interruptions**	**Operational time per day**
STAESS	32 X 125 watt solar panels = 4000 watts. Variable depending on available sunlight each day. System is rated at full sun 4000 watts from 8 AM- 5PM will give the equivalent of 6 hours of full sun. This calculated to 4000 watts X 6 =24,000 watts of solar power production	None	The STAESS system is able to operate 24 hours per day using both solar panels and battery storage.
SPM w/100W Solar	For the SPM with Solar we always plan for 70 % of the panels rating with about 5-7 hours of usable daylight. This would be a potential of 490WH	None	24 hours with proper power source
1 kW Generator	800W continuously during operation. It will run for about 5-6 hours on a tank of gas (.67 gallons) so depending on how long you operate it in a day will determine potential energy. 24 hours = 19,200WH	None	24 hours if monitored and refueled

Observations
The STAESS is more than capable of powering any of the WPS being considered for the IWPS prototype. The SPM and 1 kW generator appear to have value added as small scale power sources, and/or backup systems.

Recommendations
Continue testing the STAESS, SPM, and 1 kW generator as part of IWPS prototyping to identify any potential system requirements and TTPs. Conduct more in depth power integration assessments in future events.

Objective 3.3 Assess power technology component portability
This objective seeked to characterize the portability of the power technology. As with the water technology, portability is the weight, number of personnel required to lift, and volume of each component of the technology. The number of personnel required was reported by the least number required which was determined by dividing the component’s weight by 50 lbs., and the maximum number required which was determined by dividing the component’s weight by 35 lbs.

Table 74. Obj. 3.3 MOE 3-3-1 through 3-3-3 Data

Objective 3.3: Assess power technology component portability MOE 3-3-1 through 3-3-3				
System	**Weight**	**2-man lift (Y/N)**	**Volume (packed)**	**Volume (deployed)**
STAESS	Inverter pelican case approximately 90 LB Solar charge controller pelican case 60 LB 2 pelican case each with 16 125-watt folding solar panels, each pelican case 110 LB	Y, except for solar panel cases	In case #1 24” L X 20” W X 16”D Charge controller case #2 20”L X 18”W X 12”D Battery case # 3&4 100AH X 2 cases 20” L X 18” W X 12” D Cable case #5 36” L X 24” W X 24” D	The 5 pelican cases will fit in a 5’ x 5’ area. The 32 STORM solar panels will fit in a 30’ x 15’ area with enough space to walk between panels.
SPM w/100W Solar	< 6 lbs	Y	1.8” h x 4” w x 2.3” d	1.8” h x 4” w x 2.3” d
1 kW Generator	30.6 lbs dry	Y	17.7” x 12.3” x 14.9”	17.7” x 12.3” x 14.9”

Observations

Each of the components of the power technologies are less than 100 lbs., except for the STAESS solar panel pelican cases. These cases are 110 lbs., and might require a 3-man lift. The deployed area of the STAESS system, given it can easily power any of the tested WPS technologies, is reasonable for the size of the system.

Recommendations

Review the current STAESS design to see if it is possible to reduce the weight of the system to a 2-man lift (100 lbs. or less).

MOS 3-3-5: SME Rating of Power Source Portability

All SMEs surveyed felt the STAESS, SPM, and 1 kW generator were easily portable to support multiple mission types.

Objective 3.4: Assess ability to safely operate

The power source technology should comply with DOD and OSHA standards. SMEs will provide a rating regard the ability to safely operate the technology.

Table 75. Obj. 3.4, MOE 3-8-2 Data

Objective 3.4: Assess ability to safely operate MOE 3-8-1	
Characterize the compliance of each system with DoD and OSHA standards	
STAESS	The 125-watt solar panels are MIL STD 810G tested. STAESS main components Magnum 4 KW DC to AC inverter and Morning Star solar charge controller both are UL certified

	for safety. All DC circuits input and output has circuit breakers. The 120/240 VAC has GFI (ground fault interrupter) circuit breakers for shock hazard safety. The original lithium Iron Phosphate 24 VDC battery system is sealed and does not emit any fumes, it has a battery management circuit that protects the batteries from over and under charging. When using sealed lead acid batteries bought in country we use 24 volts DC which is low voltage and poses no shock hazard and they also are wired into the DC circuit breakers.
SPM w/100W Solar	This is a program of record in the US ARMY. Meets MILSTD 810G
1 kW Generator	This is a program of record in the US ARMY. Meets MILSTD 810G

Observations

Each of the power technologies have been designed to adequately meet or exceed safety standards. In the case of the SPM and 1 kW generator these technologies are already in compliance with MILSTD 810G. Some components of the STAESS system is MILSTD 810G compliant, UL certified, and the system has been designed with safety in mind.

