2009 JOINT SERVICE POWER EXPO

New Orleans, LA

4 - 7 May 2009

Agenda

USMC Organizations Involved in Research and Acquisition

Tuesday, May 5, 2009

WELCOMING REMARKS:

- Matt Kallmyer, Deputy Director, New Orleans Office Of Homeland Security and Emergency Preparedness

LUNCHEON SPEAKER:

- *"OSD Manufacturing Technology Overview",* Ms. Adele Ratcliff, OSD MANTECH Program

PRIMARY BATTERIES

- 8461 - "*Development of a "Half-Sized" BA-5590 with Li/CFx Cells"*, Dr. Gregg C. Bruce, EaglePicher Technologies
- 8472 - "*High Capacity Li/CFx battery with -70C to 145C Operational Range*", Dr. Hisashi Tsukamoto, PhD, CEO/CTO Quallion, LLC

FUEL CELLS I

- 8288 - "*Joint Defense Manufacturing Technology Panel (JDMTP) Power Sources Technical Working Group (TWG) Fuel Cell Roadmap*", Mr. Francis P. Sokolowski, Industrial Engineer, DCMA
- 8372 - " *U.S. Army CERDEC's Soldier and man Portable Fuel Cell Evaluation and Field Testing"*, Mr. Michael Dominick,, US Army CERDEC, Army Power Division, Fuel Cell Development Team
- 8368 - "*Lessons Learned from the Defense Logistics Agency's Hydrogen and Fuel Cell Demonstration Project at Defense Depot Susquehanna, PA (DDSP)"*, Mr. Kenneth Burt, NSWC Crane Division

RECHARGEABLE BATTERIES

- 8376 - "*Advanced Lithium Power Sources - Real World Experiences and Next Steps*", Mr. Jim Hess, Director of Defense Sales, SAFT America
- 7770 - "*Battery Requirements for Application of Lithium Ion and Lithium Polymer To Achieve Standardization and Improved Reliability"*, Mr. William R. Johnson, Manager AIR-4.4.5.2 Electrical Power.
- 8474 - "*Quallion Large Battery Pack Technology"*, Dr. Hisashi Tsukamoto, PhD, CEO/CTO Quallion, LLC

FUEL CELLS II

- 8312 - "*Direct Methanol fuel Cells: Lightweight, Portable Power for Soldiers in the Field*", Mr. Christian Boehm, Director, Defense Division Smart Fuel Cell AG & Inc
- 8484 - "*Development of a Solid Oxide Fuel Cell Utilizing Logistics Fuels"*, Dr. Neil Fernandes, Acumentrics
- "GEI MX5 High-Temperature PEM Fuel Cells Military Applications", K.J. Berry, Ph.D, P.E., President and CEO, Global Energy Innovations

CROSS-CUTTING POWER

- 8463 - "*Integrated Starter Generator - More than a 24V Vehicle Power Supply"*, Mr. Thomas Trzaska, L3 Communications
- 8488 - "*The Role of Solid State Power Controllers in Smart Power Management and Distribution"*, Mr. William Thorp, Senior Electrical Engineer, Data Device Corporation
- 8442 - "*Waste Gasification by the Use of Novel Plasma System"*, Mr. Rod B. Vera, Plasma Waste Cycling

Wednesday, May 6, 2009

LUNCHEON SPEAKER: *"An Exploration of Threats, Solutions and Alternative Futures",* (paper) (slides) Mr. Larry C. Triola, Energy and National Security

MOBILE ELECTRIC POWER
- 8377 - "*Mobile Electric Power for Today and Tomorrow*", Mr. Michael C. Padden, Project Manager Mobile Electric Power (PM MEP)

USMC WAY FORWARD
- 7990 - "*USMC Future Energy Posture*", Mr. Michael Boyd
- 7989 - "*USMC Power and Energy Future Focus*", Mr. Mike Gallagher, Program Manager - Expeditionary Power Systems, Marine Corps Systems Command
- 8308 - "*USMC Portable Power R&D Effort*", Mr. Clint J. Govar, Power Systems Engineer, Marine Corps Systems Command

LARGE SCALE POWER
- 8503 - "*Army Large Scale Power*", Mr. Kevin Sargent, U.S. Army Maneuver and Support Center (MANSCEN), Capabilities Determination and Integration Division, Combat Developer - Prime Power Requirements
- 8411 - "*Enterprise Power Selection*", Mr. Vincent Polino, NOVA Power Solutions, Inc
- 8493 - "*Power Conversion Technologies for Improved System Performance*", Kaz Furmanczyk, Crane Aerospace & Electronics

FUTURE FOCUS ON POWER
- 8307 - "*Future Naval Capability Update: Advanced Power Generation*", Mr. Clint J. Govar, Power Systems Engineer, Marine Corps Systems Command
- 8448 - "*USN Maritime Surveillance Power Requirements for Future Deployable Systems*", Mr. Jeffrey Lloyd, SPAWAR Systems Center - Pacific
- 8412 - "*NDIA Military Power Sources Committee*", Ms. Rebecca Morris, ACI Technologies

ON-BOARD VEHICLE POWER I
- 8378 - "*USMC On-Board Vehicle Power Requirements and Programs*", Mr. Jonathan Carpenter, P.E. Lead Engineer, Marine Corps Systems Command
- 8352 - "*OBVP from Legacy to Next Generation*", Dr. Brent Brzezinski, DRS Test & Energy Management
- 8391 - "*MTV Onboard Vehicle Power-Program Update*", Mr. Nader Nasr, Oshkosh Corporation

SAFETY
- 8502 - "*When Batteries Go Bad*", Ms. Julie Banner, Systems & Materials for Power & Protection Branch, Naval Surface Warfare Center, Carderock Division
- 8475 - "*Critical Power Needs for Life and Safety*", Dr. Joseph G. Palsa, P.E., Clary Corporation
- 8482 - "*Ni-Cd Battery Separator System that Improves Battery Reliability and Increases Charge Stability by Orders of Magnitude at Little or No Cost Increase*", Mr. Baird C. Newman, Mechanical Engineer, Crane Division, Naval Surface Warfare Center

CONNECTORS
- 8470 - "*Improved Battery/Power Connectors for Aircraft and other High Current Applications*", Mr. Nate Bower,

VEHICLE BATTERY MAINTENANCE
- 8321 - "*Battery Maintenance and Sustainment*", Mr. Mark D. Abelson, PulseTech Products Corporation
- 8365 - "*Power for Vehicle and Battery-Operated Weapon Systems*", Mr. Micheal J. Bissonnette, Team Lead/L-3 Communications Support Expeditionary Power Systems, Marine Corps Systems Command

PORTABLE SUPPORT EQUIPMENT
- 8483 - "*A Field-Portable Lithium Ion Battery Charger with UPS Back-up Capability*", Mr. Neil Steven Graves, Acumentrics
- 8394 - "*Kestrel - Falcon III Radio Power Adapter/Charger (AN/PRC-117G)*", Mr. Edward J. O'Rourke, Iris Technology Corporation

Thursday, May 7, 2009

POWER DISTRIBUTION I
- 8382 - "*Intelligent Power Management & Distribution*", Ms. Michelle N. Gaffney, CERDEC
- 7934 - " *Micro Grids: Harnessing & Managing Multiple Energy Resources*", Mr. Tom Lederle, NEST Energy Services
- 8458 - "*Micro Grid Development for the Tactical Operation Center*", Ms. Teri Hall, Electrical Engineering Staff, Lockheed Martin

ON-BOARD VEHICLE POWER II
- 8384 - "*High Temperature PEM Fuel Cell/Lithium Ion Hybrid Power Source for Ground, Air and Sea*", Mr. Michel Fuchs, EnerFuel

- 8364 - “*Power and Energy Management for Heavy Tactical Vehicles*”, Mr. Chris M. Rogan, P.E., Penn State ARL
    1. video .avi video files
- 8399 - “*Auxiliary Power Unit for Military Vehicles*”, Mr. Jeffrey S. Humble

RENEWABLES

- 7933 - “*Mobilizing Renewable Energy for Field Applications*”, Mr. Tom Lederle, NEST Energy Services
- 8358 - “*Hybrid Power Systems for Mission Critical Enterprise Land Mobile*”, Mr. Mark H. Viness, E.I. T, Motorola National Site Design and Integration Team
- 8393 - “*StarPower Technology - Solar Charging, Power Management and Distribution*”, Mr. Edward J. O’Rourke, Iris Technology Corporation
- “*Renewable Power in OIF*”, Mr. Daryl Wilson, Former Expeditionary Power Systems FSR in Iraq, L-3 Communications

POWER DISTRIBUTION II

- 8392 - “*QP-1800 Inverter System - USMC Workhorse*”, Mr. Edward J. O’Rourke, Iris Technology Corporation
    1. QP-1800 Transportation Testing .wmv video file
    2. QP-1800 Testing .wmv video file
- 8386 - “*30 kW Exportable Power System for Military Tactical Vehicles”*, Ms. Jennifer L. Grudnoski, GS Engineering
- 7764 - “*Maximizing Power Production from the Stock, Belt-Driven Alternator Using a Practical Constant Speed Drive”*, Mr. Scott McBroom
    1. CVAD on FMTV at BAE .wmv video files

ON-BOARD VEHICLE II

- 8362 - “*Alternative Squad Power: Taking Advantage of Solar, Fuel Cell and Scavenged Power at the Squad Level*”, Mr. Greg Cipriano, VP, Marketing & Military Development, Protonex

HYBRIDS

- 8381 - “ *System Consideration When Integrating New Battery Technologies into the XM1124 Hybrid Electric HMMWV”*, Dr. Michael J. Marcel, DRS Test and Energy Management
- 8385 - “*A Mobile Hybrid Power Source with Intelligent Control”*, Mr. Rick Silva, Sr. System Engineer, Custom Manufacturing & Engineering, Inc
- 8371 - “*New Application of Lithium-Ion Battery in Hybrid Power Supply System*”, Mr. Takefumi Inoue, GS Yuasa Corporation

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Schedule at a Glance

Monday, May 4, 2009

9:00 a.m. - 5:00 p.m.	Exhibitor Move-in

Tuesday, May 5, 2009

8:30 a.m. - 11:30 a.m.	Opening General Session
10:00 a.m. - 5:00 p.m.	Exhibit Hall Open
11:30 a.m. - 1:00 p.m.	Lunch in Exhibit Hall
1:00 p.m. - 5:00 p.m.	Conference Sessions
6:00 p.m. - 8:00 p.m.	Conference Reception in Exhibit Hall

Wednesday, May 6, 2009

8:30 a.m. - 11:30 a.m.	Conference Break-out Sessions
9:00 a.m. - 5:00 p.m.	Exhibit Hall Open
11:30 a.m. - 1:00 p.m.	Lunch in Exhibit Hall
1:00 p.m. - 4:00 p.m.	Conference Break-out Sessions

Thursday, May 7, 2009

8:00 a.m. - 11:30 a.m.	Conference Break-out Sessions
9:00 a.m. - 12:00 p.m.	Exhibit Hall Open
11:30 a.m.	Adjourn
12:00 p.m. - 5:00 p.m.	Exhibitor Move-out

MONDAY, MAY 4, 2009

9:00 a.m. - 5:00 p.m. — Exhibitor Move-in & Registration
Exhibit Hall B1 & Hall B1 Foyer
Ernest N. Morial Convention Center

