



AFRL-RX-TY-TP-2011-0014

**SOLAR INTEGRATED POWER SHELTER SYSTEM
(SIPSS) FOR BASIC EXPEDITIONARY AIRFIELD
RESOURCES (BEAR)**

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14. ABSTRACT Extreme ambient temperatures and ineffective shelter insulation are known causes for elevated power demands to cool expeditionary shelters. Studies have shown that around 60% of expeditionary power demand is for shelter cooling. Elevated demands for power requires increasing the number of generators, which results in greater demands for fuel. Therefore, reducing the demand for power will in turn reduce demand for fuel. The BEAR Solar Power Demonstration at Holloman AFB summer 2008 showed that generating power from renewable photovoltaic (PV) energy sources could reduce shelter energy demands and logistic support for base operations, and also showed the potential reduced demand provided by shading the shelters with a fly. Results from the demonstration provided a systems performance snapshot substantial enough to warrant further investigation to include PV technology for shelters in BEAR, and to evaluate thermal insulation and solar fly technologies to improve shelter thermal efficiency to further reduce demands. This presentation will focus on the follow up efforts to the BEAR Solar Power Demonstration to implement renewable sources and develop Solar Integrated Power Shelter Systems (SIPSS) for BEAR. The goal for SIPSS is to generate 3 kWp power and reduce demands by 50% to allow cooling two shelters with a single environmental control unit (ECU). In these efforts, deployable shelters are retrofit with improved or emerging shelter liner (insulation), shelter fly, and/or thin film PV modules and evaluated for their effectiveness to improve efficiency and reduce energy consumption.					
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Headquarters U.S. Air Force

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Solar Integrated Power Shelter System (SIPSS) for BEAR



*ACS Conference
1-3 March 2011*

*Mr. Rod Fisher, AFCESA/CEXX
Ms Miriam Keith, Applied Research Associates*

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Problem Statement



- **Air Force Energy Plan 2010 - Change how we think and act**
- **Goals: The Air Force Energy Plan is built upon three pillars**

- **Reduce Demand: Through energy efficiency and conservation measures, and by raising awareness of the need to reduce Air Force energy consumption.**

- **Increase Supply: By researching, testing, and certifying new technologies, including renewable, alternative, and traditional energy sources, the Air Force can assist in creating new domestic energy supplies.**

- **Culture Change: The Air Force must create a culture in which all Airmen make energy a consideration in everything they do, every day.**

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- Rod Fisher, AFCESA will brief this chart.
- Discuss the current problem for BEAR to provide energy and the AF energy plan.



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SIPSS for BEAR

Objective

Develop and demonstrate a deployable solar integrated power shelter system (SIPSS) capable of generating 3 kWp power or greater. The system will be designed and built to achieve an energy demand reduction of 40% including the ability to cool two shelters with a single environmental control unit (ECU).

Status

- Funding approved from BEAR Power American Reinvestment and Recovery Act (ARRA) Stimulus funding
- Air Force participation approved by JCTD May 2009
- BEAR Weapon System Office (WSO) forwarded funds to Air Force Research Lab (AFRL) for execution. Contract award early Nov 2009
- Deployed to National Test Center (NTC) Ft. Irwin, CA, mid Nov 2009
- **Moving to Holloman AFB CY11 for 2nd year demonstration**

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- Rod Fisher, AFCESA will brief this chart.
- Discuss the objective of SIPSS for BEAR and summary of status from beginning to present.



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Ft. Irwin LSA Warrior JCTD Layout



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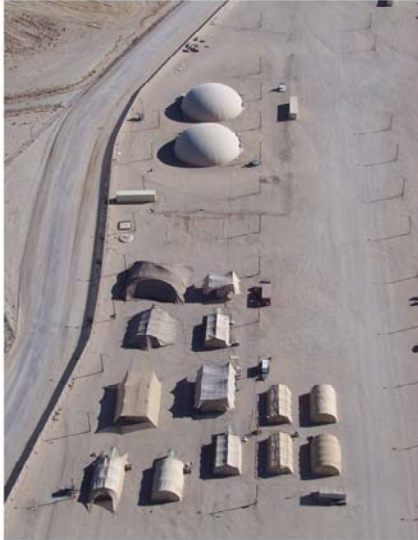
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- Rod Fisher, AFCESA will brief this slide.
- Shows layout at LSA Warrior including AF shelters under study.