Recommendations

If STAESS is chosen as the IWPS prototype power source, all components of the system should be designed and tested to ensure they meet MILSTD 810G standards.

MOS 3-4-3: SME Rating of Safety

All SMEs surveyed felt the STAESS, SPM, and 1kW generator were all safe to operate.

Objective 3.5: Assess power technology environmental operating conditions

The environmental conditions for each IWPS component are the same since most components of the kit will be stored and operated at the same location. These measures are repeated for each potential component of the IWPS since they are independently operated and assessed.

Table 76. Obj. 3.5, MOE 3-5-1 through 3-5-4 Data

Objective 3.5: Assess power technology environmental operating conditions MOE 3-5-1 through 3-5-4				
System	**Max Temp Storage**	**Max # of days in storage**	**Max Temp in Operation**	**Max # of operational days**
STAESS	70C	battery should be fully charged once a year.	60C	365 days a year
SPM w/100W Solar	Unknown	N/A	-40° to 60° C	365 days a year
1 kW Generator	Unknown	N/A	-4°F to 122°F	Varies based on usage per day this effects the maintenance cycles and Mean Time Between Essential Function Failure (MTBEFF)

Observations

There is incomplete data on the power technology environmental operating conditions, and a range of operating temperatures.

Recommendations

Objective and threshold levels should be established for the power technology requirements for the IWPS prototype so that better data can be collected, and ideal technologies can be identified or designed.

Table 77. Obj. 3.5, MOE 3-5-5 through 3-5-12 STAESS Data

Objective 3.5: Assess power technology environmental operating conditions MOE 3-5-5 through 3-5-12	
Characterize the ability of the STAESS system to operate in these conditions	
Rain	100% operational in rain with the Pelican cases closed
Snow	100% operational in snow with the pelican cases closed
Heat	100% operation in direct sunlight We operated the STAESS for 5 days in Crow Valley BK12 exposed to direct sunlight without any incident at temperatures of 55+ C
Cold	100% operational in freezing temperatures Will operate down to -20 C with some battery capacity reduction
Wind	STAESS inverter and charge controller are heavy enough to operate in very high winds, 75 miles per hour (MPH)+. The STORM solar panels will lay flat on the ground with winds up to 35 MPH, at winds above 35 MPH the STORM solar panels will need to be anchored down to the ground with ground stakes
Humidity	100% operational in humidity up to 100% Humidity
Dust	Will operate in dust with the lids of the pelican case lid closed. The STORM solar panels will operate with some reduced power depending on how much dust is covering the surface. A broom can be used to sweep the dust off the surface of the panels.
Hail	Will operate in Hail with both Pelican case lids closed. The STORM solar panels has passed MIL STD 810D and also the 1" hail stone test

Observations

The STAESS technology is capable of successfully operating in various environmental conditions.

Table 78. Obj. 3.5, MOE 3-5-5 through 3-5-12 SPM Data

Objective 3.5: Assess power technology environmental operating conditions MOE 3-5-5 through 3-5-12	
Characterize the ability of the SPM w/100W Solar system to operate in these conditions	
Rain	Passes MIL STD 810G environmental
Snow	Passes MIL STD 810G environmental
Heat	Passes MIL STD 810G environmental
Cold	Passes MIL STD 810G environmental
Wind	Passes MIL STD 810G environmental
Humidity	Passes MIL STD 810G environmental
Dust	Passes MIL STD 810G environmental
Hail	Passes MIL STD 810G environmental

Observations
The SPM technology is capable of successfully operating in various environmental conditions.

Table 79. Obj. 3.5, MOE 3-5-5 through 3-5-12 1 kW Generator Data

Objective 3.5: Assess power technology environmental operating conditions MOE 3-5-5 through 3-5-12	
Characterize the ability of the 1 kW Generator system to operate in these conditions	
Rain	Passes MIL STD 810G environmental
Snow	Passes MIL STD 810G environmental
Heat	Passes MIL STD 810G environmental
Cold	Passes MIL STD 810G environmental
Wind	Passes MIL STD 810G environmental
Humidity	Passes MIL STD 810G environmental
Dust	Passes MIL STD 810G environmental
Hail	Passes MIL STD 810G environmental

Observations
The 1 kW generator is capable of successfully operating in various environmental conditions.