3:00 p.m. - 5:00 p.m. — Early Registration Check-in
Exhibit Hall B1 Foyer
Ernest N. Morial Convention Center

TUESDAY, MAY 5, 2009

7:00 a.m. - 9:00 a.m. — Exhibitor Move-in & Registration Continues
Exhibit Hall B1 & Hall B1 Foyer

7:30 a.m. - 8:15 a.m. — Continental Breakfast
Room 225/226/227
Ernest N. Morial Convention Center

8:15 a.m. - 8:30 a.m. — Opening Session Prelude
Brass Quintet from the
Marine Forces Reserve Band
Riverside Rooms (R02/03/04/05)

8:30 a.m. - 11:30 a.m. — Opening Session

8:30 a.m. - 8:35 a.m. — Administrative Remarks

8:35 a.m. - 8:40 a.m. — Color Guard
377th Theater Support Command
Special Troops Battalion

8:40 a.m. - 9:00 a.m. — Welcoming Remarks

- Matt Kallmyer,
  Deputy Director,
  New Orleans Office of Homeland
  Security and Emergency Preparedness

9:00 a.m. - 10:00 a.m. — General Session

- Keynote Speaker

  Mr. Patrick B. Davis
  Program Manager
  Office of Vehicle Technologies Program,
  Energy Efficiency and Renewable
  Energy
  U.S. Department of Energy

TUESDAY, MAY 5, 2009 (CONTINUED)

10:00 a.m. - 5:00 p.m.	Exhibit Hall Open Exhibit Hall B1 Foyer Ernest N. Morial Convention Center
10:00 a.m. - 10:30 a.m.	Coffee Break in Exhibit Hall Exhibit Hall B1
10:30 a.m. - 11:30 a.m.	General Session (continues) Riverside Rooms (R02/03/04/05) • OIF Session Moderator: CWO5 Pam Good (USMC) "Past, Current Projected Ops for Power Missions & Lessons Learned in Iraq"
11:30 a.m. - 1:00 p.m.	LUNCH in Exhibit Hall Exhibit Hall B1 Luncheon Speaker • Ms. Adele Ratcliff OSD MANTECH Program
1:00 p.m. - 2:30 p.m.	Conference Break-out Sessions • Primary Batteries Room 228/229/230 • Fuel Cells I Room 217/218
2:30 p.m. - 3:00 p.m.	Coffee Break in Exhibit Hall Exhibit Hall B1
3:00 p.m. - 5:00 p.m.	Conference Break-out Sessions • Rechargeable Batteries Room 228/229/230 • Fuel Cells II Room 217/218 • Cross-Cutting Power Room 231/232
5:00 p.m. - 6:00 p.m.	Free Time, Exhibit Hall Closed
6:00 p.m. - 8:00 p.m.	Conference Reception in Exhibit Hall Exhibit Hall B1 Ernest N. Morial Convention Center

Highlights will include:

Tuesday, May 5, 2009

- Keynote Speaker:

  Mr. Pat Davis (DoE)

- OIF Session

- Luncheon Speaker:
  Adele Ratcliff
  OSD MANTECH Program

Break-out Sessions:

- Primary Batteries
- Fuel Cells I & II
- Rechargeable Batteries
- Cross-Cutting Power
- Mobile Electric Power
- USMC Way Forward
- Large Scale Power
- Future Focus on Power
- On-Board Vehicle Power I, II & III
- Safety
- Connectors
- Vehicle Battery Maintenance
- Portable Support Equipment
- Power Distribution I & II
- Renewables
- Hybrids

Highlights will include:

Wednesday, May 6, 2009

- Luncheon Speaker:

  Mr. Larry C. Triola
  Energy and National Security

Wednesday, May 6, 2009

7:30 a.m. - 8:30 a.m.	Continental Breakfast Room 225/226/227 Ernest N. Morial Convention Center
8:30 a.m. - 9:30 a.m.	Conference Break-out Sessions continue • Mobile Electric Power Room 228/229/230
9:00 a.m. - 5:00 p.m.	Exhibit Hall Open Exhibit Hall B1 Foyer Ernest N. Morial Convention Center
9:30 a.m. - 10:00 a.m.	Coffee Break in Exhibit Hall Exhibit Hall B1
10:00 a.m. - 11:30 a.m.	Conference Break-out Sessions continue • USMC Way Forward Room 228/229/230 • Large Scale Power Room 217/218
11:30 a.m. - 1:00 p.m.	LUNCH in Exhibit Hall Exhibit Hall B1 Luncheon Speaker • Mr. Larry C. Triola Futurist for the Warfare Systems Concepts Branch Warfare Analysis & Advanced Concepts Division, Warfare Systems Department Naval Surface Warfare Center, Dahlgren Division
1:00 p.m. - 2:30 p.m.	Conference Break-out Sessions continue • Future Focus on Power Room 228/229/230 • On-Board Vehicle Power I Room 217/218 • Safety Room 231/232
2:30 p.m. - 3:00 p.m.	Coffee Break in Exhibit Hall Exhibit Hall B1

Wednesday, May 6, 2009 (continued)

3:00 p.m. - 4:00 p.m. — Conference Break-out Sessions continue
- Vehicle Battery Maintenance
  Room 228/229/230
- Portable Support Equipment
  Room 217/218
- Connectors
  Room 231/232

~ Evening Free~

Thursday, May 7, 2009

7:30 a.m. - 8:00 a.m. — Continental Breakfast
Room 225/226/227
Ernest N. Morial Convention Center

8:00 a.m. - 9:30 a.m. — Conference Break-out Sessions continue
- Power Distribution I
  Room 228/229/230
- On-Board Vehicle Power II
  Room 217/218
- Renewables
  Room 231/232

9:00 a.m. - 12:00 p.m. — Exhibit Hall Open
Exhibit Hall B1 Foyer
Ernest N. Morial Convention Center

9:00 a.m. - 12:00 p.m. — "View Exhibits Only" General Public
Exhibit Hall B1 Foyer
Ernest N. Morial Convention Center

9:30 a.m. - 10:00 a.m. — Coffee Break in Exhibit Hall
Exhibit Hall B1

10:00 a.m. - 11:30 a.m. — Conference Break-out Sessions continue
- Power Distribution II
  Room 228/229/230
- On-Board Vehicle Power III
  Room 217/218
- Hybrids
  Room 231/232

11:30 a.m. — Adjourn

12:00 p.m. - 5:00 p.m. — Exhibitor Move-out

Break-out Sessions:

- Primary Batteries
- Fuel Cells I & II
- Rechargeable Batteries
- Cross-Cutting Power
- Mobile Electric Power
- USMC Way Forward
- Large Scale Power
- Future Focus on Power
- On-Board Vehicle
  Power I, II & III
- Safety
- Connectors
- Vehicle Battery Maintenance
- Portable Support Equipment
- Power Distribution I
- Renewables
- Power Distribution I & II
- Hybrids

Tuesday, May 5, 2009

Session Title 1:00 p.m. - 2:30 p.m.	Primary Batteries Room 228/229/230		Fuel Cells I Room 217/218
Moderator	Mike Brundage (Army)		Justin Govar (USMC)
2-A	8351 Ms. Rebecca M. Morris Advanced Commercial Battery Packaging Technology to Improve Battery Availability for Navy, Army, and Air Force Survival Systems	4-A	8288 Mr. Francis P. Sokolowski Joint Defense Manufacturing Technology Panel (JDMTP) Power Sources Technical Working Group (TWG) Fuel Cell Roadmap
2-B	8461 Dr. Gregg C. Bruce Development of a "Half-Sized" BA-5590 with Li/CFx Cells	4-B	8372 Mr. Michael Dominick U.S. Army CERDEC's Soldier and Man Portable Fuel Cell Evaluation and Field Testing
2-C	8472 Dr. Hisashi Tsukamoto High Capacity Li/CFx battery with -70°C to 145°C Operational Range	4-C	8368 Mr. Kenneth Burt Lessons Learned from the Defense Logistics Agency's Hydrogen and Fuel Cell Demonstration Project at Defense Depot Susquehanna, PA (DDSP)
2:30 p.m. - 3:00 p.m.	Coffee Break in Exhibit Hall		

3:00 p.m. - 5:00 p.m.	Rechargeable Batteries Room 228/229/230		Fuel Cells II Room 217/218		Cross-Cutting Power Room 231/232
	Don Brockel (Army)		Nick Foundos (FBI)		
3-A	8376 Mr. Jim Hess Advanced Lithium Power Sources – Real World Experiences and Next Steps	5-A	8464 Mr. Mack W. Knobbe Portable Electrical Power Supply for Aeromedical Evacuations	6-A	8283 Mr. Luis Villarreal Lithium Non-rechargeable Batteries Production Improvements
3-B	7770 Mr. William R. Johnson Standardization of Aircraft Batteries Using Lithium Rechargeable Batteries	5-B	8312 Mr. Christian Boehm Direct Methanol Fuel Cells: Lightweight, Portable Power for Soldiers in the Field	6-B	8463 Mr. Thomas Trzaska Integrated Starter Generator – More than a 24V Vehicle Power Supply
3-C	8474 Dr. Hisashi Tsukamoto Large Format Li Ion Replacement Packs for Lead Acid Applications	5-C	8501 Mr. Ian Kaye Mission Flexible, Smart, Fuel Cell Power Solutions for Remote and Long Runtime Man Portable Use	6-C	8488 Mr. William Thorp The Role of Solid State Power Controllers in Smart Power Management and Distribution
3-D	8496 Mr. John Heinzel Advanced Battery-Based Energy Storage Systems for Uninterruptible Power Supply, Single Generator Operations Application	5-D	8484 Dr. Neil Fernandes Development of a Solid Oxide Fuel Cell Utilizing Logistics Fuels	6-D	8442 Mr. Rod B.Vera Waste Gasification by the Use of Novel Plasma System
5:00 p.m.	Adjourn - Free time until Reception in Exhibit hall				

