Air Force Civil Engineer Center

Integrity - Service - Excellence

Shelter Energy Efficiencies JOCOTAS

23 July 2014

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AFCEC/CXXM

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AGENDA

- Energy initiatives background
- Advanced Energy Efficient Shelter System
  - Technologies
  - Site comparisons
  - Results comparison
- Large Shelter Energy Efficiencies
  - Progress to date
    - Thermal coatings tests
    - Advanced liner tests
    - Door curtain
    - Flooring
- Future plans

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Energy Initiatives

- BEAR Energy Efficient Shelter System (BEESS)
  - 2008; Began development/testing at Holloman AFB as Solar Integrated Powered Shelter System (SIPSS)
  - 2010; Participated in Net Zero Plus Joint Capability Technology Demonstration (JCTD) at Ft. Irwin, CA
  - 2011; Continued testing at Holloman AFB
  - 2012; Developed joint proposal with Army, funded by Director Operational Energy Plans and Programs (DOEPP) (now ASD OEPP) for Advanced Energy Efficient Shelters
    - 3-year program, over $17M; 3 phases

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Advanced Energy Efficient Shelters

- Current AF Efforts
  - Completed joint installation of 15 shelters (8 AF, 7 Army at ASAB, Kuwait
  - Portion of systems shipped to Guam for tropical testing
  - Systems installed at Northwest Field, Anderson AFB June 2014
- Future Efforts
  - Tear down and ship systems from Guam to Ellsworth AFB, SD for winter testing Nov 2014 – Apr 2015
  - Incorporate findings from initial evaluations and ongoing research into next-generation shelters and conduct demonstration/evaluation in summer 2015

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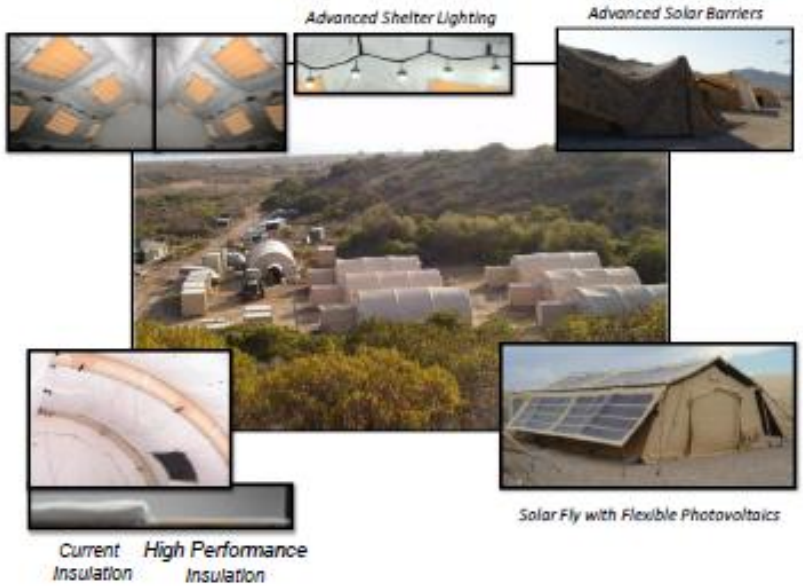
Advanced Energy Efficient Shelters

Natick Soldier Research, Development & Engineering Center
Army Corps of Engineers: Engineer Research & Development Center-Construction Engineering Research Laboratory
Air Force Research Laboratory, Air Force Civil Engineering Support Agency Current



MOTIVATION:

Current shelter systems consist of single-layer fabric shells and liners. This results in the requirement for a 5-ton environmental control unit (ECU) to heat/cool each small shelter system, a one-for-one ration. The Field Deployable ECU that is a standard has power demand of over 15kW at ambient temperatures over 115°. This equates to 4.5 mW to cool shelters at an Air Force BEAR expeditionary base (3,300 ppl) or 900 kW at an Army Force Provider camp (600 ppl).

Technology advances in energy efficient shelter technologies have demonstrated reductions in power demand. The Services are now prioritizing Operational Energy and hope that this will drive dedicated resources to leverage these technology advances. A system-level approach must be taken to integrate these technologies into a final system design that balances the trade-offs between performance, logistical impacts and cost.

PROGRAM PLAN/DESCRIPTION:

• Initial Demonstrations (Jan 2012 – Sep 2013): Test & demonstrate state-of-the-art in an operational environment
• Technology Development (Jan 2012 – Jan 2014)
• Modeling & Simulation: Computational models to optimize thermal performance
• Thermal Barriers: Mature advanced insulation technologies
• Large Shelter Efficiencies: Address the unique energy needs of larger shelter systems
• Follow-On Demonstrations (Jan – Dec 2014): Incorporate lessons learned in Initial Demonstrations and Technology Development to advance the state-of-the-art

MILITARY BENEFIT:

The ultimate products to be transitioned from this effort are energy efficient shelter systems that are optimized combinations of DOD and Industry developed technologies to reduce fuel consumption on the battlefield and manpower requirements for the Warfighter.

• Energy efficient shelter systems that are optimized to reduce fuel consumption on the battlefield and manpower requirements for the Warfighter
• 50% reduction in shelter system power consumption
• 36M gallon per year fuel savings

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Advanced Energy Efficient Shelters
AF Technologies

Evaluating technologies, not shelter manufacturers!

