



A Mobile Hybrid Power Source with Intelligent Control

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CME

Joint Service Power Expo

7May09



Overview

DREAM

DREAM Revisited

A HI-Power DREAM

Summary



DREAM

Deployable & Renewable Energy Alternative Module

Marine Corps System Command Solicitation

- Posted November 2006
- The key application for this power supply is remote operation in austere environments, with simplicity of use.



Requirements

Electrical

- Continuous AC power of 3 kW average for at least 15 days without refueling or resupply.
- Continuous AC power of 3 kW for at least a 12-hour period, with no input from the system's electrical generation or energy harvesting capability and without operator intervention.



DREAM Modeling

HOMER Simulator

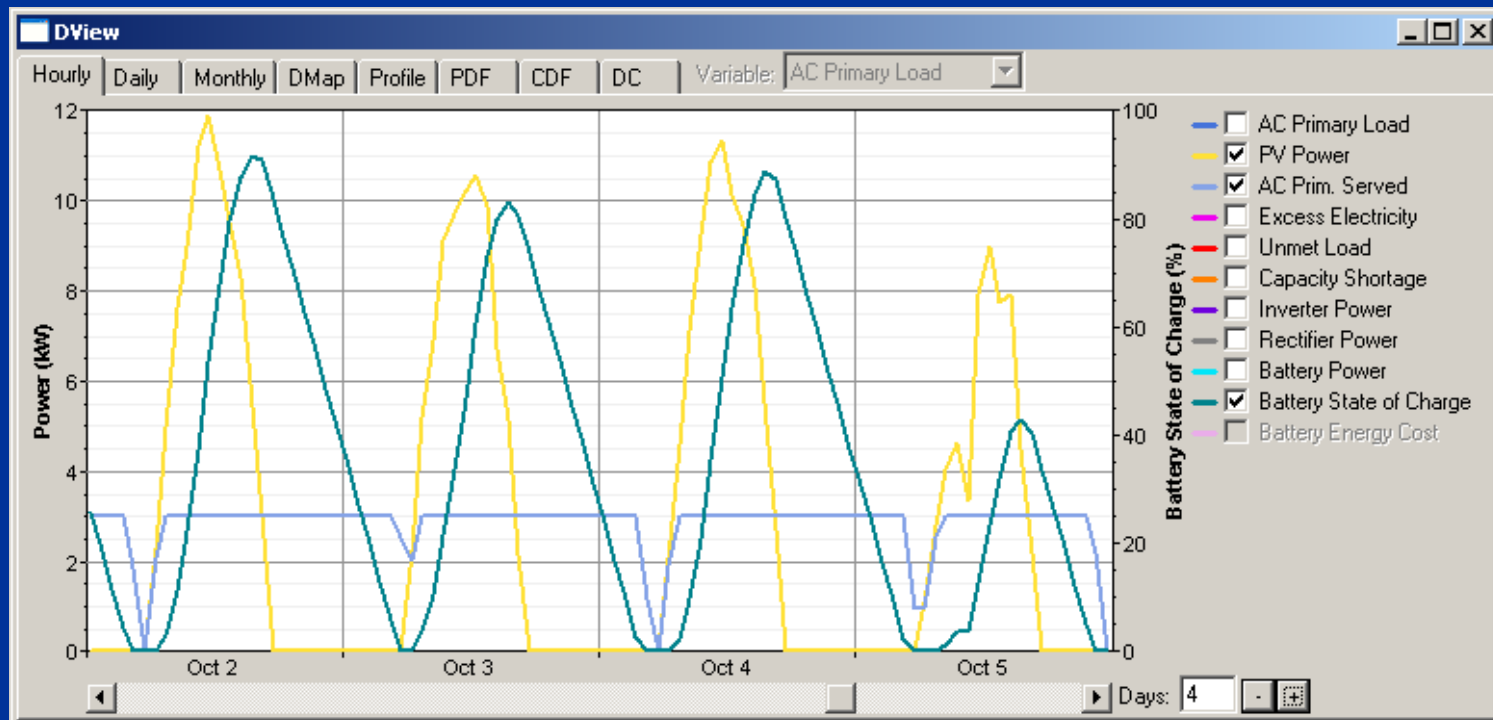
- HOMER is a free simulator developed by NREL (www.nrel.gov/homer)
- Simulations were performed for five cities
 - 29 Palms
 - Camp Lejeune
 - Baghdad
 - Kabul
 - Seoul