Wednesday, May 6, 2009

7:30 a.m. - 8:30 a.m.	Continental Breakfast Room 225/226/227				
Session Title 8:30 a.m. - 9:30 a.m.	Mobile Electric Power Room 228/229/230				
Moderator	Regina Daniels (PM-MEP)				
7-A	8377 Mr. Michael C. Padden Mobile Electric Power for Today and Tomorrow				
9:30 a.m. - 10:00 a.m.	Coffee Break in Exhibit Hall				
Session Title 10:00 a.m. - 11:30 a.m.	USMC Way Forward Room 228/229/230		Large Scale Power Room 217/218		
Moderator	Joanne Martin (USMC)		Ken Burt (Navy)		
8-A	7990 Mr. Michael Boyd USMC Future Energy Posture	11-A	8503 Mr. Kevin Sargent Army Large Scale Power		
8-B	7989 Mr. Mike A. Gallagher USMC Power and Energy Future Focus	11-B	8411 Mr. Vincent Polino Enterprise Power Selection		
8-C	8308 Mr. Clint J. Govar U.S. Marine Corps Portable Power R&D Effort	11-C	8493 Mr. Mark J. Stefanich Power Conversion Technologies for Improved System Performance		
11:30 a.m - 1:00 p.m.	Lunch in the Exhibit Hall Luncheon Speaker: Mr. Larry C. Triola, Energy and National Security				
Session Title 1:00 p.m. - 2:30 p.m.	Future Focus on Power Room 228/229/230		On-Board Vehicle Power I Room 217/218		Safety Room 231/232
Moderator	Kyle Werner (Navy)		Mike Bissonnette (USMC)		Pat Lyman (Army)
9-A	8307 Mr. Clint J. Govar Future Naval Capability Update: Advanced Power Generation	12-A	8378 Mr. Jonathan Carpenter, P.E. USMC On-Board Vehicle Power Requirements and Programs	14-A	8502 Ms. Julie Banner When Batteries Go Bad
9-B	8448 Mr. Jeffrey Lloyd USN Maritime Surveillance Power Requirements for Future Deployable Systems	12-B	8352 Dr. Brent Brzezinski OBVP from Legacy to Next Generation	14-B	8475 Dr. Joseph G. Palsa P.E. Clary Corporation Critical Power Needs for Life and Safety
9-C	8412 Ms. Rebecca Morris NDIA Military Power Sources Committee	12-C	8391 Mr. Nader Nasr MTVR Onboard Vehicle Power – Program Update	14-C	8482 Mr. Baird C. Newman Ni-Cd Battery Separator System that Improves Battery Reliability and Increases Charge Stability by Orders of Magnitude at Little or No Cost Increase

Wednesday, May 6, 2009 (continued)

2:30 p.m. - 3:00 p.m.	Coffee Break in Exhibit Hall					
Session Title 3:00 p.m. - 4:00 p.m.	Connectors Room 231/232		Vehicle Battery Maintenance Room 228/229/230		Portable Support Equipment Room 217/218	
Moderator	Frank Sokolowski (DCMA)		Jonathon Carpenter (USMC)		Don Brockel (Army)	
10-A	8380 Ms. Rebecca M. Morris Military Power Connector Advancements to Improve Performance and to Reduce Costs	13-A	8321 Mr. Mark D. Abelson Battery Maintenance and Sustainment	15-A	8483 Mr. Neil Steven Graves A Field-Portable Lithium Ion Battery Charger with UPS Back-up Capability	
10-B	8470 Mr. Nate Bower Improved Battery/Power Connectors for Aircraft and Other High Current Applications	13-B	8365 Mr. Michael J. Bissonnette Power for Vehicle and Battery-Operated Weapon Systems	15-B	8394 Mr. Edward J. O'Rourke Kestrel – Falcon III Radio Power Adapter/Charger (AN/PRC-117G)	
4:00 P.M.	Adjourn for the day					

Thursday, May 7, 2009

7:30 a.m. - 8:00 a.m.	Continental Breakfast Room 225/226/227				
Session Title 8:00 a.m. - 9:30 a.m.	Power Distribution I Room 228/229/230		On-Board Vehicle Power II Room 217/218		Renewables Room 231/232
Moderator	Regina Daniels (PM-MEP)		Jonathon Carpenter (USMC)		Malar Motley (USMC)
16-A	8382 Ms. Michelle N. Gaffney Intelligent Power Management & Distribution	18-A	8384 Mr. Michel Fuchs High Temperature PEM Fuel Cell/Lithium Ion Hybrid Power Source for Ground, Air, and Sea	20-A	7933 Mr. Tom Lederle Mobilizing Renewable Energy for Field Applications
16-B	7934 Mr. Tom Lederle Micro Grids: Harnessing & Managing Multiple Energy Resources	18-B	8364 Mr. Chris M. Rogan, P.E. Power and Energy Management for Heavy Tactical Vehicles	20-B	8358 Mr. Mark H. Viness Hybrid Power Systems for Mission Critical Enterprise Land Mobile
Session Title 8:00 a.m. - 9:30 a.m.	Power Distribution I Room 228/229/230		On-Board Vehicle Power II Room 217/218		Renewables Room 231/232

Thursday, May 7, 2009 (continued)

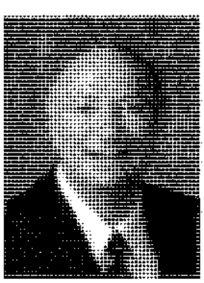
Moderator	Regina Daniels (PM-MEP)		Jonathon Carpenter (USMC)		Malar Motley (USMC)
16-C	8458 Ms. Teri Hall Micro-Grid Development for the Tactical Operation Center	18-C	8399 Mr. Jeffrey S. Humble Auxiliary Power Unit for Military Vehicles	20-C	8393 Mr. Edward J. O'Rourke StarPower Technology – Solar Charging, Power Management and Distribution
9:30 A.M. - 10:00 A.M.	Coffee Break in Exhibit Hall				
Session Title 10:00 a.m. - 11:30 a.m.	Power Distribution II Room 228/229/230		On-Board Vehicle Power III Room 217/218		Hybrids Room 231/232
Moderator	Keith DeVries (Navy)		Michelle Gaffney (Army)		Justin Govar (USMC)
19-A	8392 Mr. Edward J. O'Rourke QP-1800 Inverter System – USMC Workhorse	17-A	8370 Mr. Patrick Marshall RAPS – A Universal Power Supply	21-A	8381 Dr. Michael J. Marcel System Considerations When Integrating New Battery Technologies into the XM1124 Hybrid Electric HMMWV
19-B	8386 Mrs. Jennifer L. Grudnoski 30 kW Exportable Power System for Military Tactical Vehicles	17-B	8362 Mr. Greg Cipriano Alternative Squad Power: Taking Advantage of Solar, Fuel Cell, and Scavenged Power at the Squad Level	21-B	8385 Mr. Rick Silva A Mobile Hybrid Power Source with Intelligent Control
19-C	7764 Mr. Scott McBroom Maximizing Power Production from the Stock, Belt-Driven Alternator Using a Practical Constant Speed Drive	17-C	8361 Mr. Phil Robinson Soldier Power Management: Lightening the Load Through Active Battery Charge/Discharge Management	21-C	8371 Mr. Takefumi Inoue New Applications of Lithium-Ion Battery in Hybrid Power Supply System
11:30 a.m.	**2009 Joint Service Power Expo Adjourns**				
Post-JSPE Expo Meetings	USMC Meeting Room 228/229/230		Shelf Life Meeting Room 214		NDIA Manufacturing Division Military Power Sources Meeting Room 217/218

Patrick Davis is the Program Manager of the Vehicle Technologies Program Office at the U. S. Department of Energy. Vehicle Technologies supports over $270 million in annual research funding for hybrid drivetrains, advanced batteries, lightweight materials, advanced combustion and fuels, vehicle systems integration, and deployment activities. He is responsible for two major government industry partnerships, the FreedomCAR and Fuel Partnership and the 21st Century Truck Partnership. Patrick also serves on the Board of Directors of the American National Standards Institute.

Mr. Davis previously served as a senior advisor for transportation technologies in the office of Energy Efficiency and Renewable Energy, as the Acting Program Manager of the Office of Hydrogen, Fuel Cells and Infrastructure Technologies, Team Leader for Hydrogen Production, Team Leader for Fuel Cell Technology, co-chair of two FreedomCAR and Fuel Partnership Technical Teams, and the U.S. representative to the International Energy Agency's Hydrogen Implementing Agreement.

Mr. Davis is a Chemical Engineer with over 25 years of experience in the development of vehicle, alternative fuel, and electrochemical technologies.

Ms. A Adele Ratcliff is the OSD Director, Manufacturing Technology (ManTech) for ODUSD Advanced Systems & Concepts (AS&C). She has a long acquisition career, including Program Manager for the congressionally mandated Defense Acquisition Challenge Program (DAC), Deputy Program Manager for the Foreign Comparative Test (FCT) Program and more than eleven years in Air Force Test and Evaluation at Eglin AFB. As Test Manager, she guided the Air Force ACAT II Wind Corrected Munitions Dispenser (WCMD) test program from prototype through Milestone C decision, earning the AF Civilian Test Engineer of the Year Award. More importantly, her efforts positioned WCMD to support the initial phases of Operation Enduring Freedom. She is a proud alumnus of the Mississippi State University Bulldogs, earning a BS in Mechanical Engineering in 1988.



Mr. Larry C. Triola is the NSWCDD Director of Science and Technology. His engineering career with the Navy began in 1976 at Port Hueneme, California. After 2 years on assignment at the Aegis Combat Systems Engineering Developments Site (CSEDS) in Moorestown, New Jersey, he transferred to Dahlgren in 1979. His team's performance at CSEDS earned them written commendation from Rear Admiral Wayne E. Meyer, the Chief of Naval Operations, and the Secretary of the Navy. He has served in the OPNAV office for RDT&E involved in S&T Requirements. He served 6 years as Deputy Chief Scientist for DRPM Aegis/PEO Surface Combatants where he was awarded the Aegis Excellence Award by Rear Admiral Huchting. He obtained degrees in psychology and electrical engineering from the University of Houston and attended graduate school at Baylor College of Medicine. He is a member of Tau Beta Pi engineering honors fraternity, IEEE, the Old Crows, and Mensa. He is the current Chairman of the Technical Advisory Board of the NSWCDD Technical Digest.

When Batteries Go Bad

"9310"

Serious Testing for Serious Batteries

Julie Banner
Systems & Materials for Power & Protection Branch
Naval Surface Warfare Center, Carderock Division

Mark Tisher
Power and Circuit Board Technologies Division
Naval Surface Warfare Center, Crane Division

Glen Bowling
VP of Sales
Saft Specialty Battery Group

Joint Power Expo, New Orleans LA,
5-7 May 2009

What exactly do you mean by "bad?"

Oh, you mean something like this…

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

The Genesis

- NAVSEAINST – 9310.1b of 13 June 1991
  - Issued the policy requiring and established the responsibilities for implementing lithium battery safety certifications
  - First issued in 1979 and is being updated to be reissued in CY2009
  - Designates NAVSEA as technical authority for the Dept of the Navy for lithium battery safety
  - “Owner” of system or development determines final approval after recommendation of NAVSEA 00V* (formerly SEA665)
    - Program managers are responsible for safely applying lithium batteries in their programs
    - Program managers must advise NASEA 00V of plans to incorporate lithium batteries
- Interim Guidance issued 2 Apr 09 by NOSSA ltr N84/521

*AKA NOSSA (Naval Ordnance Safety and Security Activity)

Roles

- Program Office:
  - Budgets for the testing and samples
  - Determines hazard mitigation methods and makes the final decision to accept risks
- Contractor:
  - Provides technical info on the battery
  - Builds the samples using the best practices, etc.
- Crane/Carderock: Provide the expertise and testing needed and advice when it isn't exactly what you hoped
- NAVSEA 05Z32 & NAVAIR 4.4.5.2: Evaluate platform integration issues related to safety and provide concurrence for certification
- NAVSEA00V/NOSSA: Provides a reasoned and thoughtful review and certification recommendation for the PO
- Open, honest and cooperative approach working as a team always is the best way!