Objective 3.6: Assess power technology maintenance actions
As stated above, a formal reliability, availability, and maintainability assessment was not conducted since it is beyond the scope of the IWPS project. However, the TEC gathered any maintenance issues on event logs conducted during CV16. The TECrecorded the maintenance actions taken, where the maintenance occurred, maintenance level, the number of occurrence(s), number of proprietary components, and special tools required for the maintenance.

MOE 3-6-1 and 3-6-2
No power technology maintenance issues occurred during CV16.

Objective 3.7: Assess power technology training
The TEC will gather objective and subjective data in order to assess the power technology training. Objective data includes the time required for operators to become proficient with the system, training requirements (i.e., slide and projectors or on-site) and training materials to ensure local nations can understand material and pre-event training can be conducted to maintain proficiency. Users will rate the adequacy and time allocated for classroom and hands-on training as well as the adequacy of the user manuals and handout material.

Table 80. Obj. 3.7, MOE 3-7-1 Data

Objective 3.7 Assess power technology training **MOE 3-7-1**	
System	**Est. Time to Achieve User Proficiency**
STAESS	Less than 2 hours
SPM w/100W Solar	1-2 hours
1 kW Generator	1 hour

Observations

The IWPS team did not have users during CV16. The times listed for MOE 3-7-1 are estimated times by the developers.

Recommendations

Future tests should include users. Data should be collected on actual training time required with various user group types.

Table 81. Obj. 3.7, MOE 3-7-2 and 3-7-3 Data

Objective 3.7: Assess power technology training MOE 3-7-2 and 3-7-3	
Characterize the training requirements and materials for each system.	
STAESS	Training is verbal and visual, using hands-on deployment and set up of the system. Currently training materials do not exist for this system
SPM w/100W Solar	TRADOC standard Training Support Package (TSP). A power point presentation and practical exercise class that explains what the equipment is, how it works, maintenance and troubleshooting using Small Group Instruction (SGI)
1 kW Generator	TRADOC standard TSP. A power point presentation and practical exercise class that explains what the equipment is, how it works, maintenance and troubleshooting using SGI.

Observations

Each of the power technologies tested during CV16 requires a relatively short time to train users. However, training is all currently either all verbal and demonstration based, or where training materials exist, they are all only in English. This might pose an issue in countries were potential users do not speak English, or the trainer does not speak the native language.

Recommendations

All IWPS prototype technology components should come with a simple picture only training and operations manual to ensure users at various skill levels and who speak various languages can learn to operate the system.

Objective 3.8: Assess semi-autonomous operations

This objective seeks to ensure there is a semi-autonomous capability that ensures the power source technology does not have to be constantly manned and will automatically shut off prior to a system failure.

Observation

Each of the SMEs surveyed during CV16 felt all of the energy technologies demonstrated at the event would be considered to be semi-autonomous.

Recommendation

Any future technologies considered for the IWPS prototype should be semi-autonomous.

Table 82. Obj. 3.8, MOE 3-8-2 Data

Objective 3.8: Assess semi-autonomous operations MOE 3-8-2	
Characterize the automatic shut off capability of each system	
STAESS	The STAESS has circuit breakers. The Inverter is programmed to disconnect when the battery voltage drops below a determined value. This is to protect the batteries from being damaged. The Magnum inverter has a fault indicator on the LCD screen that will send an error code. The Lithium Iron Phosphate Battery management system has a LCD screen that has real time cell voltage and temperature
SPM w/100W Solar	The system will self-protect and shut off in any over current or over voltage situation. System will shut off when no power source is available
1 kW Generator	System automatically shuts off when overloaded or oil pressure in not acceptable.

Observation

All energy technologies tested during CV16 incorporate some form of automatic shut off capability.

Table 83. Obj. 3.8, MOE 3-8-3 Data

Objective 3.8: Assess semi-autonomous operations MOE 3-8-3	
Characterize power performance monitoring capability of each system	
STAESS	NO. But the inverter control panel has a voltage and current display to show the dc voltage and amps it is drawing. Power being used by the inverter can be calculated by multiplying the volts X the amps = watts. We use an external watt meter to measure the load in real time.
SPM w/100W Solar	The SPM has a graphical interface that shows the user what power is coming into the system, how much power is coming into the system, and where that power is going. Additionally it has data logging capability.
1 kW Generator	There is no power performance capability in the system (future models will have graphical interface that shows how much power is being used)

Observations

Only the SPM provides an internal performance monitoring capability.