DREAM Modeling

Best HOMER Results

- 29 Palms, CA in early October
- Downtime was 3 hours





DREAM Modeling

HOMER Results

- Load met on an annual basis
 - 29 Palms, 70% of the time
 - Camp Lejeune, 57%
 - Baghdad, 58%
 - Baghdad with variable load, 54%
 - Kabul, 68%
 - Seoul, 51%
- With two trailers connected together, Baghdad load could be met 91.7% of the time.



Design Goals

Reduce JP-8 and maximize renewable energy use for electrical power

- Solar energy is the most prevalent renewable source
- A generator reduces solar panels that can be carried and defeats the purpose of DREAM

Weight was king ($4200 \text{ lb} - 1440 \text{ lb} = 2760 \text{ lb}$)

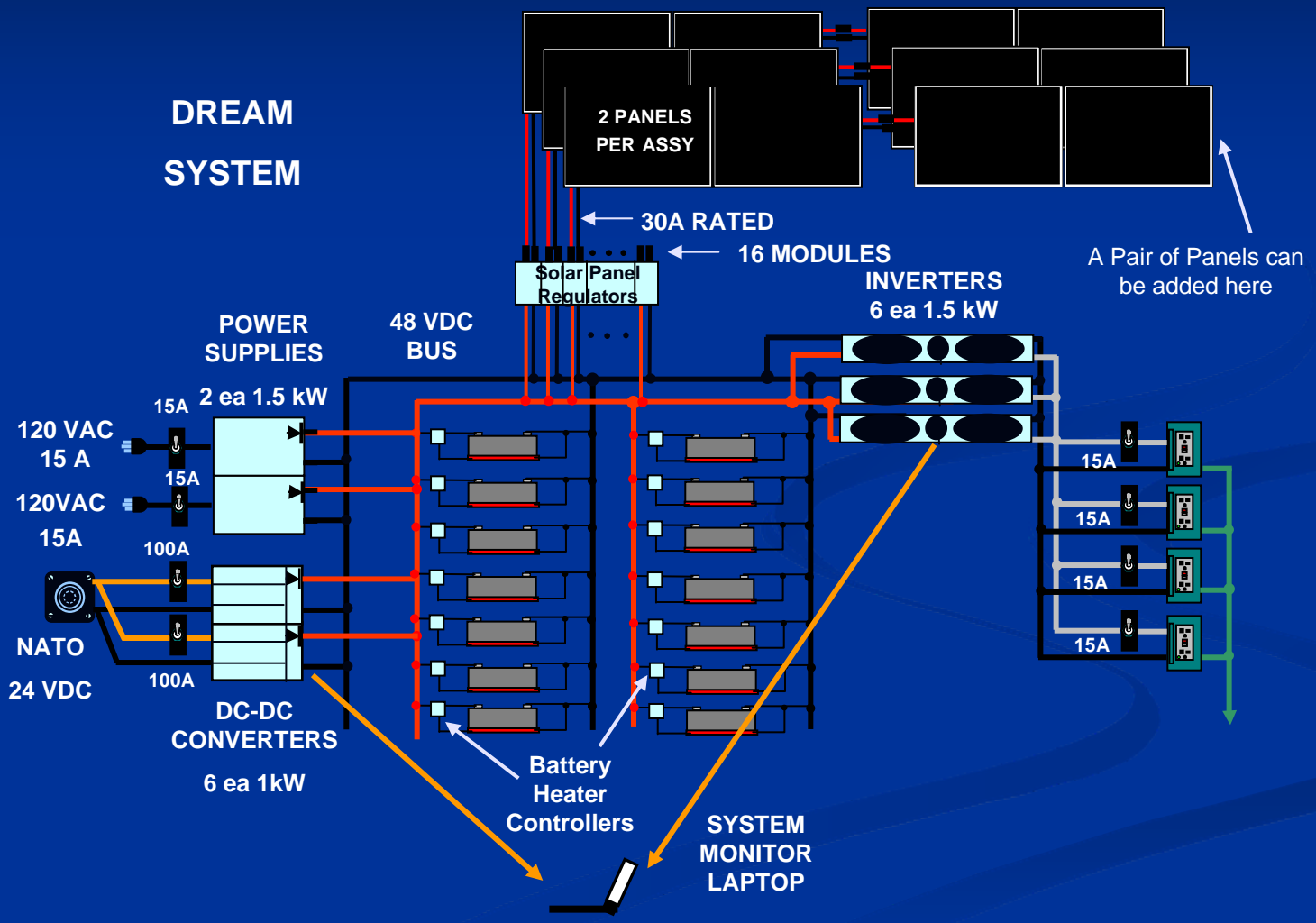
- Maximize the weight for solar panels

Output: 5 kW at 0.8 PF at 135°F at 4000 ft

Designed as an expandable platform



DREAM Design





DREAM Design

Weight

LTT-MCC	1440
Panel Assemblies (18)	1440
Battery Bank	676
Electronics/Wiring	97
Misc & Structures	493
Total	4146

Expansion

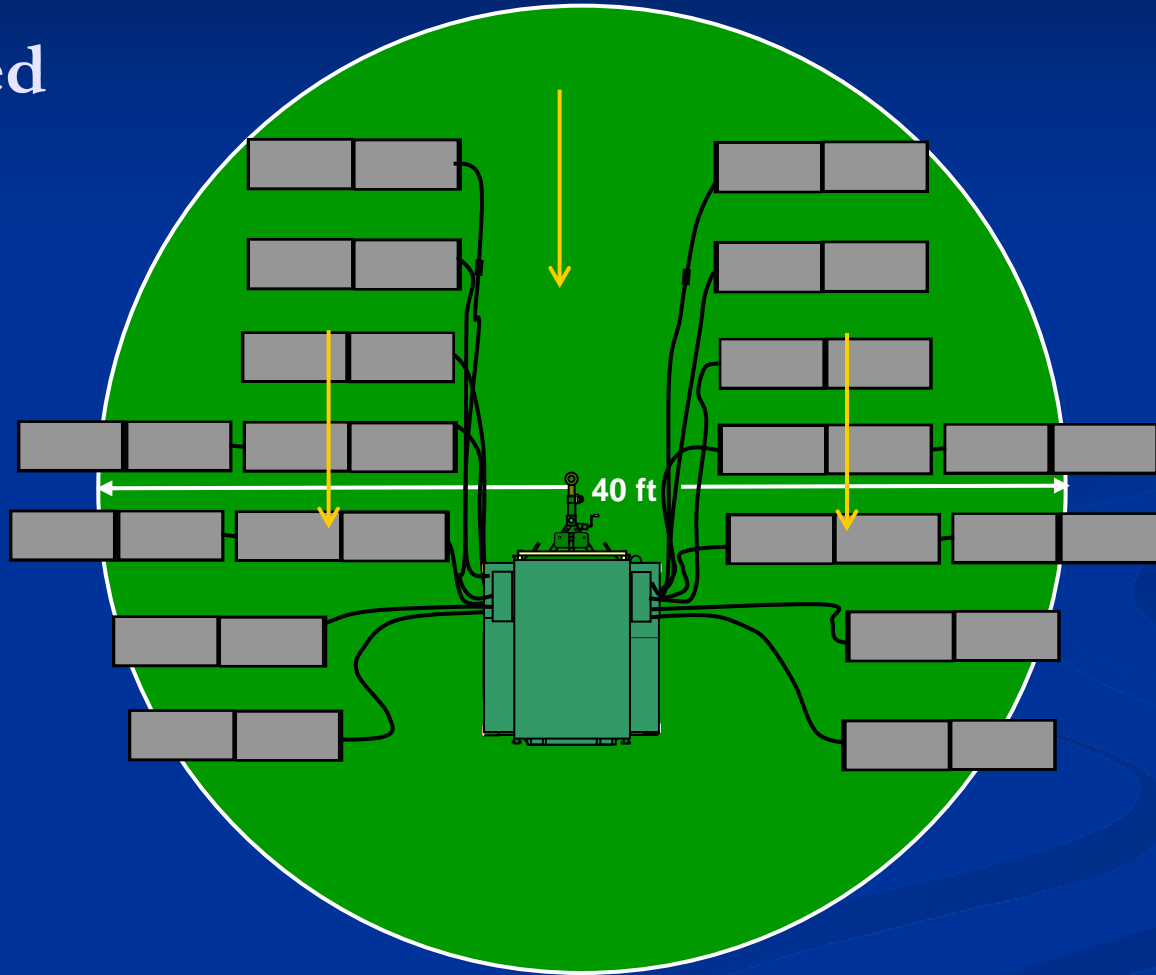
6 panels per regulator
16 regulator modules
96 panels or 48 Assemblies
19,200 W





