Examining Alternative C3I Server Cooling Approaches:

More fight, less fuel — improving the resiliency of the warfighter while reducing the costs of fuel and the supporting supply logistics

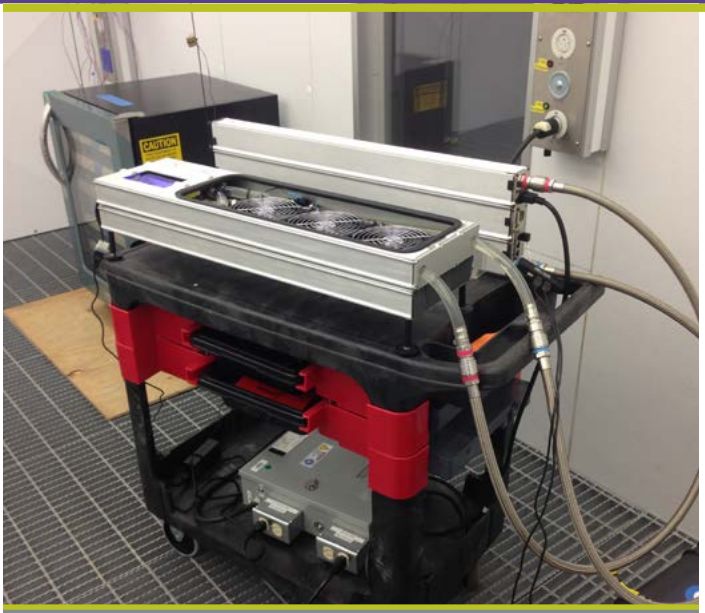
The Opportunity

Servers located in Combat Operations Center/Tactical Operations Center (COC/TOC) shelters performing Combat Coordination Center (C3I) functions are indispensable in war fighting and must perform to a high level of reliability. Cooling is fundamental to achieve high reliability in the filed. COC/TOC-based servers in field use today are cooled like commercial rack mounted versions that rely on conditioned (cooled and filtered) room air drawn through case fans to keep main components within acceptable operating temperature limits and protected from excessive dust and contaminants. Waste heat from the server is expelled into the conditioned shelter. Supplying these air-cooled "commercial-like" servers with conditioned room air requires conditioning the entire interior volume of the shelter with ruggedized, military air conditioner — "environmental control units" or "ECUs." The use of these air-cooled servers in forward operating bases (FOBs) sets up a system of dependencies that have associated high energy and operating costs and expose the warfighter to a series of vulnerabilities and failure points. Long supply chains are dedicated to ensuring conditioned air is supplied to the COC/TOC servers.

Finding a better approach to hosting these mission critical C3I servers is central to reducing energy, operational, logistical costs and vulnerabilities. Understanding this tremendous capabilities improvement opportunity, researchers and military managers in the TROPEC program decided to investigate new approaches to hosting critical servers.

Technologies Assessed To Date

Working through industry outreach, screening, application and assessment systems established in the TROPEC program, six companies submitted cooling technologies that were then assessed in lab environmental test chambers at Lawrence Berkeley National Lab (LBNL), one of two DOE labs providing technology assessments. One of the six technologies excelled in the lab assessment and is headed into the field for testing in the filed.



Liquid cooling technology testing. *Photo Credit: Andrew Weber, LBNL TROPEC Team, EETD, Berkeley Lab, 2013.*

About the TROPEC Program

The TROPEC program (www.tropec.net) identifies potential materiel and non-materiel solutions to reduce energy use in military expeditionary and contingency environments with particular focus on utility in tropical environments. The program partners are: U.S. Pacific Command (PACOM), Oak Ridge National Laboratory (ORNL), Lawrence Berkeley National Laboratory (LBNL), SPAWAR System Center Pacific (SSC PAC) and NAVFAC Engineering and Expeditionary Warfare Center (EXWC). TROPEC utilizes a multi-stage approach to identify, assess and transition innovative energy-reduction solutions. The stages in this screening process are: 1) initial review of applications for military relevance, 2) laboratory assessment to confirm operational performance in a controlled environment, and/or 3) field assessment by the SPAWAR in military exercises or other field environments to validate military utility.

Energy efficient memory modules undergoing Lab testing.
Photo Credit: Andrew Weber, LBNL TROPEC Team, EETD, Berkeley Lab, 2013.

Lab Assessments

Each technology was assessed through the use of a formal laboratory test plan and in environmental chambers designed to simulate the humidity and temperature extremes found in tropical climates. The testing done was designed to verify the technology's ability to save energy first and foremost with military "deployability" and capabilities improvements assessed at a later stage during field assessment. The TROPEC program is designed to open up novel channels to industry in order to discover technologies with strong energy savings potential that have as of yet not been considered by military planners.

Each cooling technology was tested under both full and idle modes throughout ten different temperature/humidity extremes — Table 1. Extended stress tests were performed at the conclusion of each test cycle to examine how well the technology would perform under full processor loads at high temperatures and humidity levels over long periods of time.