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JCTD Technology Focus



Air Force

- Solar Flies
- Thermal Liners
- PV Solar Flies
- Flies/Liners separate and combined
- Lighting; CFLs, fluorescents
- At least 4 ECUs
- Move to Holloman for 2nd year

Army

- Solar Shades
- Thermal Liners
- PV Shades
- Lighting; panels, LEDs, fluorescents

AF and Army Will Share Data

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- Rod Fisher, AFCESA will brief this slide.
- Discuss the technology focus



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SIPSS for BEAR



Objective

Develop and Demonstrate Solar Integrated Powered Shelter System (SIPSS) to Reduce Energy Demands for BEAR

Approach

- Monitor thermal performance of deployable shelters
- Thermal fly (shade) spans shelter roof and sides
- Thermal liners for interior insulation
- Thin-film flexible PV
- High-efficiency power conditioning system
- Energy-efficient lighting

Benefits to the Warfighter

- Energy-efficient shelter
- Best combination of thermal fly/liner
- Condition 2 shelters with one ECU; significant reduction in number of ECUs, electrical distribution, power demand
- Option to equip thermal fly with PV for power generation
- Reduce the cost and danger associated with a logistics fuel trail convoyed into hostile areas.

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- Quad chart for SIPSS for BEAR



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Shelter Energy Dynamics

Shelter Demand Reduction (I.E. Cooling Load)

- Reduction in thermal load
 - Insulated liner
 - Shelter fly
 - PV integrated shelter fly

Power Demand

- Reduction in Shelter Power Demands (ECU, Lighting)
 - Evaluate minimum of 4 ECUs for performance, power demand



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- Discuss the energy dynamics that are important to achieving the goal.



Technologies Applied

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Shelter 1	Technology 1	Technology 2	Technology 3	Technology 4
Liner	Shelter 1 Standard w/Reflective Backing	Improved Insulation_1	Phase Change Material (PCM)	Improved Insulation_2
Shelter Fly	Mesh	N/A	N/A	N/A
Shelter 2				
Liner	Shelter 2 Standard w/out Reflective Backing	Aerogel	Improved Insulation_1	N/A
Fly	Mesh	Thermal Reduction Coating	a-Si PV Integrated	CIGS PV Integrated
PV Generation	3.9 kWp (a-Si)	5 kWp (CIGS)	N/A	N/A

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- A total of four shelters, two different shelter architectural designs, are included in the SIPSS for BEAR investigations. Each shelter has a dedicated baseline for comparative analysis of the improved liner and fly technology to be evaluated. Technologies included in the investigation consist of those that were currently available or are near commercialization for both shelter types. In addition we applied a few emerging technologies to enable us to be proactive and look ahead for the future.



Tests at Net Zero Plus JCTD

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FY10 Tests at Ft. Irwin, CA	Test Configuration	Test Period
Insulation (Winter & Spring)	1 & 2	16 Jan – 2 Apr
Insulation & Fly (Spring)	3 – 6	3 Apr – 20 Jun
Insulation, Fly, & PV Generation (Summer)	7 – 9	21 Jun – 3 Sep
Two Shelters on One ECU (Summer & Fall)	10	4 Sep – 30 Sep
Visitors Day		

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- To determine the impact and ability of the technologies applied in achieving the reductions desired we designed our tests to evaluate shelter efficiency with and without the addition of liners, flies, and PV generation technologies. This experiment design will also enable a fundamental understanding of shelter performance, the technologies applied for efficiency improvement, and the interactions of the technologies combined as a system. Environmental conditions at NTC are very close to what is experienced at deployed desert locations and investigations under such conditions will prove to be invaluable for analysis of systems operation to identify suitable liner-fly combinations to reach the goal.