DREAM Design

Deployed





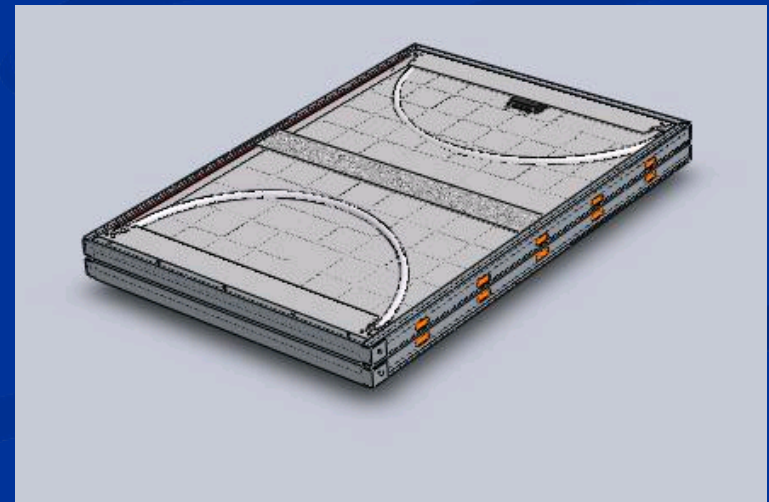
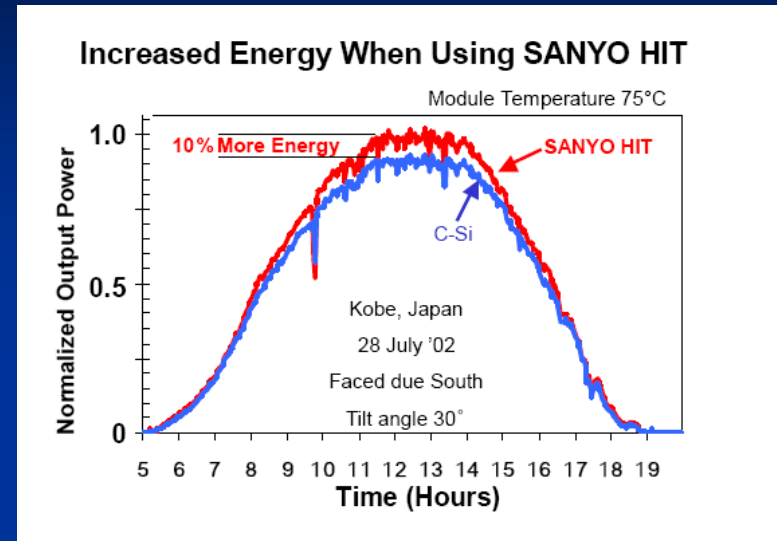
DREAM Design

Solar Panel

- Sanyo HIP-200BA3, 200 W
- 55.8 VDC, 3.59 A
- 51.9 " by 35.2 " by 1.4 "
- 30.9 lb, 6.5 W/lb

Panel Assembly

- Configured as pairs
- Glass sides fold inward
- Weighed 80 lb, 5 W/lb
- 30A rated cabling
- Single pin IP67 connectors