Recommendations

A performance monitoring capability should be incorporated in the STAESS and 1 kW generator technologies.

Table 84. Obj. 3.8, MOE 3-8-4 Data

Objective 3.8: Assess semi-autonomous operations MOE 3-8-4	
Characterize embedded diagnostic capability of each system	
STAESS	None
SPM w/100W Solar	Through the user interface.
1 kW Generator	none

Observations
Only the SPM provides an embedded diagnostic capability.

Recommendations
An embedded diagnostic capability should be incorporated in the STAESS and 1 kW generator technologies.

Table 85. Obj. 3.8, MOE 3-8-5 Data

Objective 3.8: Assess semi-autonomous operations MOE 3-8-5	
Characterize start and stop process of each system	
STAESS	There is a MAIN circuit breaker that is also the MAIN ON/OFF switch to turn the system on and off. The charge controller also has the same circuit breaker ON/OFF switch. These switches are manually turned to the ON or OFF position by the operator. If there is an overload or short in the system these switches will automatically turn OFF
SPM w/100W Solar	Apply power using one of the provided cables and appropriate power source. Disconnect all power sources to shut off
1 kW Generator	Ensure on switch is on, fuel knob turned on and choke is out before pulling start coil.

Observations
Each of the energy technologies use simple processes to both start and stop the systems.

Recommendations
None

Objective 3.9: Assess renewable energy source
This Objective characterized the type of energy source used, either hybrid or renewable, used by the power technology. In addition to the objective data, the TEC gathered subjective data regarding the ruggedness and ease of cleaning the energy source.

Table 86. Obj., MOE 3-9-1 and 3-9-3 Data

Objective 3.9: Assess renewable energy source MOE 3-9-1 and 3-9-3		
System	**Type of energy source (hybrid or renewable)**	**Easy to clean (Y/N)**
STAESS	The STAESS is a HYBRID, but the main power source is renewable energy using high efficiency single crystal solar cell panels. It is also a HYBRID since the inverter has a built in high current charger allowing a generator or any external 120 VAC source to be plugged into the STAESS to charge the battery if there is not enough sun.	Y
SPM w/100W Solar	Renewable	Y
1 kW Generator	Nonrenewable (fuel based)	Y

Observations
The STAESS technology provides flexibility by providing both renewable, battery, and generator power to be integrated into the system. The 1 kW generator is a nonrenewable technology, but it might be useful as a backup power system for the IWPS prototype.

Recommendations
Continue testing all three technologies as part of an IWPS prototype design.

MOS 3-9-3: SME Rating on Ruggedness of Component

Observations
All SMEs agreed that the STAES and SPM are sufficiently ruggedized for multiple mission types. The SMEs also felt the 1 kW generator was somewhat ruggedized, but could be improved.

Recommendations
Consider ways to improve the ruggedness of any power system that is incorporated into the IWPS prototype.