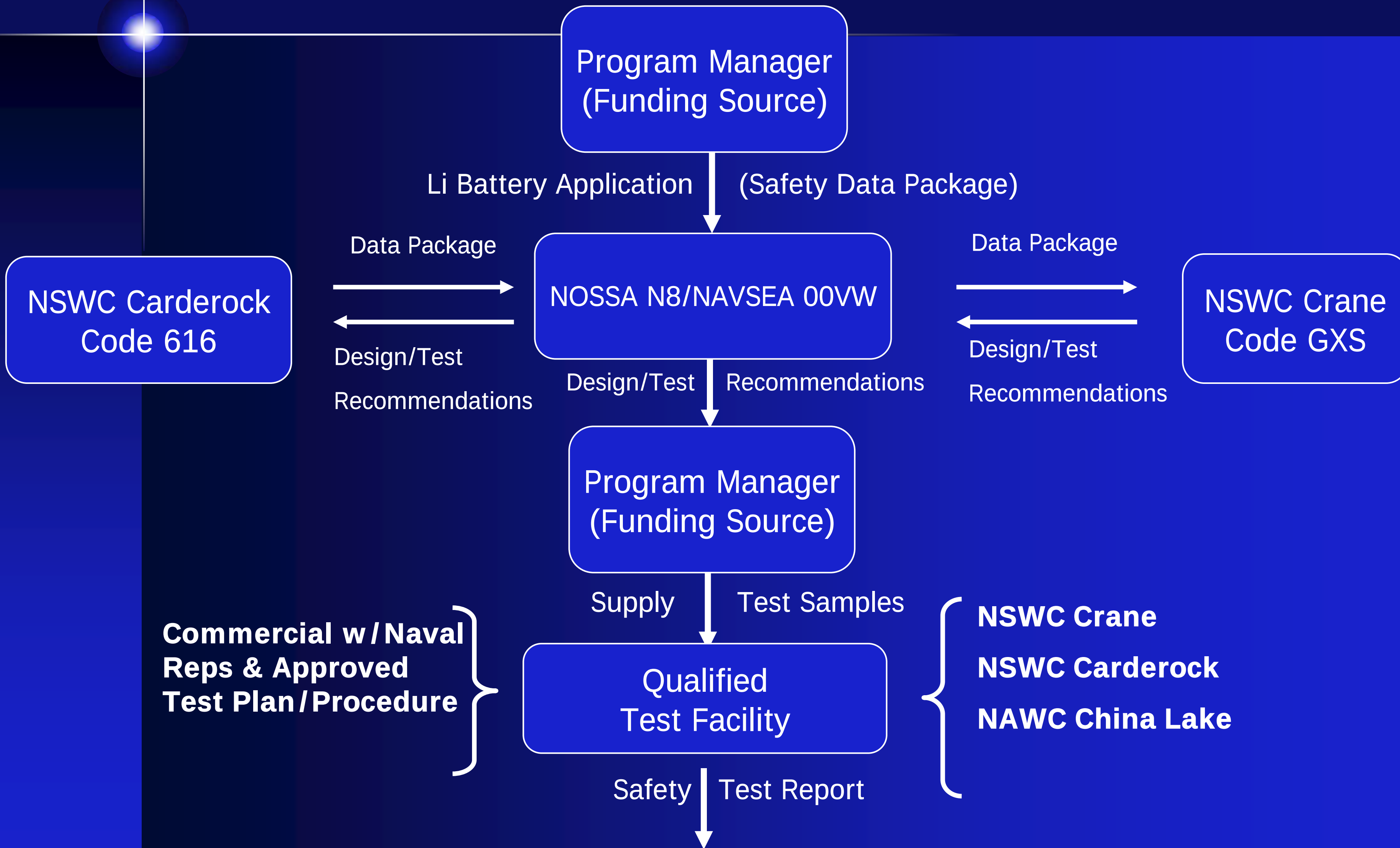
"Just Gimme the Certified Battery List…"

- Navy Lithium Battery Safety Certifications are system specific
- Safety Certifications for previously reviewed batteries:
  - Leverage data from previous programs (testing, analysis, design) when appropriate
  - Do not required duplicative testing
  - Are usually quicker
- Contact Carderock or Crane to determine if a battery has previous safety reviews on file

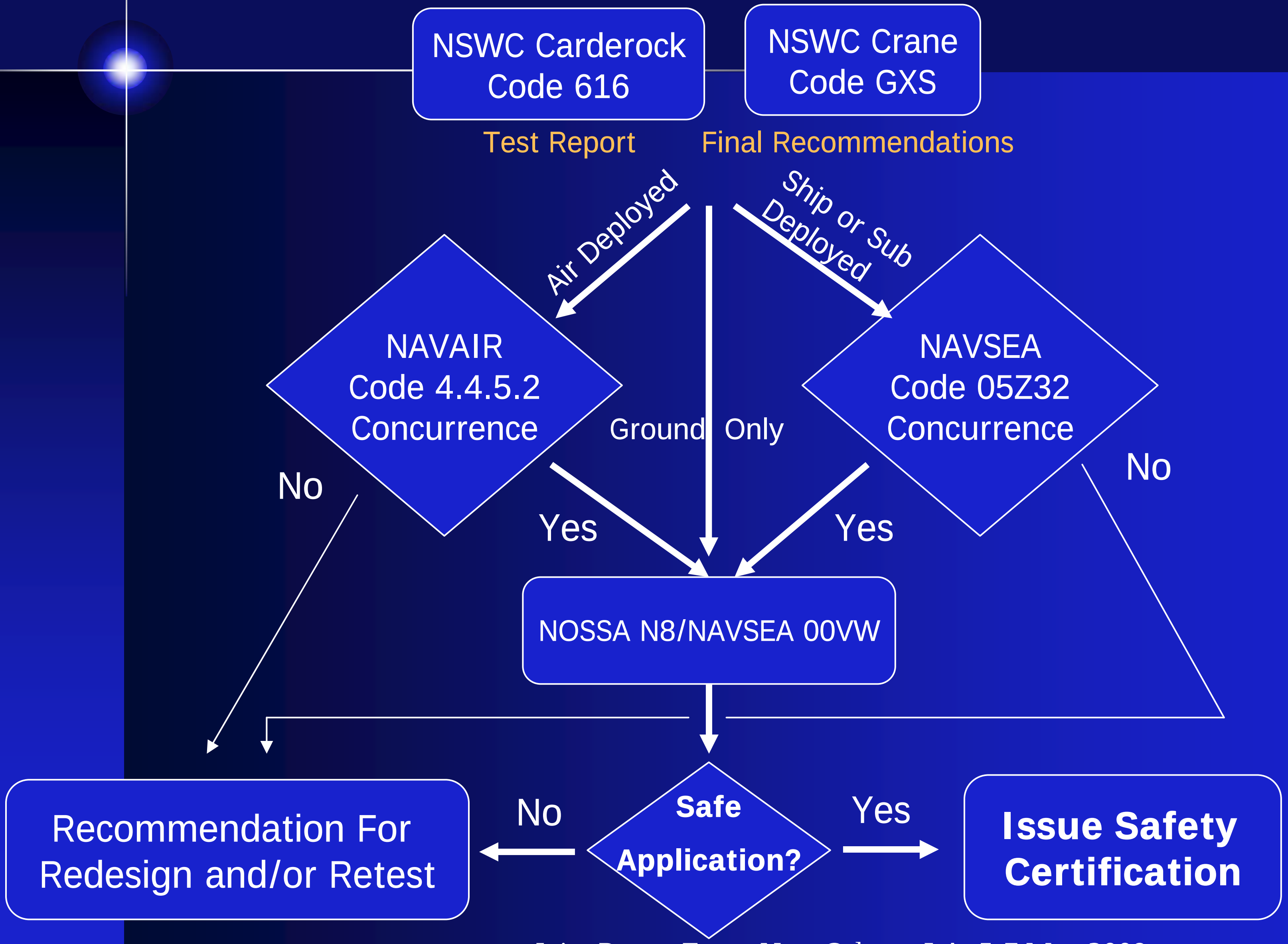
NOSSA/NAVSEA00V Interim 9310 Guidance

- Small battery exceptions, exemptions and blanket approvals remain unchanged from TM S9310
- Defines special class of batteries as "Large Format Batteries/Systems"
  - Lithium batteries (primary & secondary) with 1kWh total energy or greater
  - Systems with 2 kWh total energy or greater
- Imposes additional requirements on Large Format Batteries/Systems
  - 9310 compliance AND
  - System Safety Program IAW MIL-STD-882
- Imposes additional requirements for surface ship and sub deployed batteries/systems
  - 9310 compliance AND
  - Concurrence from NAVSEA05Z IAW their independent review criteria
  - Additional risk mitigation requirements to be imposed on systems that will be recharged aboard ship and sub carried batteries/systems

The Process (Part I)



The Process (Part II)



Independent Navy Safety Review Processes

- Lithium Battery Safety Review
- Weapon Systems Explosive Safety Review Board (WSESRB)
- TEMPALT or SHIPALT
- PMS399 Authorization for Submarine Stowage, Transport & Deployment from DSS

Each Process has
Individual Criteria for Applicability

The "Bible": NAVSEA TM-S9310-AQ-SAF-010 of 19 Aug 2004

- Lays out the details we will cover today
- Includes "Pass – Fail" criteria listed by deployment platform but offers case-by-case determination
- Intended to Over – Test to Find the Real Worst Case Scenario
- Final Recommendations Come from Results
  - Acceptable for Application
  - Redesign
  - Change or Limit Application
- THESE TESTS ARE SEVERE AND DANGEROUS!

What has to be certified?

- Any battery which contains Lithium, even if the lithium is ionized…
  - Primaries: Li/SO_2, Li/SO_2Cl_2, Li/$SOCl_2$, Li/MnO_2, Li/CF_x, Li/FeS_2, Etc…
  - Rechargeables: Li Ion, Li Metal, Even if they say it is not lithium, but they use Li somewhere
  - Thermals: If they contain Lithium
- Regardless of source - even if they are sold by the U.S. Army or DLA as Mil Spec, such as BA-5590, BB-2590, etc.