Performance Measurements

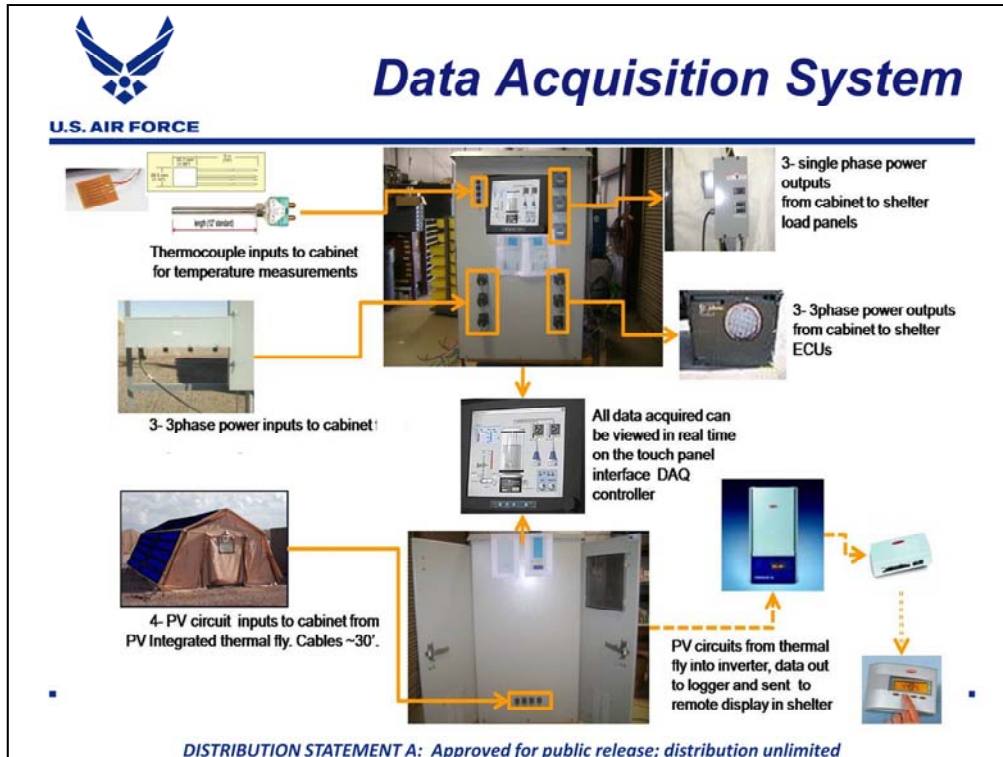
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Measurement Parameter	Unit	Purpose
Solar Module Temperatures	°F/°C	Measure PV module temperature. Impact efficiency of PV module. Determine operational efficiency under extreme conditions
Shelter Interior Temperatures	°F/°C	Measure shelter interior conditions
Shelter Systems Heat Flux Measurement	Btu/Ft ² 2Hr	Measure temperature heat loss or gain on shelter and insulation surfaces
ECU Supply Temperature	°F/°C	Measure supply temperature of air provided by the ECU to the shelter
Outdoor Ambient Temperature	°F/°C	Measure outdoor ambient temperature at the demonstration site
Wind Speed and Direction at Site	m/s	
Relative Humidity at Site	%RH	Measure humidity at site
Solar Irradiance (Pyranometer)	W/m ²	Measure solar radiation incident over the shelters
Grid Supplied Power	Watts	Measure power supplied by the grid
PV DC Amperage	ADC	Measure DC current provided from each PV circuit
PV DC Voltage	VDC	Measure DC voltage provided by PV
PV Power Generated for AC Consumption	Watts, AC	Measure AC power provided by PV post inversion (power conditioned to 208 VAC 3phase)
Shelter Light & Convenience Loads	Watts, AC	Measure shelter interior power demands (lighting & receptacles)
Time	HH:MM:SS	Measure duration