- **AF Technologies**
  - **Two shelter types; Standard BEAR SSS (barrel), Utilis (gable)**
  - **Shade Flys**
  - **Photovoltaic covered shade flys (4kW and 5kW peak power)**
  - **Insulated Liners**
  - **LED Lights**
  - **ECUs (currently using IECU for demos)**
  - **Thermal coatings, covers for ECUs and ducts**
  - **Insulated vestibules with flys, hard doors**

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Advanced Energy Efficient Shelter System Comparison

AF deployed 4 shelters, 2 Alaska and 2 Utilis. 1st-generation energy technologies

- Liners
- Shade flys
- 1st-generation PV fly
- First attempt to cool 2 shelters with one ECU

AF deployed 8 shelters, 2 Alaska and 6 Utilis with next-generation energy technologies

- New shelter design for ECU ports
- New liner (manufacturer issues)
- 1st- and 2nd-generation PV flys
- Insulated vestibule with shade fly
- Thermal coated/shaded ECU/ducts

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Advanced Energy Efficient Shelters
Comparison

ECU/duct improvements from Ft. Irwin to ASAB, Kuwait

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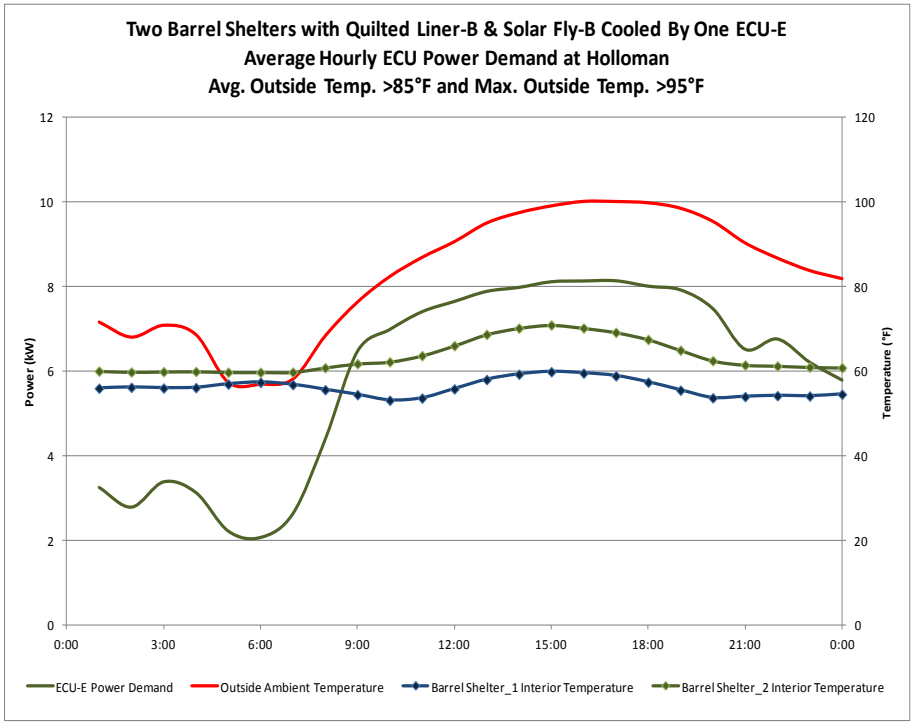
Advanced Energy Efficient Shelter System

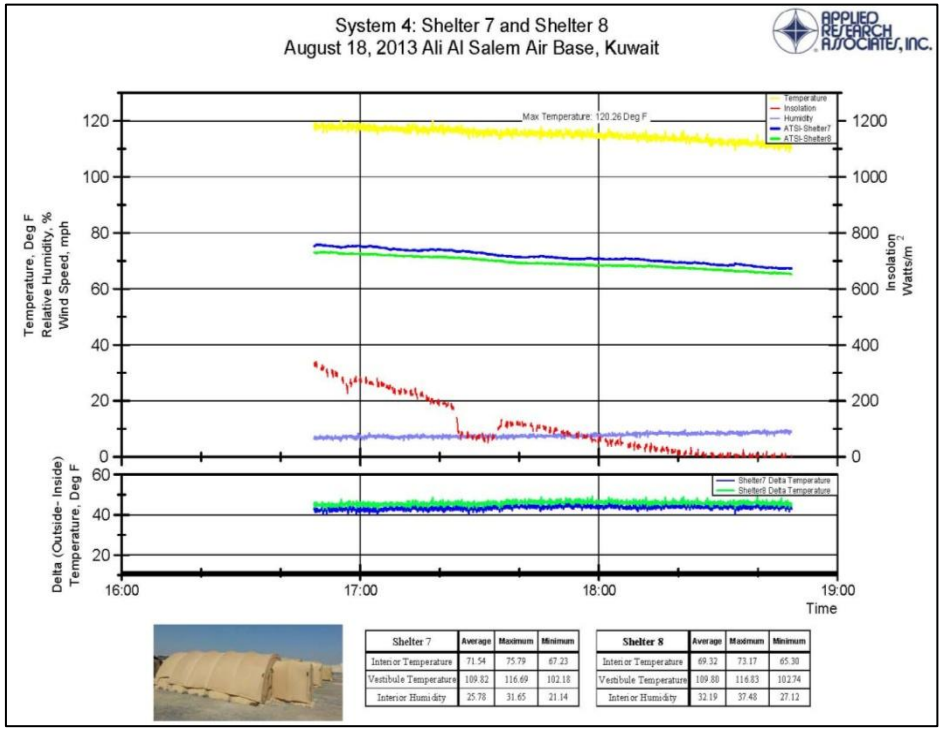
Results Comparison

Ft. Irwin/Holloman



Temperatures peaking at 100°, temperature delta between 35° and 39°

ASAB, Kuwait



Shelter 7	Average	Maximum	Minimum
Interior Temperature	71.54	75.79	67.23
Vestibule Temperature	109.82	116.69	102.18
Interior Humidity	25.78	31.65	21.14