Design Recommendations

- Smallest battery possible
- Safety devices (Fuses, Thermal Cutoffs, Diodes for Primaries, Vents, etc)
- Specific Compartment
- No Cell Mixing
- Safe Power Switch
- Hermetic Seals
- Protection from Shorting
- Protection from Inadvertent Activation (Reserve & Thermal)
- Shorted Initiated Leads (Reserve & Thermal)
- Protection from inappropriate chargers (Rechargeable)
- Balancing (Rechargeable)
- Etc…

Other Paragraphs

- Use: info about safe use of batteries in general
- Packaging: Info on proper packaging, including reference to the 49CFR 173.185 transportation regulations
- Storage
  - Surface/Submarines approval by SEA-05Z3
  - Aircraft approval by AIR-4.4.5.2.
  - Other guidelines for various storage medium
  - Marking instructions
- Transportation
  - Surface/Submarines approval by SEA-05Z3
  - Aircraft approval by AIR-4.4.5.2.
  - DOD AFMAN24-204/TM 38-250/NAVSUP PUB 505/MCO P4030.19/DLAI4145.3
  - Civilian transport makes reference to the 49CFR 173.185, 172.101 transportation regulations

More "Other" Paragraphs

- Disposal – bring them home and dispose at DRMO, EOD if damaged or dangerous
- Emergency Response
  - Instructions for reporting
  - Instructions for leaking batteries
  - Instructions for hot or swollen batteries, venting batteries

Chapter 2 Testing

- Aimed at discovery of the worst case and designing or planning to mitigate the risks involved
- Defines a Set of Tests but allows/expects Addition or Modification with Approved Plans
- Electrical Safety Device (ESD) Pass Criteria are firm; other criteria are subject to operational need, judgment of the evaluators and other factors

Platform	Criteria		
Submarines	Venting of gaseous/liquid/solid materials and flames outside of the test unit is **prohibited**	and	The peak pressure remains **equal to or below** 50 % of the yield pressure of the unit in any test
Aircraft *	Venting of gaseous/liquid is **permitted**. Venting of solid materials and flames outside of the test unit is **prohibited.** Rupture of the test unit is **prohibited**	and	The peak pressure remains **equal to or below** 50 % of the yield pressure of the unit in any test
Surface Ships	Venting of gaseous/liquid/solid materials is **permitted**. Venting of flames outside of the test unit is **prohibited.** Rupture of the test unit is **prohibited**	and	The peak pressure remains **equal to or below** 50 % of the yield pressure of the unit in any test
Land	Venting of gaseous/liquid/solid materials and flames is **permitted**. Rupture of the test unit is **prohibited**	and	The peak pressure remains **equal to or below** 50 % of the yield pressure of the unit in any test
Unsafe	Rupture of the test unit	or	The peak pressure **exceeds** 50 % of the yield pressure of the unit in any test

*See notes on aircraft application in the Manual

The Tests (Generally)

- Electrical Safety Device (ESD) – making sure the devices work
- Most other tests are conducted without battery-level safety devices (wsd)
  - Discharge and Reversal – wsd - reactions due to poorly balanced electrochemistry
  - Short Circuit – wsd - reactions due to overheating
  - High Temp (500^{o}C) – reactions when internal constituents melt
  - Abusive Charging – wsd – on primaries looking for reaction to lithium plating and run-away; on secondaries imposing abusive charging voltage
  - Physical Abuse – Shock, Vibe, etc.
  - Cycling of Rechargeables – reactions due to aging and use
- Voltage, Current and temperature data and video are collected

Results are Spectacular!

- Fires, Flames and Smoke!
- Sometimes things move around…
- Video is the best way to show it

Overcharge/Propagation Test of Li Ion Cells

Overcharge/Propagation of Lithium Ion Cell

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

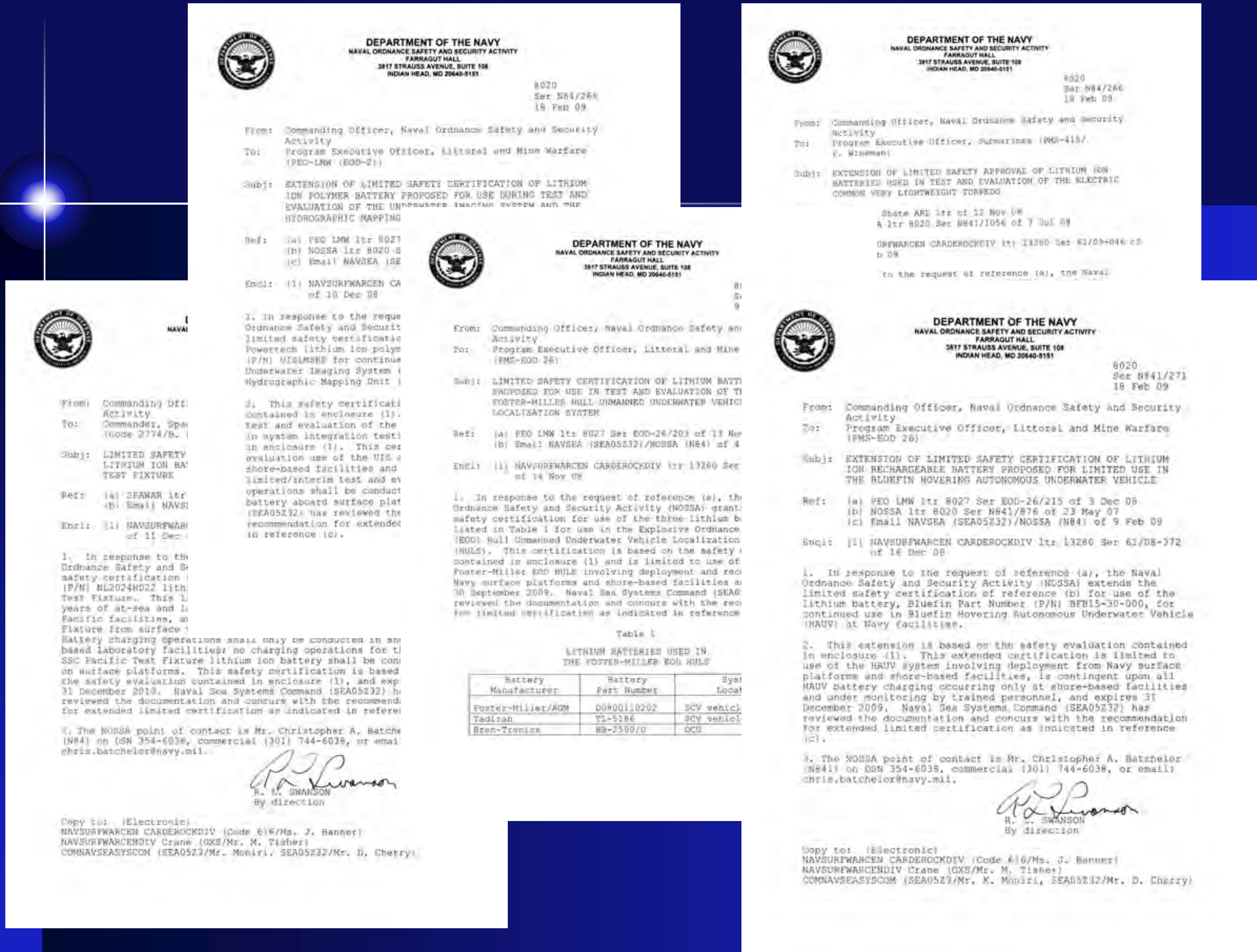
Thermal Abuse of Lithium Ion Battery Module

Results in the Field Shouldn't Be!

- The testing is tough!
- The testing creates misunderstandings among the uninformed (IT FAILED!!!!)
- The testing has brought a great deal of understanding to the safe use of lithium batteries in the Navy, and other Services
- A lot of lessons learned
- Roles for the whole team in order to be successful

Lessons Learned

- Only use lithium batteries when they are required to meet the mission
- Early communication between design agents and certification authorities is critical
- Consider safety in all aspects of the battery (and system) design
- Plan for time and funds to address safety
  - Cost & schedule increase with size and complexity of design
  - Utilizing an existing, certified battery design can save time and money



140 Lithium Battery Safety Certifications issued in 2008
Over 30 Lithium Battery Safety Certifications issued to date in 2009

Joint Service Power Expo

RENEWABLE POWER IN OIF

Daryl Wilson

Former Expeditionary Power Systems FSR in Iraq

July 2004 to November 2008

L-3 Communications

May 5-7 2009

Briefing Topics

- Logistics Support for Generators
- Solar Power Equipment Uses
- Adaptive Field Expedient Solutions

Logistics Support for Generators

Logistics Support for Generators

	Fuel Capacity	Fuel Consumption	Oil Capacity	Coolant Capacity
2KW **Mep 531A**	1.6 gal	**.33 GPH**	.85 qt	Air
3 KW **Mep 831A**	4 gal	**.5 GPH**	1.2 qt	Air
10 KW **Mep 803A**	9 gal	**.97 GPH**	5.9 qt	8.2 qt
20 KW **MMG-25**	46 gal	**2.1 GPH**	8.5 qt	10.4 qt
30 KW **Mep 805B**	23 gal	**2.60 GPH**	15 qt	15.5 qt
60 KW **Mep 806B**	43 gal	**4.7 GPH**	18 qt	20.5 qt
100 KW **Mep 007B**	91 gal	**12 GPH**	30 qt	42.3 qt
Commercial **Mega Watt**	External Tank	**41.5 GPH** **@75% load**	58 gal	27.1 gal