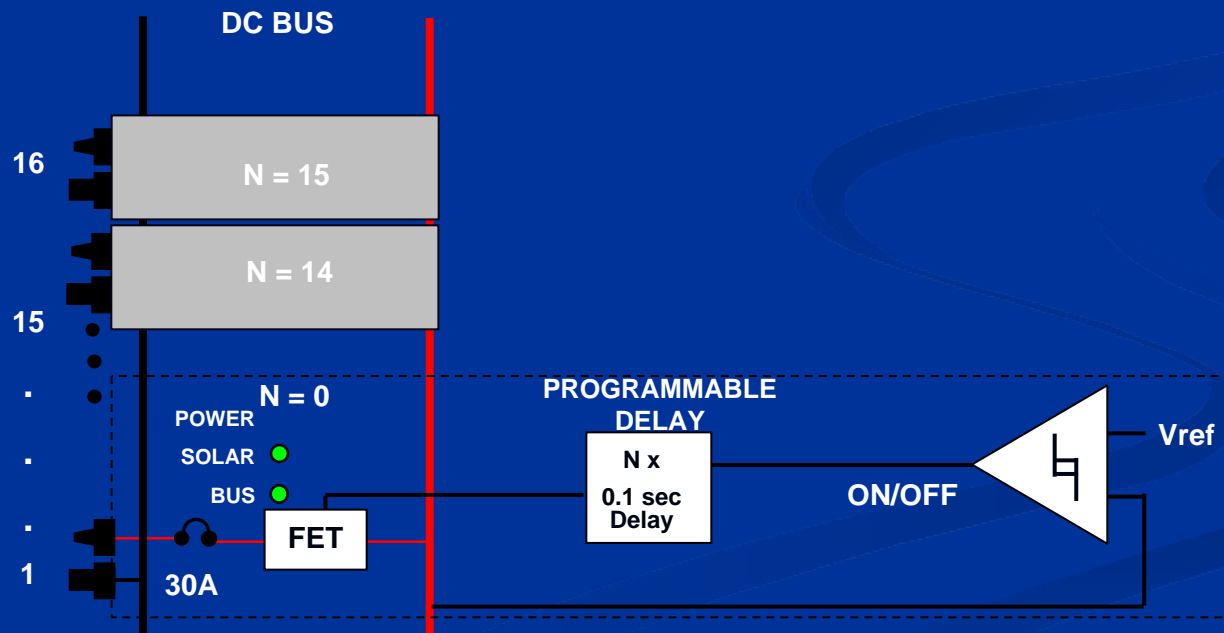




DREAM Design

Solar Array Voltage Regulator

- Maintains Array Voltage to 54.5 VDC or less
- Connects/Disconnects Panel Sets as needed





DREAM Design

Battery Bank

- Boundless Corp, Boulder, CO
- 48.1 VDC, 75 A-h, 47 lb lithium ion battery
- 2.5Ah, 18650 cell, 390 ea, 30P13S configuration
- Built-in battery management
 - Balances and limits charge across stack
 - Disconnects for over temperature, overcharge, Discharge, lack of use
- 14 Batteries, 50 kWh
- External battery heater





Phase III

Completed Phase II

- CME provided training in Aberdeen on May 29, 2008
- After evaluation, AeroVironment was selected to move to Phase III
- Weight won
 - Panels had to be discarded; needed 24 assemblies, weight limited to 18



Lessons Learned

A pure solar/battery solution

- Needs more hardware than is feasible for a lot of applications
- Produces a very expensive 5 kW generator
- Has a large footprint
- Needs the help of a generator



DREAM

Revisited



New Technology

Solar Panel Survey

- There are more 200 to 300 W panels available
- Sunpower topped Sanyo with 19% efficiency
 - Panel assemblies still about 5 W/lb
- Ascent Solar Thin Film Panels
 - Equivalent panel assemblies now provide 7 W/lb
 - Panel assemblies would be less than 1/3 the weight and thickness allowing for possibly three times the panels



New Technology

Cell/Battery Survey

- There are more 2.5Ah Li ion cells available
- Lithium Phosphate (A123) are safer, faster charging but less energy dense
- Lead Acid is still too heavy
 - Firefly Microcell Foam technology