Shelter 8	Average	Maximum	Minimum
Interior Temperature	69.32	73.17	65.30
Vestibule Temperature	109.88	116.83	102.74
Interior Humidity	32.19	37.48	27.12

Temperatures peaking at almost 120°, temperature delta well over 40° (shelter temperatures in mid 70s)

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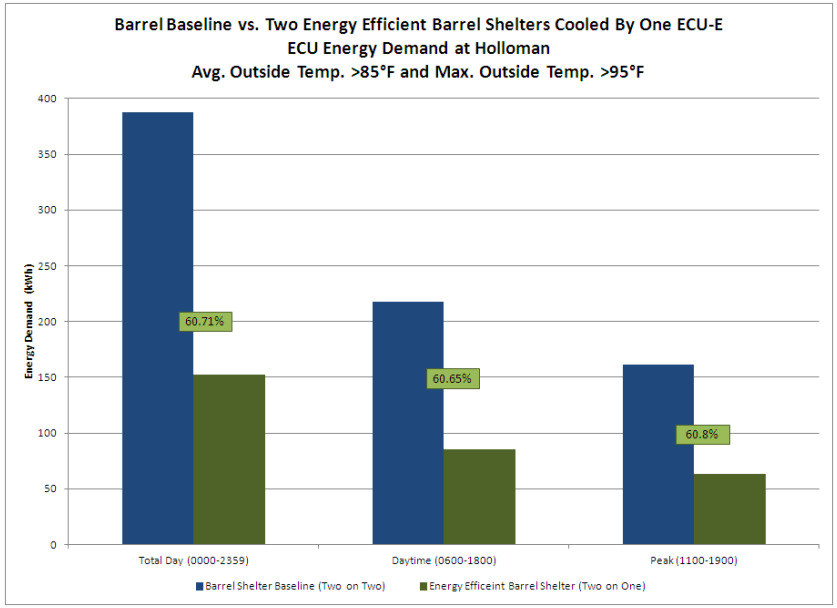
Advanced Energy Efficient Shelter System

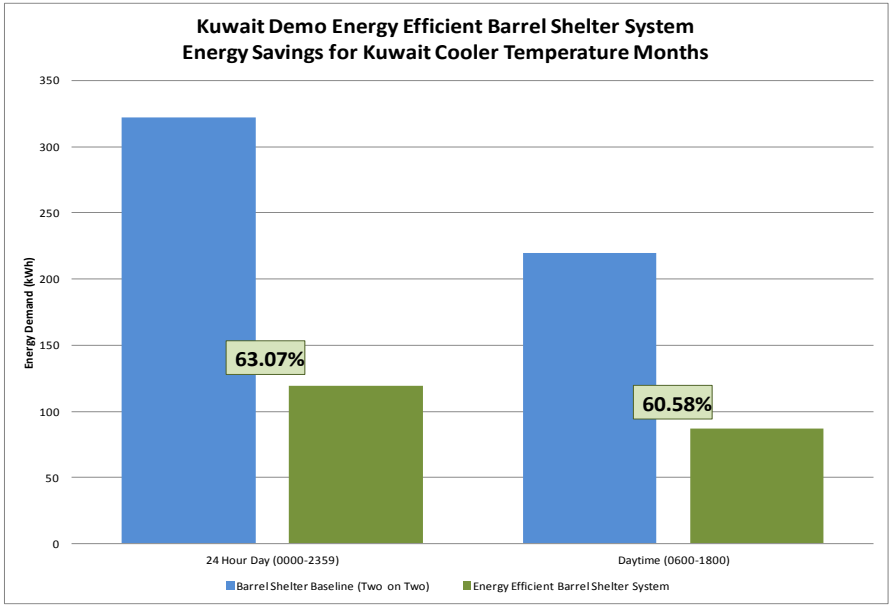
Results Comparison

Ft. Irwin/Holloman



Energy saving achieved higher than 50% target

ASAB, Kuwait



Savings maintained from Ft. Irwin for similar temperatures while improving temperature deltas.