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- Space conditioning makes up 60 – 80% of a shelter’s total energy demand. This large demand for energy is driven, in part, by exterior and interior heat loads. Exterior heat loads are outdoor ambient conditions and incident solar radiation, while interior heat loads include personnel, lighting and convenience loads. This transfer of heat occurs on all surfaces of the shelter (i.e. interior/exterior walls and roof) impacting the cooling requirement. In order to reduce the need for cooling it was important that our performance measurements would allow us to examine shelter thermal performance with and without improved liners and flys. When possible, measurement devices were selected with accuracies of 5% or less to reduce the potential for systematic error.




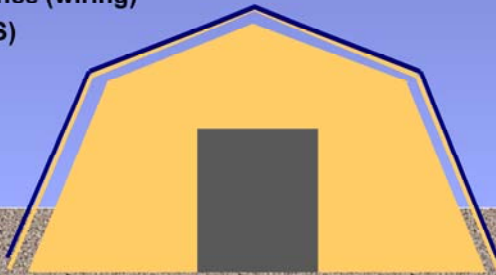
- All shelters were operating in their field ready conditions and monitored for performance. Each shelter contained a data box to collect shelter surface temperatures, airgap temperatures, shelter interior temperatures, door entry/exit, and/or incident solar radiation (insolation). The data boxes were daisy chained to each other and connected to one central data acquisition and control cabinet, shown here. This is the data acquisition and balance of systems (DAQ/BOS) cabinet developed for the 2008 Holloman study. The cabinet was updated to acquire the additional measurements and allow for remote monitoring/access. In this cabinet, data was collected for electric power consumed by the ECUs, electric power supplied by the generator, shelter loads, ambient temperature and environmental conditions at the site, and PV power generated. The data from these systems were written daily.



SIPSS Performance at JCTD

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- **Environmental Impact & Loss Factors for PV**
 - Irradiance (clouds)
 - Partial shading
 - Production tolerance
 - Dirt and dust (soiling)
 - Incident angle
 - Shelter orientation
 - Outdoor ambient temperature
 - Series resistance (wiring)
 - Inverters (BOS)

- Shelter performance testing occurred under real outdoor conditions experienced at the LSA Warrior Site at NTC, Ft. Irwin, CA. The four shelters included in the thermal performance investigations followed the orientation of the other shelters at LSA Warrior. This orientation of shelters prohibited preferred placement of the shelters but would allow technology and demand comparisons between AF and Army shelter systems under test. During the demonstration at LSA Warrior the shelters were oriented with doors facing east and west. All shelters were installed in a conventional manner according to manufacturer's specifications, current practice, and with the assistance of the shelter manufacturer to ensure that shelter installation was carried out to meet their specifications. The installation and addition of sensors to acquire shelter performance data did not impede or obstruct their standard specifications.



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Interim Results

2 shelters on 1 ECU

- **Conducted 27–30 Sep**
- **Results encouraging**
- **Further analysis, tech refinement & testing required**



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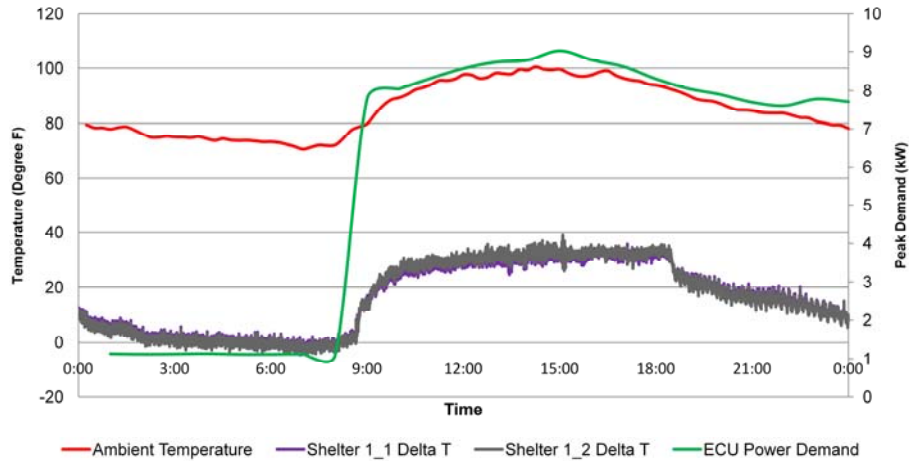
- Rod Fisher, AFCESA will brief this slide