A HI-Power DREAM



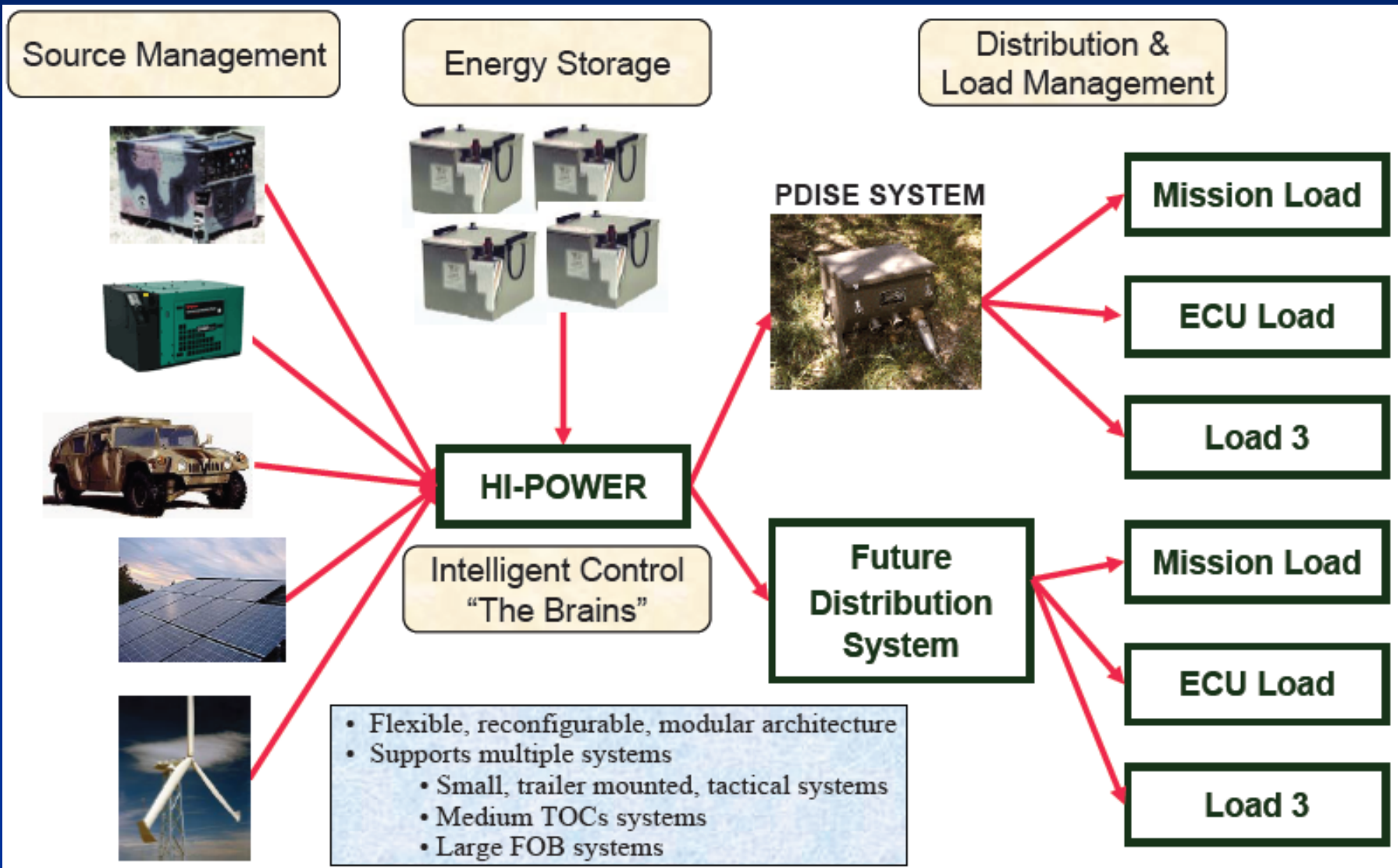
HI-Power

Hybrid Intelligent Power Management

- **Broad Agency Announcement (BAA)**
 - Introduced during my presentation at the Joint Service Power Expo in 2007
- **To develop a general architecture capable of managing power more efficiently and effectively on the battlefield.**
 - Includes renewable and traditional sources, AC and DC, controls them and delivers clean, reliable AC