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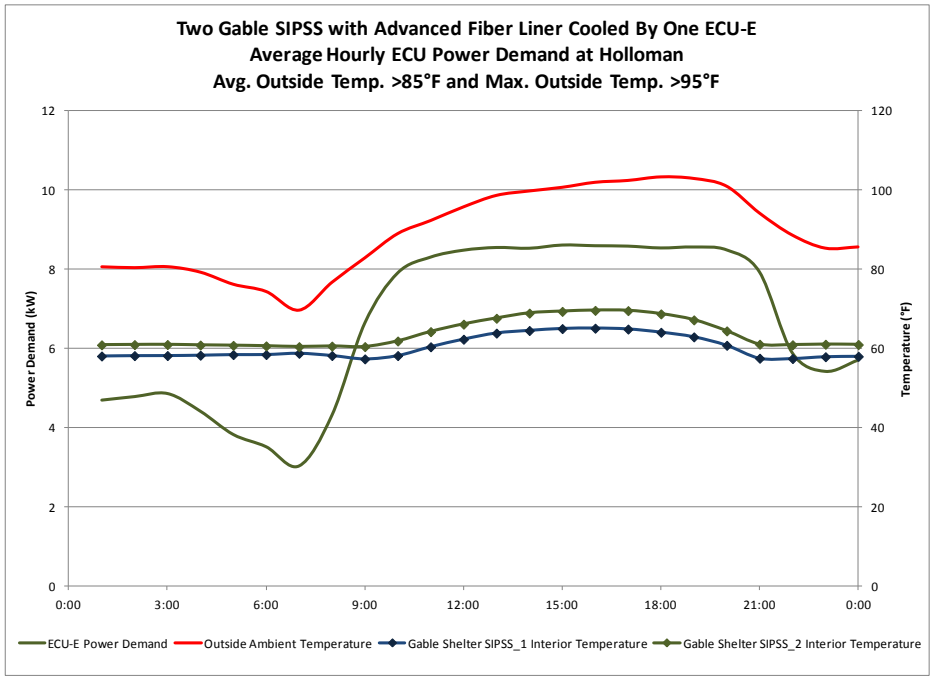
Advanced Energy Efficient Shelter System

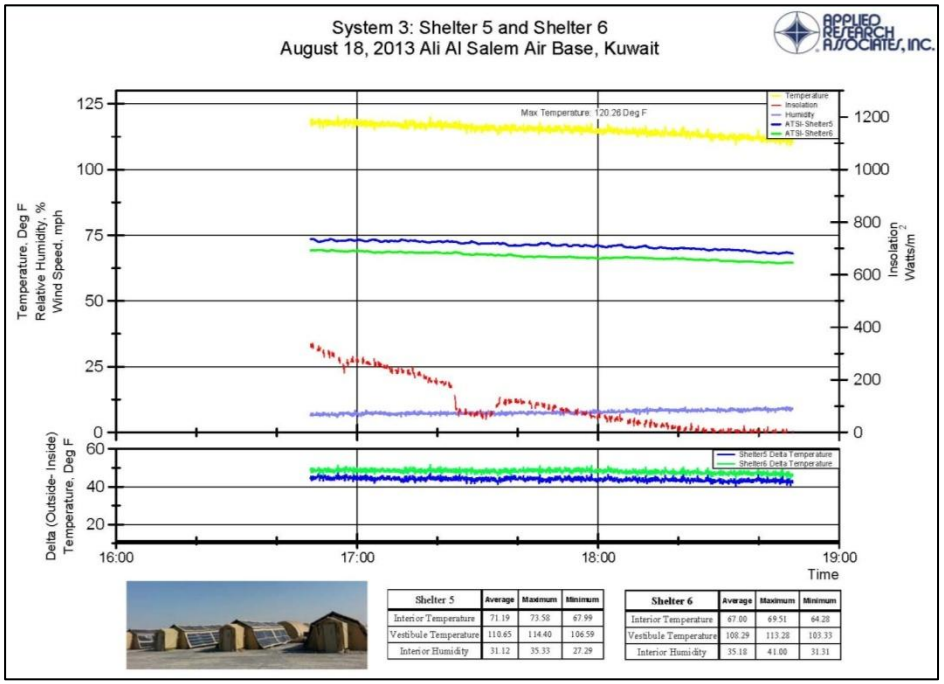
Results Comparison

Ft. Irwin/Holloman



Temperatures peaking at slightly over 100°, temperature delta between 35° and 39°

ASAB, Kuwait



Shelter 5	Average	Maximum	Minimum
Interior Temperature	71.19	73.58	67.99
Vestibule Temperature	110.65	114.40	106.59
Interior Humidity	31.12	35.33	27.29

Shelter 6	Average	Maximum	Minimum
Interior Temperature	67.00	69.51	64.28
Vestibule Temperature	108.29	113.28	103.33
Interior Humidity	35.18	41.00	31.31

Temperatures peaking at almost 120°, temperature delta well over 40° (shelter temperatures below 75°!)