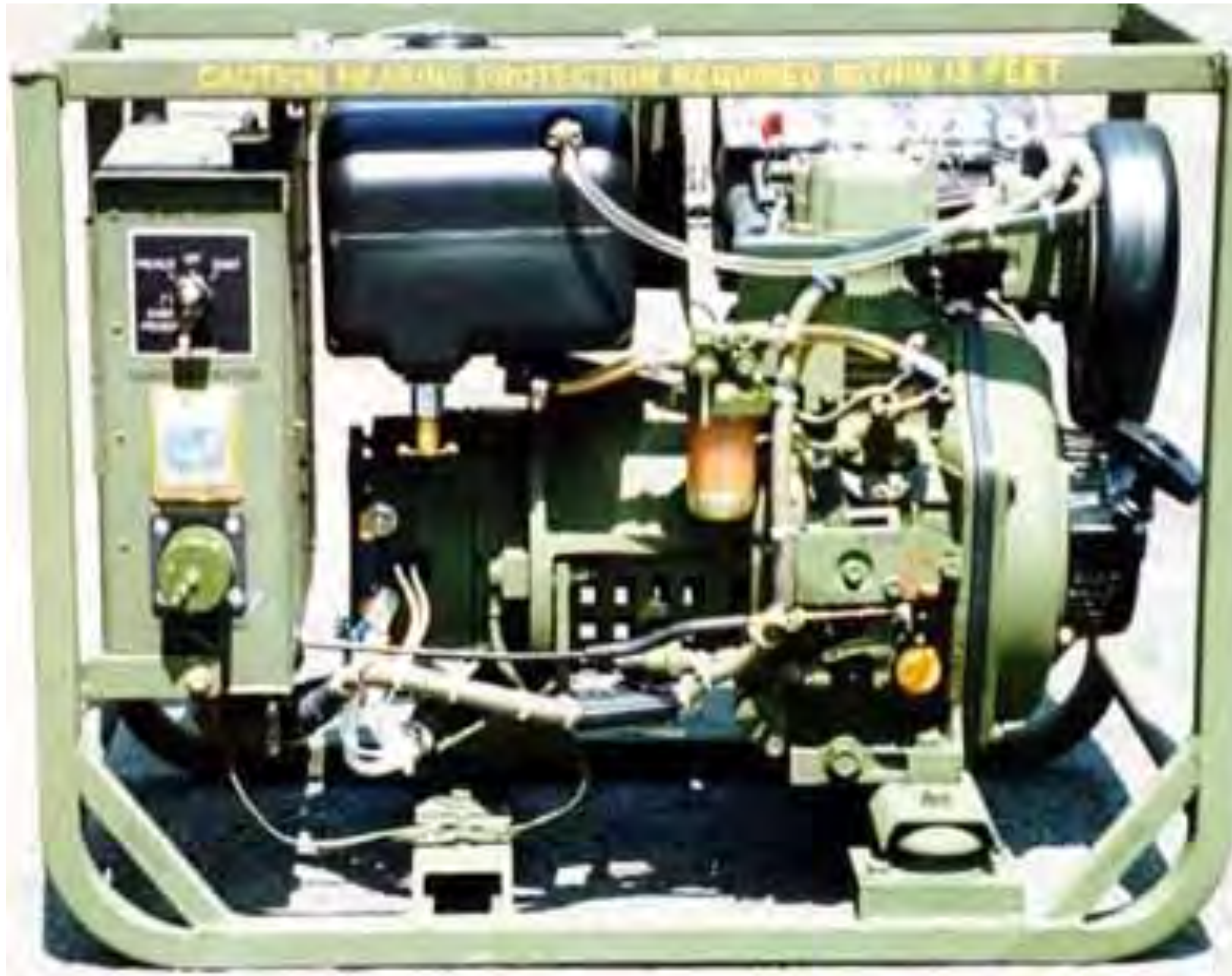
Logistics Support for Generators

2 kW

Week (168 Hrs)
Fuel 55 Gal
Oil .85 Qt
JP8 $157.75

Month (672 Hrs)
Fuel 221.7 Gal
Oil 1.2 Gal
JP8 $631.00

6 Months (4032Hrs)
Fuel 1,330.5 Gal
Oil 8.5 Gal
JP8 $3,786.04



Logistics Support for Generators

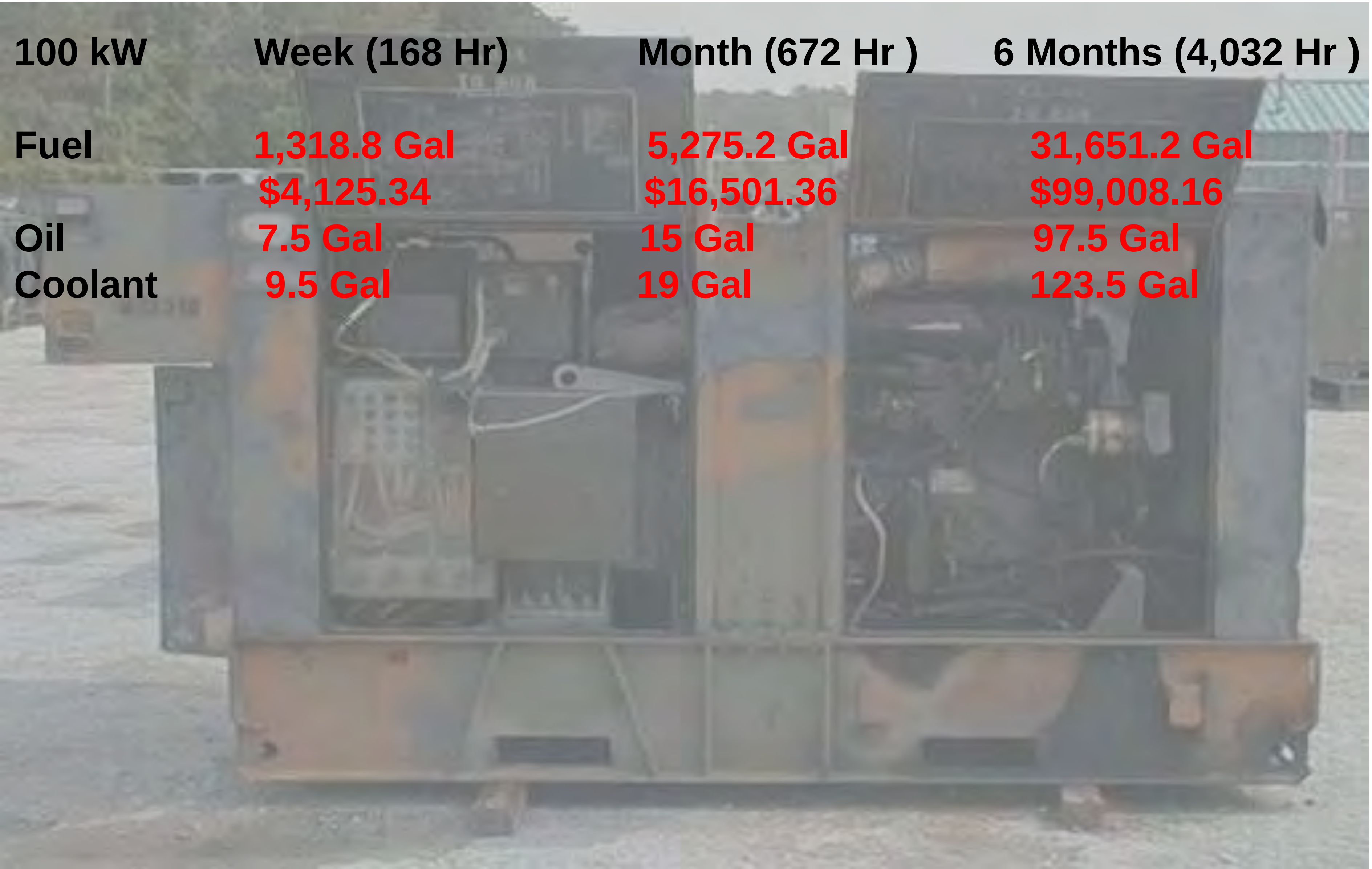
30 kW

Week (168 Hrs)
Fuel 436.8 Gal
$1,364.68
Oil 3.7 Gal
Coolant 3.8 Gal

Month (672 Hrs)
Fuel 1,747.2 Gal
$5,458.72
Oil 7.5 Gal
Coolant 7.7 Gal

6 Months (4,032 Hrs)
Fuel 10,483.2 Gal
$32,752.32
Oil 48 Gal
Coolant 59 Gal

Logistics Support for Generators



100 kW	Week (168 Hr)	Month (672 Hr)	6 Months (4,032 Hr)
Fuel	1,318.8 Gal $4,125.34	5,275.2 Gal $16,501.36	31,651.2 Gal $99,008.16
Oil	7.5 Gal	15 Gal	97.5 Gal
Coolant	9.5 Gal	19 Gal	123.5 Gal

Logistics Support for Generators

Mega watt	Week (168 Hr)	Month (672 Hr)	6 Months (4,032 Hr)
Fuel	6,972 Gal $21,822.36	27,888 Gal $87,289.44	167,328 Gal $523,736.64

Solar Power Equipment Uses

Whelen Solar Powered Siren System

Solar Power Equipment Uses

Solar Street Light Fallujah

Solar Power Equipment Uses

Solar Power Equipment Uses

World Water & Solar Technologies
Solar Powered Water Purification System

Solar Power Equipment Uses

Solar Power Equipment Uses

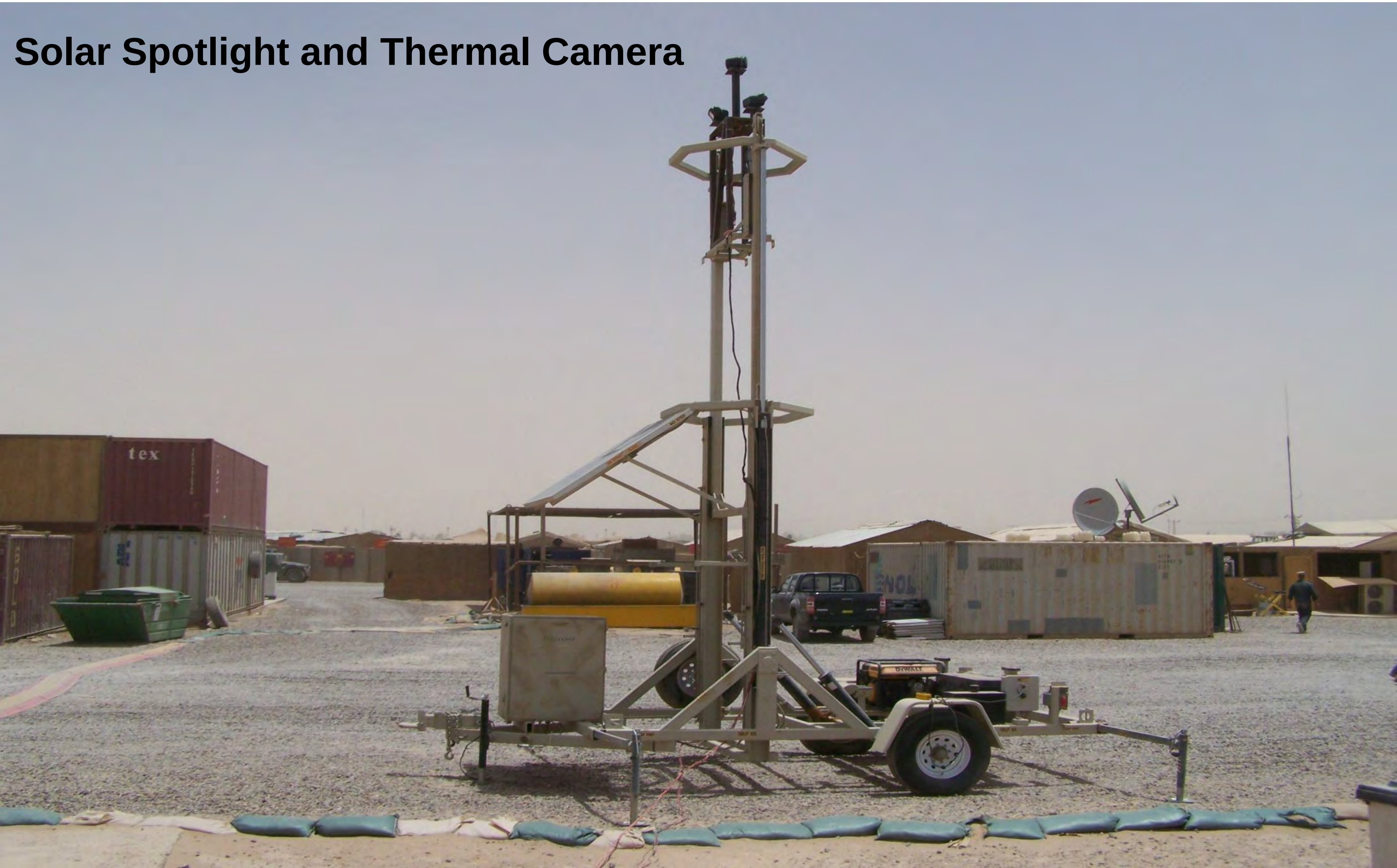
Commercial 12VDC Solar Power Supply

Adaptive Field Expedient Solutions

Adaptive Field Expedient Solutions

Adaptive Field Expedient Solutions

Solar Spotlight and Thermal Camera



Adaptive Field Expedient Solutions

Adaptive Field Expedient Solutions

Adaptive Field Expedient Solutions

Sun Wize 60 Amp Solar Power Supply

Adaptive Field Expedient Solutions

Adaptive Field Expedient Solutions

?? Questions ??