APPENDIX A: WATER SAMPLE DATA

Sample Date	Test Date	System	CL2	SD	Ozone	Recon	Recon (SD)	Odor	Turbidity (NTU)	pH	TDS (mg/l)	Coliform	E-Coli	Temp	Storage Coliform	Storage E Coli
8/30	8/30	FR	No	0	0			Odorless	0.18	9	260	N	N	90.7	n	n
8/30	8/31	FR	yes	0	0	R2-3	0	Faint chlorine	0.18	8.8	290	N	N	91	n	n
8/30	8/30	FR	yes	0	0			Faint chlorine	0.18	8.8	290	N	N	91	n	n
8/30	8/31	FR	yes	0	0	R2-4	2	Faint chlorine	0.18	8.8	290	N	N	91	y	y
8/30	8/30	FR	no	2	0			Odorless	15.8	8.2	260	N	N	90.3	n	n
8/30	8/31	FR	no	2	0	R2-5	0	Odorless	15.8	8.2	260	N	N	90.3	n	n
8/30	8/31	FR	no	2	0	R2-6	2	Odorless	15.8	8.2	260	N	N	90.3	n/a	n/a
9/1	9/1	FR	no	0	0			Odorless	0.39	8.4	290	N	N	88	y	n
9/1	9/1	FR	yes	0	0			Odorless	0.24	9.3	280	N	N	88	y	y
9/1	9/1	FR	yes	0	0			Odorless	0.24	9.3	280	N	N	88	n	n
9/1	9/1	FR	no	2	0			Odorless	5.73	8.7	280	N	N	88	y	n
9/1	9/1	FR	no	2	0			Odorless	0.39	8.4	290	N	N	88	y	n
9/1	9/2	FR	Yes	0	0	yes	0	Odorless	0.24	9.3	280	N	N	88	n	n
9/1	9/2	FR	yes	2	0	yes	2	Odorless	0.24	9.3	280	N	N	88	n	n
9/1	9/2	FR	no	0	0	yes	0	Odorless	0.39	8.4	290	N	N	88	n	n
9/1	9/2	FR	no	2	0	yes	2	Odorless	0.39	8.4	290	N	N	88	y	n
9/3	9/3	FR	no	0	30			Odorless	0.32	9	270	N	N	86	n	n
9/3	9/3	FR	no	0	30			Odorless	0.32	9	270	N	N	86	n	n
9/3	9/3	FR	no	0	30			Odorless	0.32	9	270	N	N	86	n	n
9/3	9/4	FR	no	0	30	yes	0	Odorless	0.15	9.1	280	N	N	84.2	n	n
9/3	9/4	FR	no	0	30	yes	2	Odorless	7.92	9	280	N	N	84.2	n	n
9/5	9/5	Guardian	no	0	0			Odorless	0.28	8.6	280	N	N	78.8	y	n
9/5	9/5	Guardian	no	0	0			Odorless	0.28	8.6	280	N	N	78.8	y	y
9/5	9/5	Guardian	no	2	0			Odorless	6.25	8.5	270	N	N	69.6	y	y

Sample Date	Test Date	System	CL2	SD	Ozone	Recon	Recon (SD)	Odor	Turbidity (NTU)	pH	TDS (mg/l)	Coliform	E-Coli	Temp	Storage Coliform	Storage E Coli
9/5	9/5	Guardian	no	2	0			Odorless	6.25	8.5	270	N	N	69.6	n	n
9/5	9/5	Guardian	no	2	0			Odorless	6.25	8.5	270	N	N	69.6	y	y
9/5	9/5	Guardian	no	0	30			Odorless	0.15	8.5	280	N	N	75	Y	y
9/5	9/5	Guardian	no	0	30			Odorless	0.15	8.5	280	N	N	75	N	N
9/5	9/5	Guardian	no	0	30			Odorless	0.15	8.5	280	N	N	75	y	y
9/5	9/6	Guardian	no	2	0	yes	0	Odorless	4.95	8.4	280	y	n	69.1	y	n
9/5	9/6	Guardian	no	2	0	yes	2	Odorless	10.8	8.6	280	n	n	68.5	n	n
9/5	9/6	Guardian	no	0	30	yes	0	Odorless	0.14	8.5	280	y	y	75.9		
9/5	9/6	Guardian	no	0	30	yes	2	Odorless	5.46	8.7	280	n	n	68	y	y
9/5	9/6	Guardian	no	0	0	yes	0	odorless	0.25	8.4	280	y	y	74.3		
9/5	9/6	Guardian	no	0	0	yes	2	Odorless	5.36	8.4	270	n	n	69.3	n	n
9/3	9/3	Modus	no	0	0			odorless	0.18	9.6	270	N	N	89.1	n	n
9/3	9/3	Modus	no	0	0			odorless	0.18	9.6	270	N	N	89.1	n	n
9/5	9/5	Modus	yes	0	0			Odorless	0.34	9.2	290	N	N	71.2	n	n
9/5	9/5	Modus	yes	0	0			Odorless	0.34	9.2	290	N	N	71.2	n	n
9/5	9/5	Modus	yes	0	0			Odorless	0.34	9.2	290	N	N	71.2	n	n
9/3	9/3	Modus	no	2	0			odorless	4.21	9.7	270	N	N	70.3	n	n
9/3	9/3	Modus	no	2	0			odorless	4.21	9.7	270	N	N	70.3	n	n
9/3	9/3	Modus	no	2	0			odorless	4.21	9.7	270	N	N	70.3	n	n
9/3	9/3	Modus	no	0	30			Odorless	0.33	9.6	270	N	N	78.4	n	n
9/3	9/3	Modus	no	0	30			Odorless	0.33	9.6	270	N	N	78.4	n	n
9/3	9/3	Modus	no	0	30			Odorless	0.33	9.6	270	N	N	78.4	y	y
9/5	9/6	Modus	yes	0	0	yes	0	Odorless	0.34	9.1	280	y	y	70.3		
9/5	9/6	Modus	yes	0	0	yes	2	Odorless	13.3	9.2	280	n	n	71.1	y	n
9/3	9/4	Modus	no	2	0	yes	0	Odorless	0.59	9.6	270	N	N	67.1	n	n
9/3	9/4	Modus	no	2	0	yes	2	Odorless	1.37	9.5	610	N	N	66.2	n	n
9/3	9/4	Modus	no	0	30	yes	0	Odorless	0.39	9.6	270	N	N	74.8	n	n
9/3	9/4	Modus	no	0	30	yes	2	Odorless	8.03	9.6	270	N	N	68	n	n