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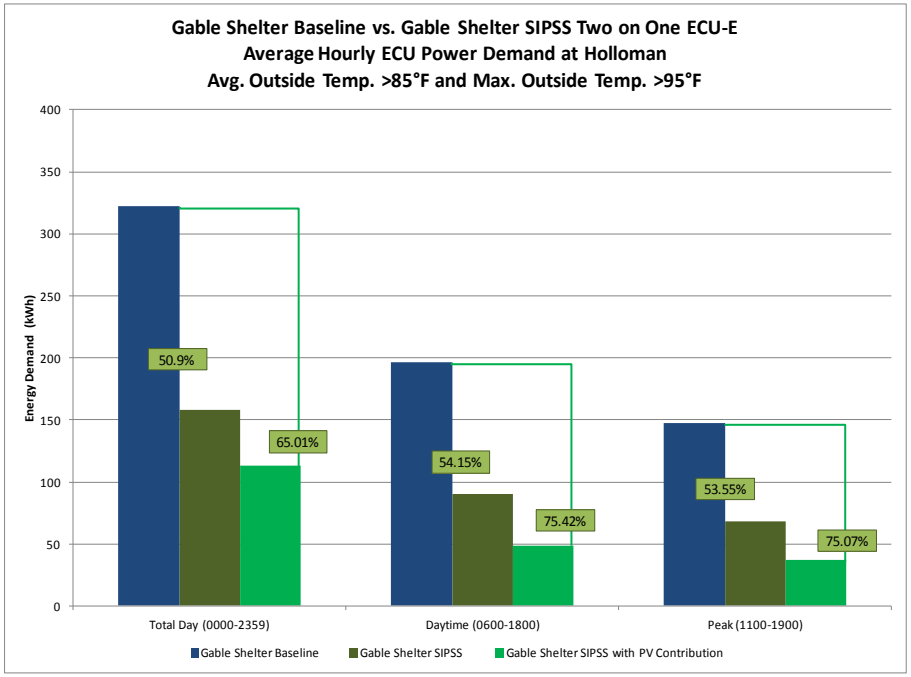
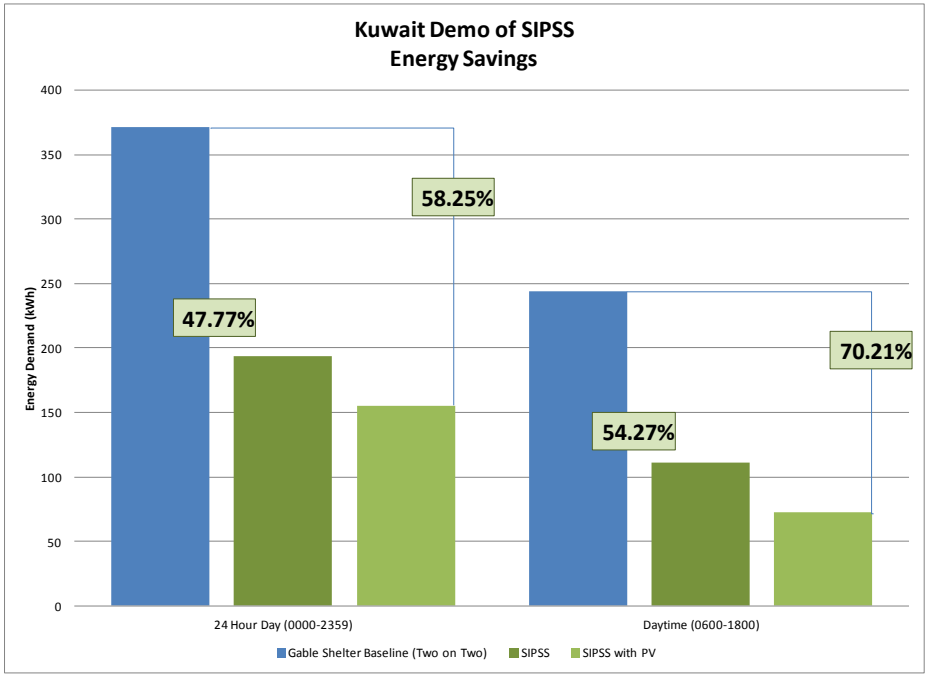
Results Comparison

Ft. Irwin/Holloman



Energy savings achieved higher than 50% target

ASAB, Kuwait



Energy saving achieved slightly missed the 50% target for total day; however thermostats were set to max cooling, and shelter temps were below 75° (troops said they were cold). Raising thermostat would improve savings.

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Advanced Energy Efficient Shelter Systems AF Future Plans

- **AF future plans**
  - **Tear down and ship shelters from Guam to Ellsworth AFB, SD, for winter testing Nov 14 – April 15**
  - **Incorporate findings/new technologies into next generation shelter**
    - Improved liner from Large Shelter testing
    - Shelter fabric; working with BondCote to incorporate reflective/low-E coating into shelter fabric
    - Improved ducts with new fabric/insulation
    - Flooring
    - Improved doors
  - **Conduct testing of new shelters summer 2015**
    - Evaluate improvements of new technologies
    - Evaluate trade-off between new shelter skin, flys
  - **Develop requirements document for next-generation BEAR energy efficient small shelter fall 2015/spring 2016**
    - BEAR 3080 POM funding beginning 2018

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Large Shelter Energy Efficiencies

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Overview

***Objective*: Maximize energy security for BEAR assets in the field by addressing the energy consumption of medium and larger shelters and the unique energy needs they impose on the deployed unit**

- **Short-, mid- and long-term efforts**
- **Combination of government and COTS technologies tailored for retrofit of existing military shelters and development of next-generation requirements**
- **Adaptive to incorporate emerging technologies as appropriate**

Technical Challenge: Achieve energy efficient designs without negatively impacting the functionality of the large shelters

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Progress To Date

- Explored large shelters' needs and potential near-term solutions: July 2012–Sept 2012
- Installed 2 Alaska medium shelters: End of Sept 2012
- Built 15 jigs to accommodate combinations of layers of tent materials representing liners, tent skin, and flys to test and evaluate thermal coatings (reflective and low-e), and advanced liners against a baseline
- Collaborated with BERG Manufacturing, Co. to design a transformer liner with a wall divider. Received their prototype mid May, 2014
- Evaluated a full-scale prototype ULCANS fly by SAAB Barracudas, Inc. for Alaska's medium shelter

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Progress To Date Continued

- **Received Re-ply Roofing coated samples from ASTEC, Inc. and Oak Tree Mesh fly from BondCote to include in next round of thermal coating testing this summer**
- **Coordinated with all vendors of tested thermal coatings and BondCote, the main manufacturer of tent fabrics, to integrate coatings into tent fabric**
- **Met with BondCote on 21 May 2014 to discuss the integration of the thermal coatings into the tent materials**