HI-Power





A Problem

Fuel Tank Limited Power

- Disaster recovery, emergency services, first responders typically need portable power
 - Commercial grid may be down for days or weeks
 - Initial refueling may not be available for days
 - Refueling may be difficult on a continuing basis
- Power lasts until the tank is empty



A Solution

Hybrid Power Source

- Develop a solar-battery-fuel powered source
 - Solar panels for daytime power
 - Batteries for evening power
 - Smart variable speed generator for backup or supplemental power
 - Transported/mounted on FMTV or similar vehicle
 - Intelligently control sources



A Solution

Hybrid Power Source Features

- Extended operation without refueling
- Sources use can be scheduled or automatic
 - Batteries can be reserved for night use
 - Cost based source selection
- Sources can be combined for peak demand
- Multiple systems combine for more power
- Pallet-based system easily transportable



New Technology

Solar Panels

- There are more 200 to 300 W panels available
- Thin Films are more viable now
- Efficiency inversely proportional to footprint but weight and size effect deployment
- Weight is less of an issue on 2.5 to 5 ton vehicles
- Packaged on 463L pallets is a consideration



New Technology

Batteries

- There are more 2.5Ah Li ion cells available
- Lithium Phosphate are safer (A123), faster charging but less energy dense
- Again weight is less of an issue
- Lead Acid is a cost consideration
 - Firefly Microcell Foam technology
- Could be packaged on 463L pallets with panels



New Technology

Variable Speed Generators

- Rolls-Royce 15 kW VSG
- Varying speed engine and 3-phase inverter
- Speed is proportional to demand
- Start-Stop controlled by system demand
- Paralleling is automatic
- 15% less fuel usage at low loads





Smart Technology

Fixed Speed Smart Generators

- PSI 20 to 60 kW Gensets
- Start-Stop controlled by system demand
- Paralleling is automatic
- Fuel savings for multiple generator system





Options

Hard-mounted System

- System is not designed to be removed from the vehicle bed or trailer
 - Shorter setup time
 - Vehicle not available for other uses

Modular System

- Module is transported to location
 - May be dropped off in an open area
 - Vehicle can be used for other purposes
 - May be left on vehicle



Pallet

Military 463L

- Standardized pallet used for transporting military air cargo
 - 88 in. by 108 in. by 2.25 in., 84 in. by 104 in. usable
 - 10,000 lb capacity
 - Can be airdropped





Pallet

Commercial

- Not well standardized
 - NA has twelve “standard” sizes
 - European have six standard sizes
 - Most popular is GMA, 48 in. by 40 in. wood
- No pallet over 48 in
 - Will not accommodate the length of a number of solar panels



Concept Design

Choices

- Modular – More flexibility than hard-mounted
- Thin Film Panels – Weight/Volume advantage
- Lithium Phosphate Batteries – Charging options/safety advantage
- Variable Speed Generator – Inverter eases paralleling and 15% less fuel usage at low load
- 463L pallet – Large enough for any panel or generator



Concept Design

Thin Film Solar Panels

- 2 m by 1 m panel
- Frame used to make thin film panels rigid to aim at the sun
- 61.6 VDC at 1.71 A, 105 W, 5.25 lb, 20 lb framed