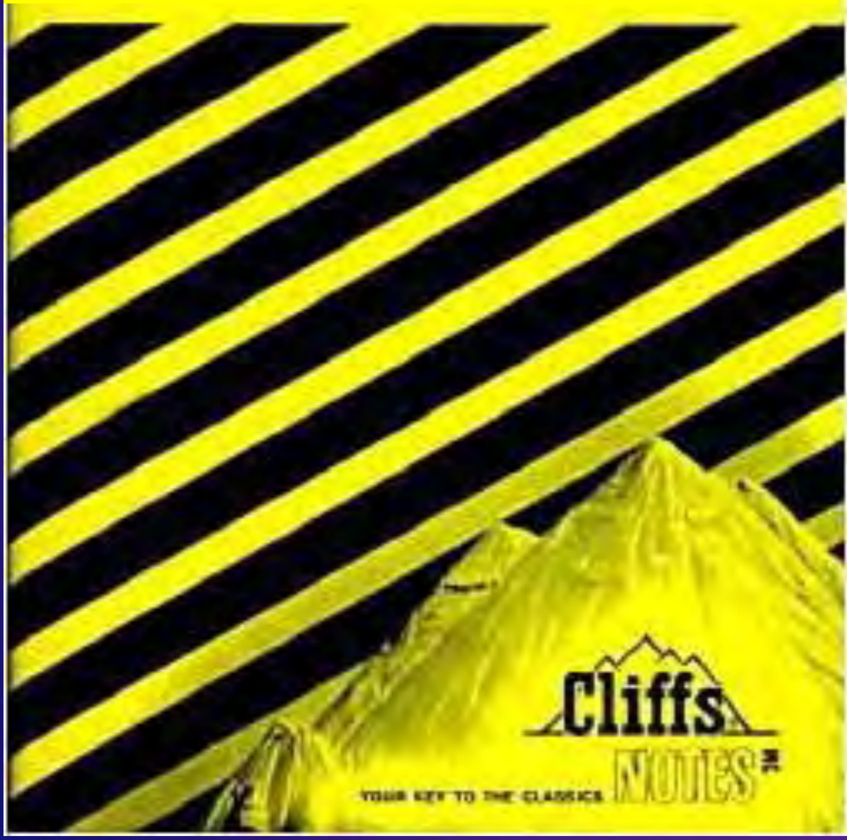

NDIA
PROMOTING NATIONAL SECURITY SINCE 1919
2009 JOINT SERVICE
POWER EXPO
ENERGY FOR THE WARFIGHTER
Interact with Military Users and Decision Makers from DoD, DHS & other Government Agencies
THE CITY OF NEW ORLEANS WELCOMES
CITY OF NEW ORLEANS
MAY 5-7, 2009
ERNEST N. MORIAL CONVENTION CENTER

Why we need your intelligence….

- Military technology is the driving force behind civilian sector products
- We have evolved into a 100% power dependant society
- Post disaster needs
  - Batteries and Battery Chargers
  - Generators
  - Green Power – Wind & Solar
  - Portable Power Systems

New Orleans

The 10 min highlight of a completely different way of life.



A Little History Lesson

French	vs.	Spanish

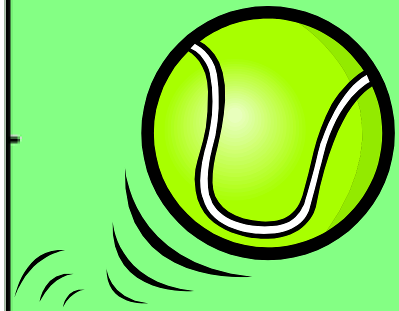
Founded in 1718 as a French Colony

1800, Spain ceded it back to France

1763 Transferred to the Spanish

A Little History Lesson (cont)

French VS. **United States**

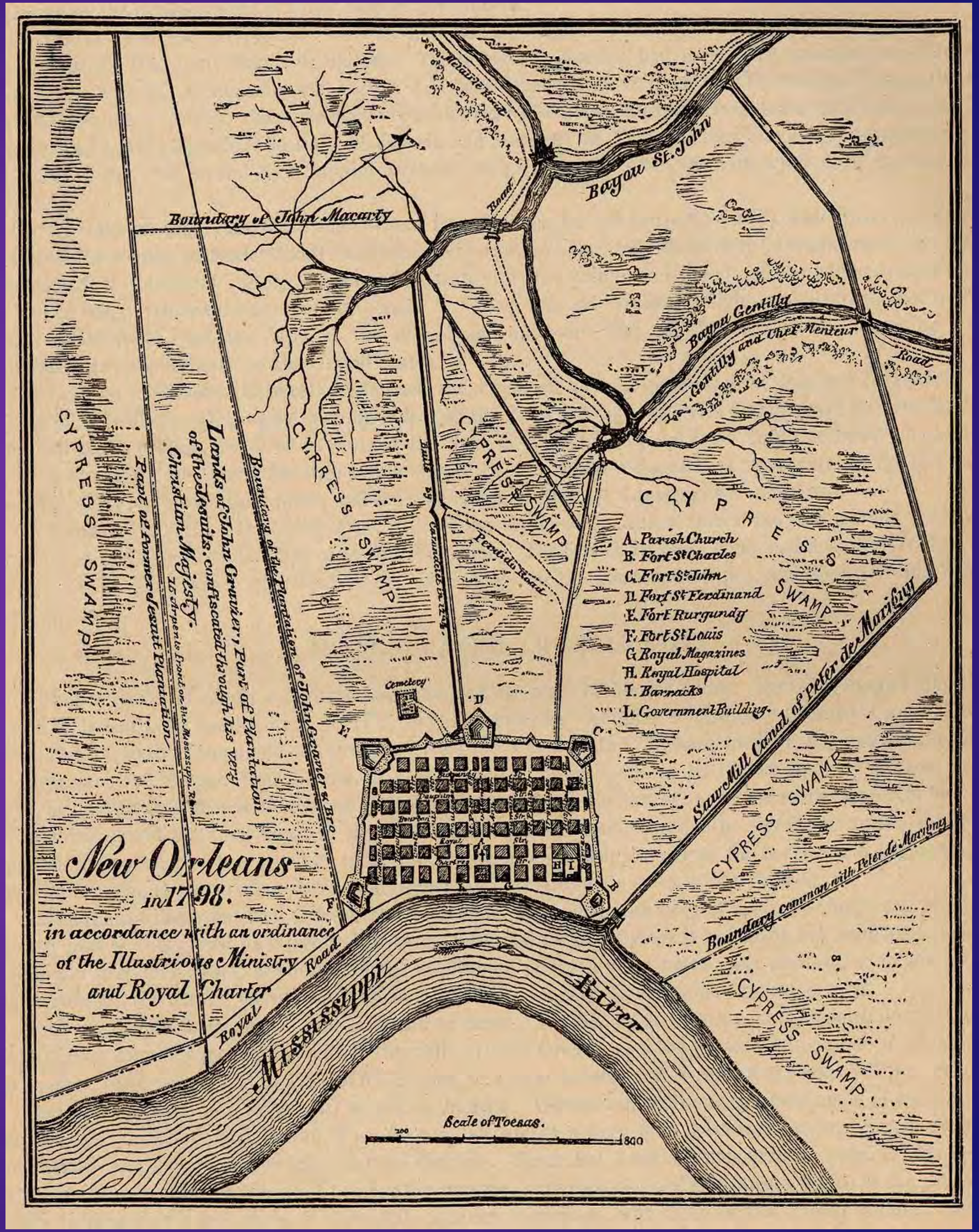


1803, New Orleans Sold (Louisiana Purchase)

- **1812 NOLA admitted to the Union as the 18th state.**
- **1861 secedes from the Union**
- **1865 returns to the Union**
- **1872 Krewe of Rex organized**
  - **Mardi Gras colors –**
    - **purple for justice**
    - **green for faith**
    - **gold for power**

Crescent City

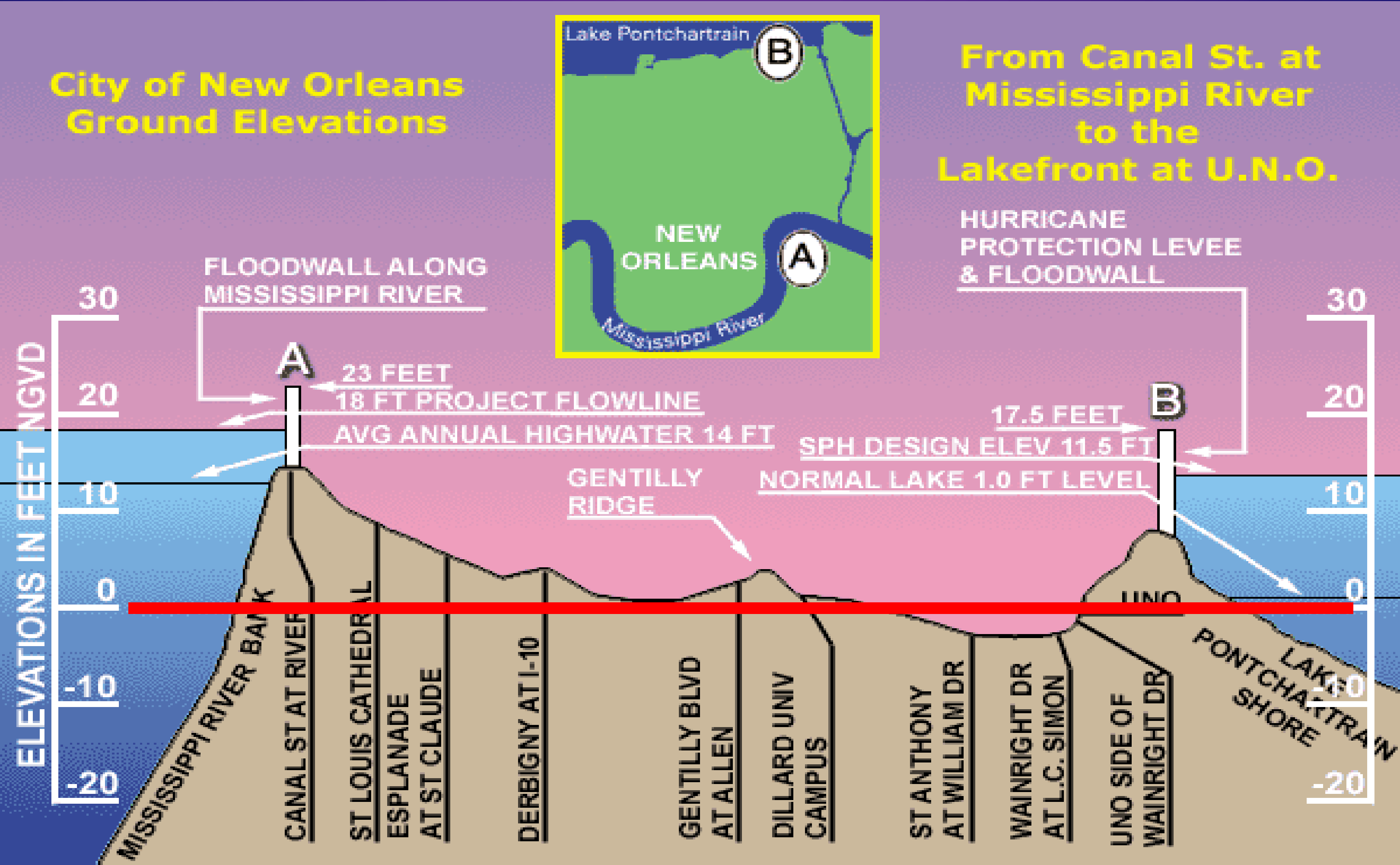
Due to the curvature of the Mississippi river as it surrounds the city



French Quarter
Vieux Carre
“old square”

We are a bowl….

Elevations range from 12 ft above sea level to 6.5 ft below.



Directions...