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Thermal Coatings Tests

Figure 1

Figure 2

- **Figures 1 and 2 show the progress of building the test jigs.**
- **Test timeline: from mid May till end of September 2013**
- **Compared the average interior temperatures for 24-hour period, daytime period, and peak hour for 3 thermal coatings applied in different combinations of 4 tent layers against a baseline**
- **Sample results are shown in Figures 3 and 4 and listed in Tables 1 and 2**

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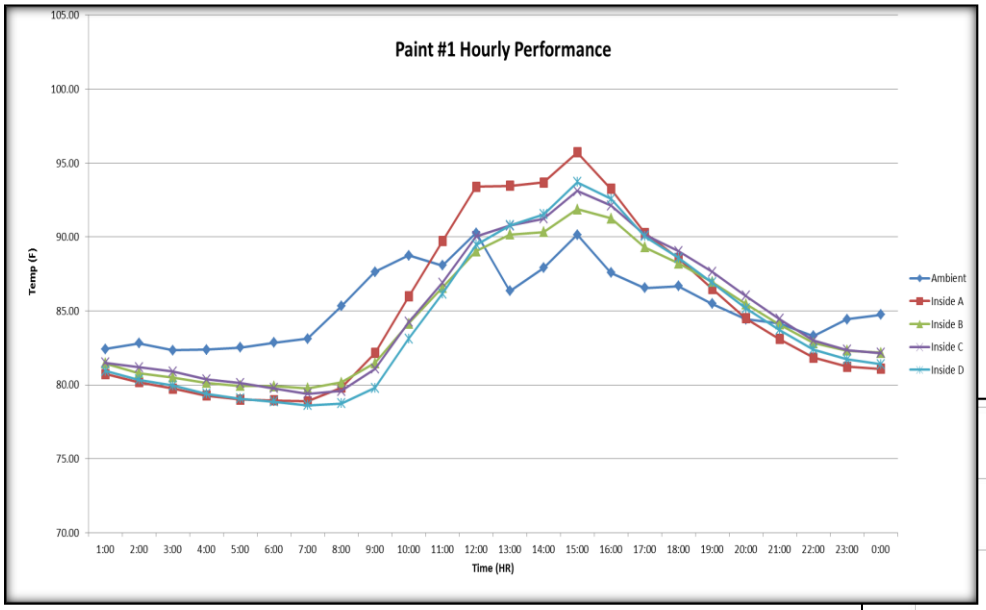
Thermal Coatings Tests



September 1, 2013

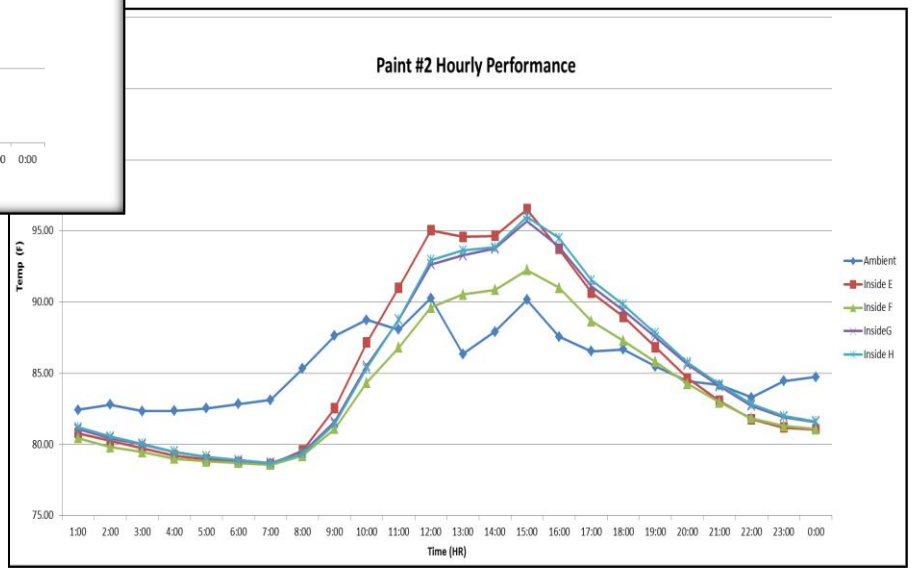


Figure 3

Figure 4

Thermal Coatings Tests

September 1, 2013

Paint #1---24 hour average				Paint #2---24 hour average				Paint #3---24 hour average				Base Lines---24 hour average		
Inside A	Inside B	Inside C	Inside D	Inside E	Inside F	Inside G	Inside H	Inside I	Inside J	Inside K	Inside L	Inside M	Inside N	Inside O
85.04	84.54	84.88	84.29	85.38	83.90	85.26	85.39	84.88	83.47	83.69	83.88	85.13	83.55	83.56
			↑		↑				↑			↑		
			Lowest		Lowest				Lowest					
									Lowest					
Paint #1---Day Time average				Paint #2---Day time average				Paint #3---Day time average				Base Lines---Day time average		
Inside A	Inside B	Inside C	Inside D	Inside E	Inside F	Inside G	Inside H	Inside I	Inside J	Inside K	Inside L	Inside M	Inside N	Inside O
87.88	86.37	86.79	86.35	88.47	86.05	87.87	88.04	87.33	85.05	85.54	85.61	88.09	85.42	85.55
			↑		↑				↑			↑		
			Lowest		Lowest				Lowest					
									Lowest					
Paint #1--peak hour average				Paint #2---Peak hour average				Paint #3---Peak hour average				Base Lines---Peak hour average		
Inside A	Inside B	Inside C	Inside D	Inside E	Inside F	Inside G	Inside H	Inside I	Inside J	Inside K	Inside L	Inside M	Inside N	Inside O
91.62	89.30	90.11	89.98	92.45	89.20	91.79	92.09	90.90	87.89	88.66	88.68	91.89	88.27	88.42
			↑		↑				↑			↑		
			Lowest		Lowest				Lowest					
									Lowest					