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Interim Results; Shelter 1

Two Shelters with Fly and Insulated Liners
Cooled by One ECU
Temperature Difference from Ambient and Power Demand



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- Rod Fisher, AFCESA will brief this slide.
- Discuss shelter requirements for cooling and prelim results from cooling two shelters with one ECU.

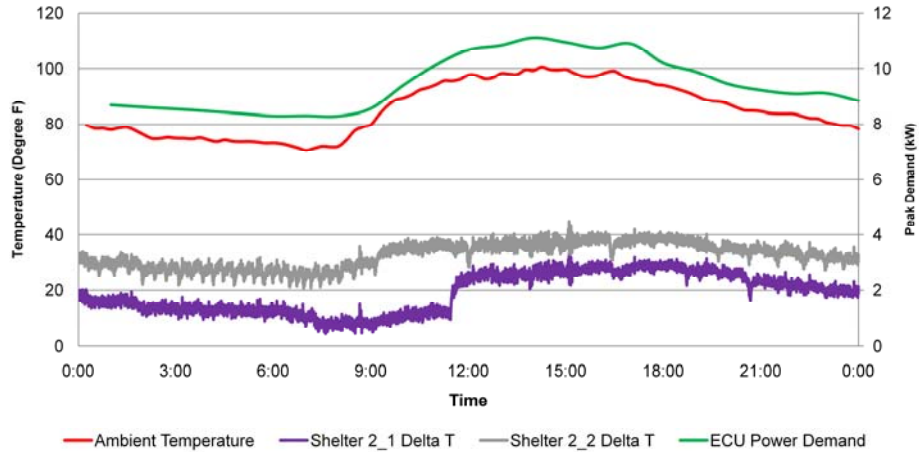


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Interim Results; Shelter 2

Two Shelters with PV Integrated Fly and Insulated Liners
Cooled by One ECU

Temperature Difference from Ambient and Power Demand



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- Rod Fisher, AFCESA will brief this slide.
- Discuss shelter requirements for cooling and prelim results from cooling two shelters with one ECU.



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DV Visit - 29 Sep 10

- Ms Katherine Hammack, SAA/IE
- Ms. Sharon Burke, DoD Dir of Op Energy Plans & Prgms
- Army Science Board



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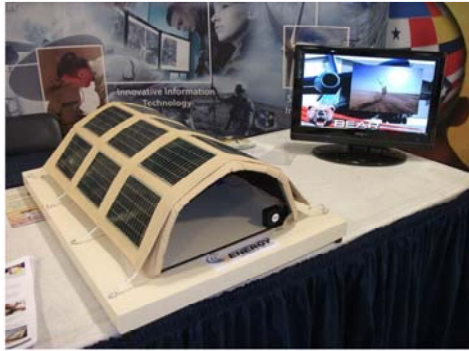
- Rod Fisher, AFCESA will brief this slide
- Discuss DV visit during the two shelters on one ECU evaluation



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Recent Events

AFCESA, AFRL participated in Pentagon Energy Security Event



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Next Steps

- **Systems remained at Ft. Irwin through Jan 2011**
- **Moving to Holloman Mar 2011 for additional testing**
 - **Advantage of controlled environment, secure power**
 - **Thermal liner and fly configurations**
 - **ECU testing including FDECU-9, possibly others**
 - **2 shelters on 1 ECU**
- **Investigating cost, opportunities to deploy test assets to AOR**

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Questions?



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