Common FOB generators and ECUs in use today lack any ability to moderate output in response to varying cooling and electrical loads, which limits savings opportunities today. However, as current efforts result in new generators and shelter cooling units, savings from new server cooling approaches will be fully realized. Even with current cooling systems and generators, savings can be realized now as all of the alternative cooling approaches assessed would enable the main COC/TOC shelter ECU to be turned off completely when not occupied with warfighters (a capability increase that also increases resiliency).

How These Alternatives Differ From Current Practice

The use of alternative server cooling approaches eliminates the need altogether for conditioned spaces to house servers. Benefits from adapting this systemic approach positively impact many aspects of a FOB. Going well beyond impressive energy savings, benefits include a reduction in shelter footprint, reduction in moving parts that represent potential points of failure and adaptation of robust server platforms that do not rely on a long chain of fragile supply chains. Figure 1 depicts the non-energy related impacts from adapting a liquid cooling strategy.

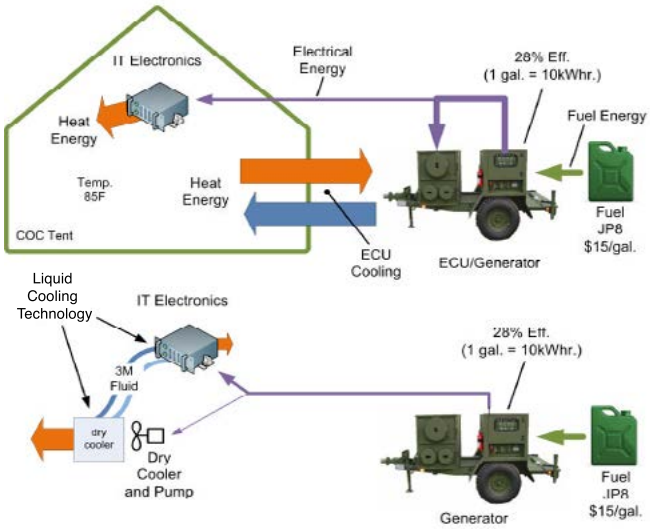


Fig 1. Example Simplification of Systems with Alternative Cooling.

What Was Discovered

Most excitingly, all cooling technologies demonstrated very impressive energy savings when compared to current cooling practices with only one technology failing to cool properly during testing.

Chamber Test Run #	Temperature (F)	Relative Humidity (RH)	Server Processor Loading
1	101	29	Full
2	81	61	Full
3	87	89	Full
4	98	54	Idle
5	86	28	Idle
6	73	72	Idle
7	70	44	Full
8	59	64	Idle
9	66	95	Full
10	80	98	Idle

Table 1. Temperature and RH Test Points.

The lab assessment measured equipment efficiency using three metrics, kWh and gallons of JP8 savings and the coefficient of performance (COP). The COP metric is the ratio of total power (kW) to the cooling power (kW). Existing ECUs in use that condition a COC/TOC shelter have an average of 1.6 COP.[1] The most efficient technology assessed so far demonstrated an astounding COP of 74 under full load conditions equating to 9,589 kWh/year in reduced generator demand which in turn translates to 959 gallons of JP8 savings (Table 2). Using $15/gal of JP8, there is the potential to save an astounding $14,385/year, which doesn't include the priceless benefit of reducing refueling convoys. The technologies assessed are summarized below and are classified as 1) Liquid Cooling via Heat Exchanger 2) Liquid Immersion Cooling 3) Spot Cooling and 4) High Temp Server Convection Cooling.

Alternative Server Technologies Examined in TROPEC

	Electricity Reduction FOB Generators - kWh/yr	JP8 Fuel Savings - kWh/yr	Moving Parts
Cooling Technology			
Liquid Cooling via Heat Exchanger	9,589	959	Pumps & Fans
Liquid Immersion Cooling	5,300	539	Pumps & Fans
Spot Cooling • Integrated Transit Case Mounted Server (Compressor Based)	4,391	439	Compressor & Fans
• Integrated Server Rack Cooling System (Compressor Based)	429	43	Compressor & Fans
High Temp Server Convection Cooling	Undergoing Lab Testing		No Moving Parts

Table 2.

Promising Technology

Probably the most promising cooling concept is a server topology that is already used in military aircraft and land vehicles but most likely due to higher first cost has not yet been considered for use at FOBs. This server technology can operate at much higher temperatures and simply cool by the dissipation of heat through a ventilated, ruggedized case. With this kind of passive cooling, all moving parts are eliminated not only saving energy but also eliminating failure points represented by fans, pumps, compressors valves and controllers. The server central processing unit, memory chips and control board are all designed to operate at higher temperatures.

Lab assessment of one of these high-temperature, passively cooled servers is next in line for evaluation. This kind of server topology is expected to deliver the greatest amount of savings and operational benefits.

No Moving Parts!

Air cooled server technology under test in LBNL Environmental Chamber. *Photo Credit: Andrew Weber, LBNL TROPEC Team, EETD, Berkeley Lab, 2013.*

[1] ORNL, Heather Buckberry — ECU COP Calculation.

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