Table 1

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Thermal Coatings Tests

	The Lowest Temp for Paint Combination						
	24-Hr Avg.		Daytime Avg.				
Date	Paint	Jig	Paint	Jig			
15-Aug	Solec	J	Solec	J			
16-Aug	Inca	D	Inca	D			
20-Aug	Barracudas		Barracudas			52.00%	Solec J 24 hr
21-Aug	Barracudas		Barracudas			4.00%	Solec K 24 hr
24-Aug	Solec	K	Solec	L		32.00%	Barracudas 24 hr
25-Aug	Barracudas		Solec	L		8.00%	INCA D 24 hr
27-Aug	Barracudas		Solec	J		4.00%	Mesh 24 hr
28-Aug	Solec	J	Solec	J			
29-Aug	Solec	J	Solec	J		80.00%	Solec J Day time
30-Aug	Solec	J	Solec	J		8.00%	Solec L Day time
31-Aug	Barracudas		Solec	J		8.00%	Barracudas Day time
1-Sep	Solec	J	Solec	J		4.00%	INCA D Day time
2-Sep	Solec	J	Solec	J			
3-Sep	Mesh		Solec	J			
4-Sep	Solec	J	Solec	J			
5-Sep	Solec	J	Solec	J			
6-Sep	Solec	J	Solec	J			
7-Sep	Barracudas		Solec	J			
8-Sep	Solec	J	Solec	J			
9-Sep	Solec	J	Solec	J			
10-Sep	Barracudas		Solec	J			
11-Sep	Barracudas		Solec	J			
14-Sep	Solec	J	Solec	J			
15-Sep	Solec	J	Solec	J			
17-Sep	Inca	D	Solec	J			

Table 2

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Thermal Coatings Tests

ULCANS Thermal Fly

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Thermal Coatings Tests

- The best thermal coating is SOLEC with layer combination from the interior out: layer one is the standard liner, layer two is the tent skin painted with SOLEC, and layer three is the standard mesh fly
  - Achieved 3 °F reduction in the interior temperature as a daytime average and was 4 °F less at the peak hours
  - Operational issues as a coating due to durability and reliability issues with repeated use; manufacturer working with BondCote
- The second-best thermal coating combination is ULCANS as a fly over a baseline
- Coordinating with all vendors and BondCote, the main manufacturer of tent fabrics, to integrate coatings into tent fabric
  - INCA coating performed near ULCANS; good progress working with BondCote to integrate into fabric manufacturing process
  - Army and AF testing initial fabrics
- Samples from ASTEC, Inc. and BondCote will be included in next round of thermal coating testing this summer

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Advanced Liner Tests

- **Test timeline: mid October 2013 till end of April 2014**
- **Compared the average interior temperatures for 24-hour period and for daytime period for 9 advanced liners from four vendors (3M-Thinsulate, Berg silver, Berg tan, AKSSS Enerlayer, and 5 liners from HDT: sample A through F) against baseline**
- **Sample results shown in Figure 7 and listed in Table 3**
- **The best advanced liner is a split between BERG-Silver and HDT-A&B**