Smart Controller

- Source usage
- Load management
- Adaptive charging current



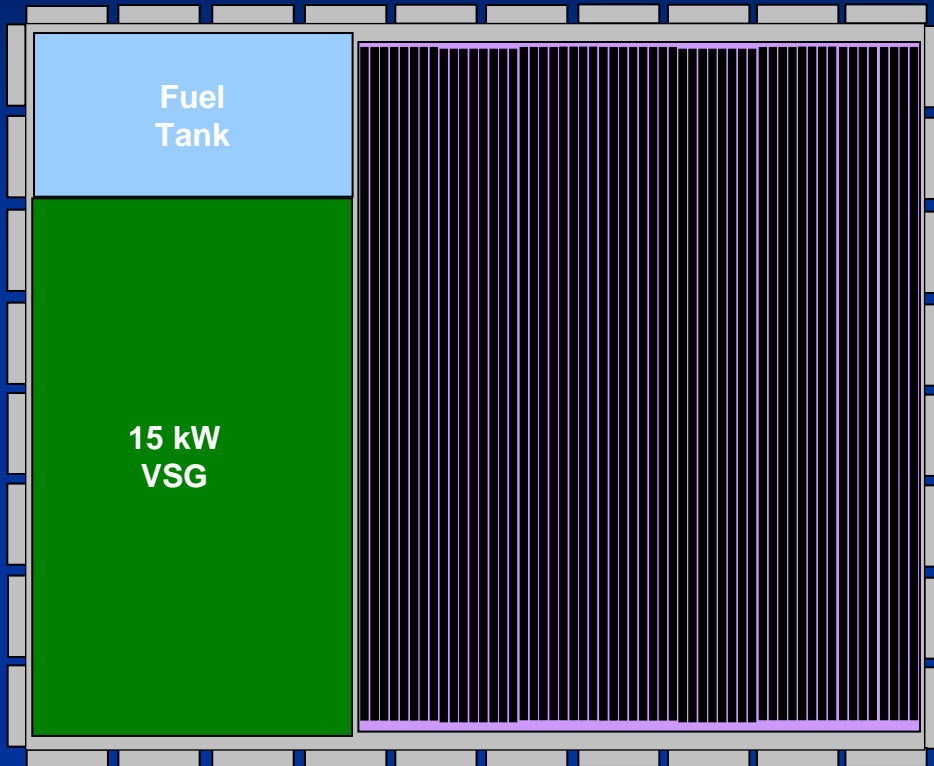
Concept Design

Lithium Phosphate Batteries

- Similar in size to the original battery
 - 26650 size versus 18650
 - 2.3 Ah versus 2.5 Ah
- 27P14S configuration
 - 3.3 VDC versus 3.7 VDC working voltage
 - 62 Ah versus 75 Ah
 - 378 cells versus 390 cells
- Built-in battery management



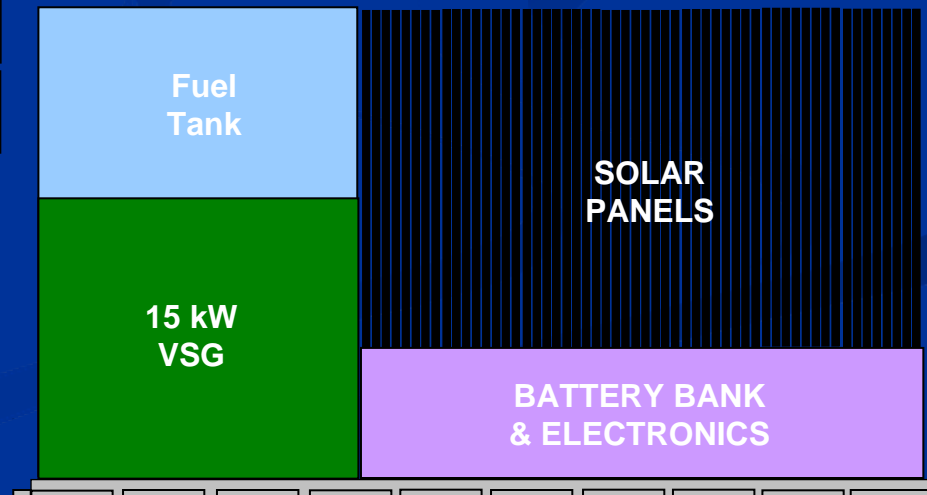
Concept Design



Dimensions

88 in W by 108 L by 57 in H

Meets C130 Height limit on FMTV





Design Issues

Who are the customers for this system

- Homeland Defense, National Guard, FEMA, Red Cross, State Emergency Response Groups

Customer Input

- Is this concept design viable?
- Are there operational issues that can be addressed?
- What minimum level of power is needed?
- At what price point?



Summary

A Hybrid Intelligent Source

- Can be designed today
- Can reduce the need for fuel
- Can have HI-Power characteristics in a modular form
- But it must meet the users needs
- And be affordable



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