Sample Date	Test Date	System	CL2	SD	Ozone	Recon	Recon (SD)	Odor	Turbidity (NTU)	pH	TDS (mg/l)	Coliform	E-Coli	Temp	Storage Coliform	Storage E Coli
9/3	9/4	Modus	no	0	0	yes	0	Odorless	0.21	9.8	280	N	N	72.3	n	n
9/3	9/4	Modus	no	0	0	yes	2	Odorless	5.29	9.7	270	N	N	68	n	n
8/30	8/30	Roving Blue		0	0			Odorless	0.13	9.1	270	N	N	86	n	n
8/30	8/31	Roving Blue		0	0	R2-7	0	Odorless	0.13	9.1	270	N	N	86	n/a	n/a
8/30	8/31	Roving Blue		0	0	R2-8	2	Odorless	0.13	9.1	270	N	N	86	y	n
9/1	9/1	Roving Blue	no	0	0			Odorless	0.24	7.8	270	N	N	91.8	n	n
9/1	9/1	Roving Blue	no	0	0			Odorless	0.24	7.8	270	N	N	91.8	n	n
9/1	9/2	Roving Blue	no	0	0	yes	0	Odorless	0.24	7.8	270	N	N	91.8	y	y
9/1	9/2	Roving Blue	no	2	0	yes	2	Odorless	0.24	7.8	270	N	N	91.8	n	n
8/30	8/30	Source	no	0	0			Odorless	56.6	8.9	250	y	Y	88.9		
8/30	8/30	Source	no	2	0			Odorless	37.4	8	310	Y	N	88.9	y	y
8/30	8/31	Source	no	2	0	R2-1	2	Odorless	37.4	8	310	Y	Y	88.9		
8/30	8/30	Source	no	4	0			Odorless	44.2	8.5	300	Y	N	88.9	Y	Y
8/30	8/31	Source	no	4	0	R2-2	2	Odorless	44.2	8.5	300	Y	Y	88.9		
9/1	9/1	Source	no	0	0			Odorless	38.1	8.5	270	Y	Y	84.2		
9/1	9/1	Source	no	2	0			Odorless	38.2	8.7	290	Y	Y	84.2		
9/1	9/1	Source	no	4	0			Odorless	41.6	8.4	290	Y	Y	84.2		
9/1	9/1	Source	no	0	30			Odorless	45.1	8.6	280	Y	Y	87.4		
9/1	9/2	Source	no	2	0	yes	2	Odorless	38.2	8.7	290	Y	Y	84.2		
9/1	9/2	Source	no	2	0	yes	2	Odorless	41.6	8.4	290	Y	Y	84.2		
9/3	9/3	Source	no	0	30			Odorless	25.7	8.6	320	Y	Y	66.7		

Sample Date	Test Date	System	CL2	SD	Ozone	Recon	Recon (SD)	Odor	Turbidity (NTU)	pH	TDS (mg/l)	Coliform	E-Coli	Temp	Storage Coliform	Storage E Coli
9/3	9/3	Source	no	0	60			Odorless	25.7	8.6	320	Y	N	66.7	y	y
9/3	9/3	Source	no	0	30			Odorless	25.7	8.6	320	Y	N	66.7	y	y
9/3	9/4	Source	no	0	30	yes	0	Odorless	47.6	8.8	270	Y	Y	80		
9/3	9/4	Source	no	0	30	yes	2	Odorless	46.1	8.9	280	Y	Y	80		
9/1	9/1	Source (1L source water with 2 gtts SilverDyne)	no	*2	0	no		Odorless	38.1	8	300	Y	Y	87.4		