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Advanced Liner Tests

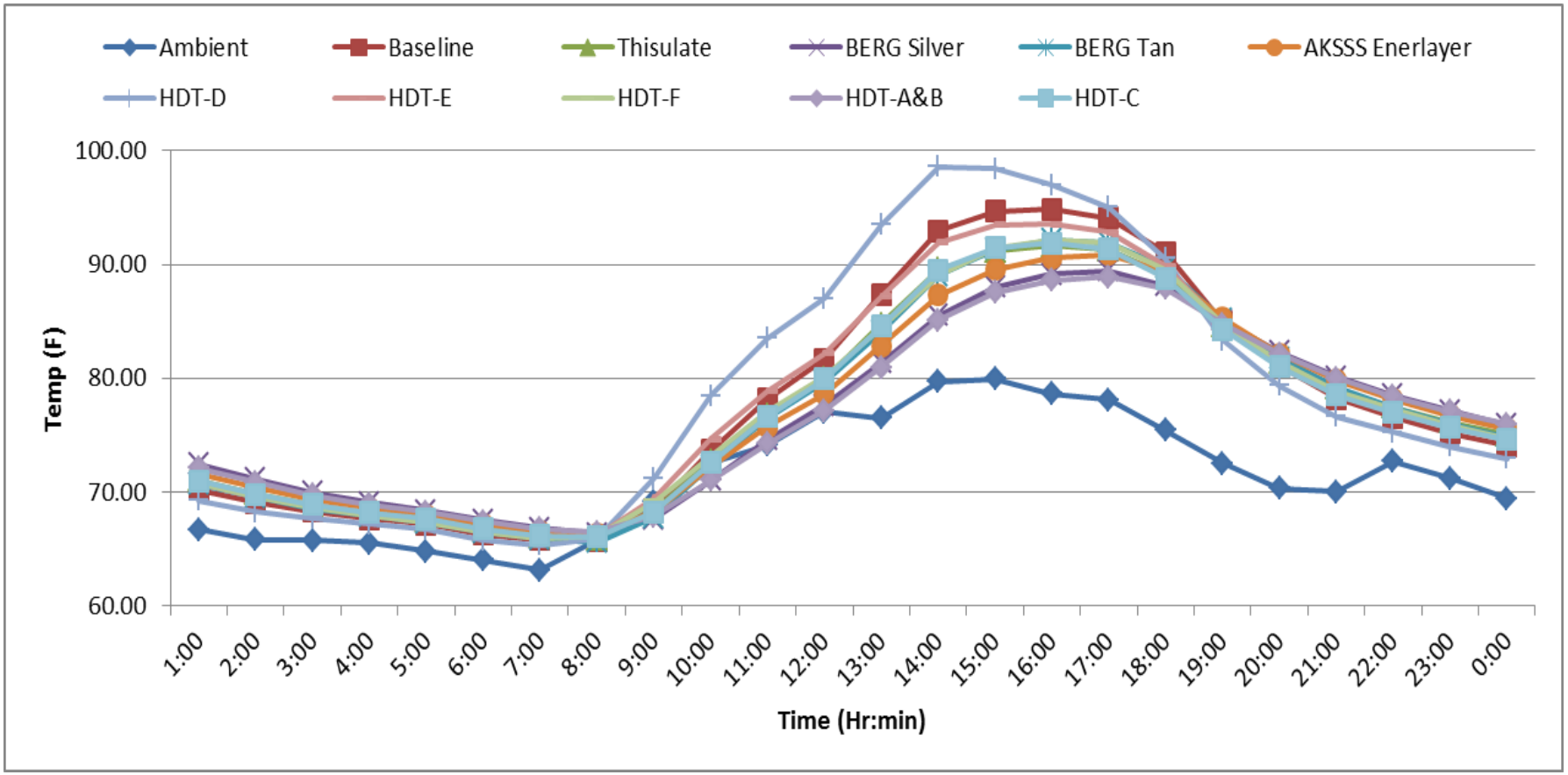

Figure 7

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Advanced Liner Tests

10/8/2013									
24 hour average									
Baseline	Thisulate	BERG Silve	BERG Tan	AKSSS Ene	HDT-D	HDT-E	HDT-F	HDT-A&B	HDT-C
77.79	77.19	76.79	77.11	77.11	78.77	77.89	77.23	76.57	77.08
		↑						↑	
Day Time average									
Baseline	Thisulate	BERG Silve	BERG Tan	AKSSS Ene	HDT-D	HDT-E	HDT-F	HDT-A&B	HDT-C
81.39	79.88	78.43	79.82	79.32	83.81	81.24	80.09	78.18	79.86
		↑						↑	

Table 3

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Advanced Liner Tests

Transformer liner in Medium Shelter

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Door Curtain

Flooring

Future Plans

- **Near Term:**
  - **Continue evaluation of near COTS thermal coatings**
  - **Analyze test results for ULCANS fly**
  - **Collect and analyze ULCANS test data for small shelter**
  - **Collect and analyze transformer liner test data**
  - **Collect and analyze data for door curtain**
  - **Adapt data from flooring test on small shelter to large shelter**
  - **Test tent fabric with INCA thermal coating incorporated**

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Future Plans

- **Mid term: tech infusion to include:**
  - **Identify and test methods to ventilate "attic" between tent skin and liner based on the outcome of transformer liner design**
  - **Implement all energy-saving findings from jig testing and shelter testing and run a full-scale instrumented "best of show" medium shelter test against baseline**

- **Long term:**
  - **Evaluate a small shelter as a prototype with outer skin impregnated with thermal coating**
  - **Plan and coordinate for demonstration of larger shelter (Dome and/or LAMS) testing to take place at Holloman AFB, NM**
  - **Develop requirements for next-generation BEAR medium/large energy efficient shelters**

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Schedule

	FY 14		FY15				FY16	
TASK	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Data Analysis for ULCANS (MSS)								
Install Transformer Liner (MSS)								
Data Collection Transformer Liner (MSS)								
Develop Air Curtain (MSS)								
Demo Air Curtain (MSS)								
Powered Attic Venitlation (MSS)								
Best Case Demo (MSS)								
Demo at Holloman AFB (MSS)								
Install ULCANS (Utilis)								
Data Collection ULCANS (Utilis)								
Data Collection Flooring System (Utilis)								
Develop Tent Skin Impregnated with INCA technology								
Demo Tent Skin on full tent with INCA (Utilis)								
Final Report								

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Issues/Summary

- Issues
  - Joint shelter program impacted by funding delays, contracting delays, and shutdown. About a year behind schedule, will continue into 2015
  - Availability of modernization acquisition funding to modernize BEAR with new energy systems/capabilities
- Summary
  - We have a strong program to develop technologies/systems to significantly reduce BEAR energy demands, respond to the AF Energy Plan with a minimum 50% reduction
  - Working closely with the joint community through joint programs, JCTDs, JOCOTAS and JEBWG

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Questions

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