We navigate by the landscape

- **North** or toward the lake = **Lakeside**
- **South or** toward the river = **Riverside**
- **West** is **Uptown**
- **East** is **Downtown**

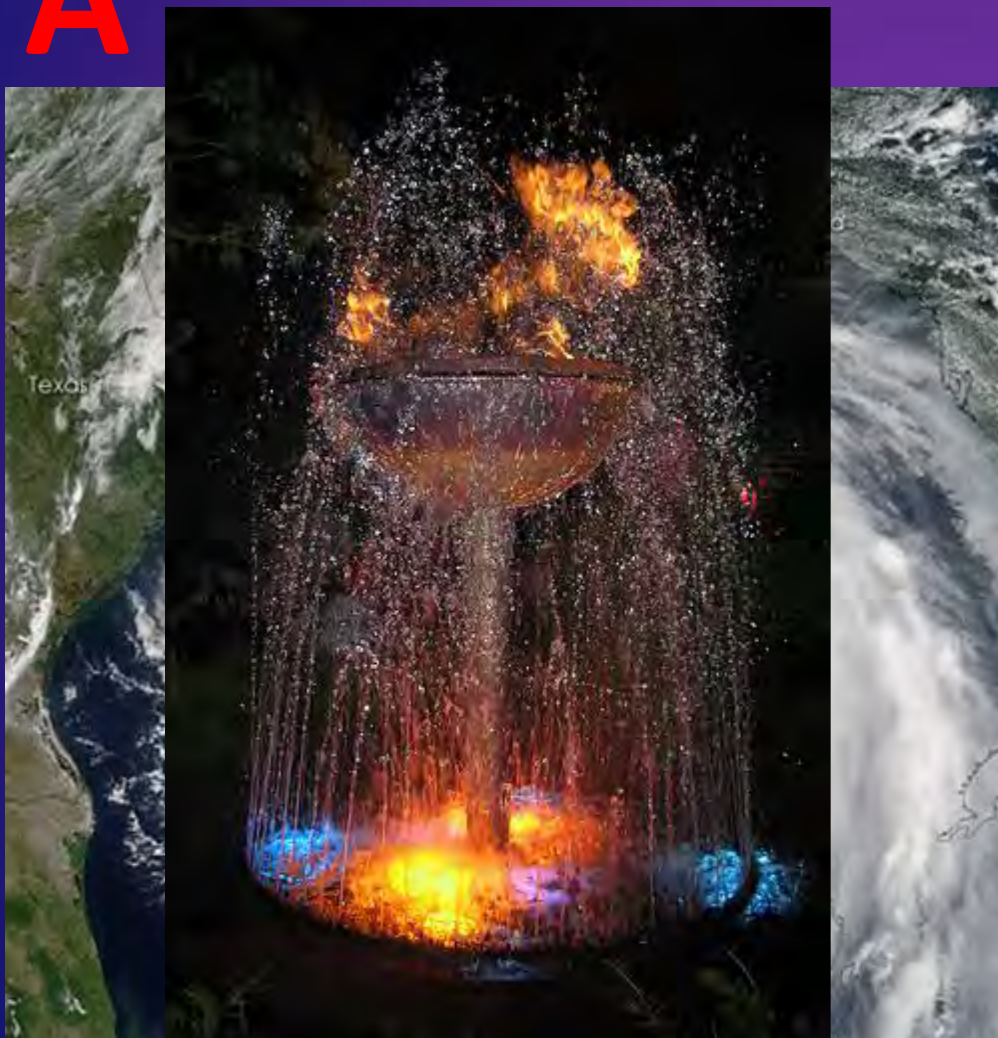
We also travel by neighborhoods

Neutral Ground

- The grassy or cement strip in the middle of the road.
- The terms "median" and/or "island" are **NEVER** used in New Orleans
- Place where French and Spanish could do business between sections of the city.

Hurricane Quiz

A



B

Hand Grenade Quiz

A

B

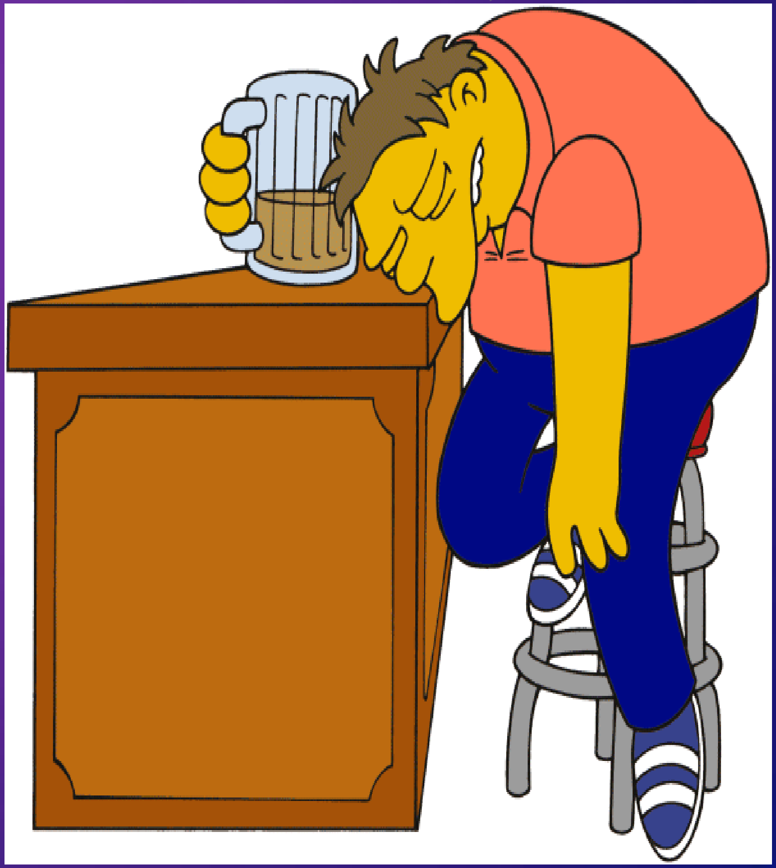
We pronounce stuff weird

- Tchoupitoulas = chop-a-TOO-luss
- Calliope = CAL-lee-ope
- Burgundy = bur-GUN-dee
- Rigolets = WRIGGLEeese
- LAGNIAPPE = LAN-yap

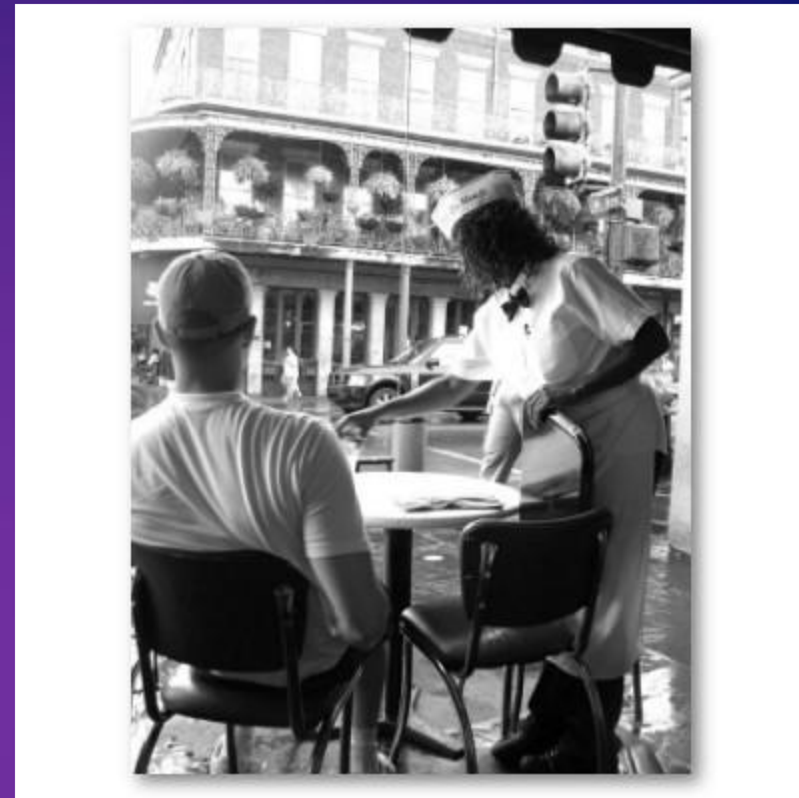
  (A little something extra)

PRAH-leen versus Pray –lean

Praline



Our cuisine is an addiction…



Best way to
START or END
a day....

<u>3 or 4 Suggestions while you are here…</u>

1. Eat in our expensive restaurants. (It helps the economy)
2. Stay at our most expensive hotels (it helps our economy)
3. Park illegally (It helps our economy)

<u>Completely voluntary suggestion</u>

4. Get arrested…it helps our economy

On behalf of

Mayor C. Ray Nagin

and the

City Of New Orleans Office of Homeland Security and Emergency Preparedness

Laissez Les Bons Temps Rouler!

LET THE GOOD TIMES ROLL

QUALLION




Qualion Large Battery Pack Technology

May 2009

Hisashi Tsukamoto, PhD. CEO/CTO Quallion LLC

Powering Life.

Qualllion Milestones

- **1998** — Company established in Southern California, USA
- **2001** — Developed 7 new cell designs (4 implantable grade); shipped 30,000 production units; plant reached 6,000 unit per month volume
- **2002** — Entered Aerospace/Defense market with OGA and CECOM Contracts Initiated Development of Primary Chemistries
- **2003** — Registered under ISO 9001 &13485; Zero-VoltTM technology patented (recertified in December 2004)
- **2004** — Zero-Volt™ technology patented
- **2005** — SaFE-LYTE™ technology patented
- **2006** — Title III Award; Registered AS9100
- **2007** — Frost & Sullivan Award for Lithium Ion Power Sources
- **2008** — Boeing Technology Supplier Award

Powering Life.

Origin of Quallion:
Implantable Micro Battery

Inductive charging Technology

Miniature Injectable (implantable) neurostimulator

Quallion Battery
(2.8mmD, 12mmL, Li-ion)

Powering Life.

High Reliable Li-ion Cells for USG Satellite

QL075KA

	QL075KA
Height	173.7.0 (mm)
Width	80.9 (mm)
Thickness	56.2 (mm)
Weight	1820 g
Operating voltage	2.7 – 4.1V
Discharge capacity	72 Ah
Weight energy density	148 wh/kg
Zero-Volt™ technology	Applicable

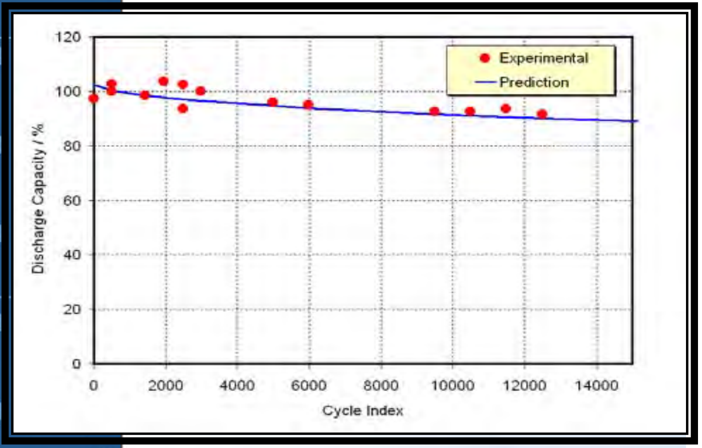
Powering Life.

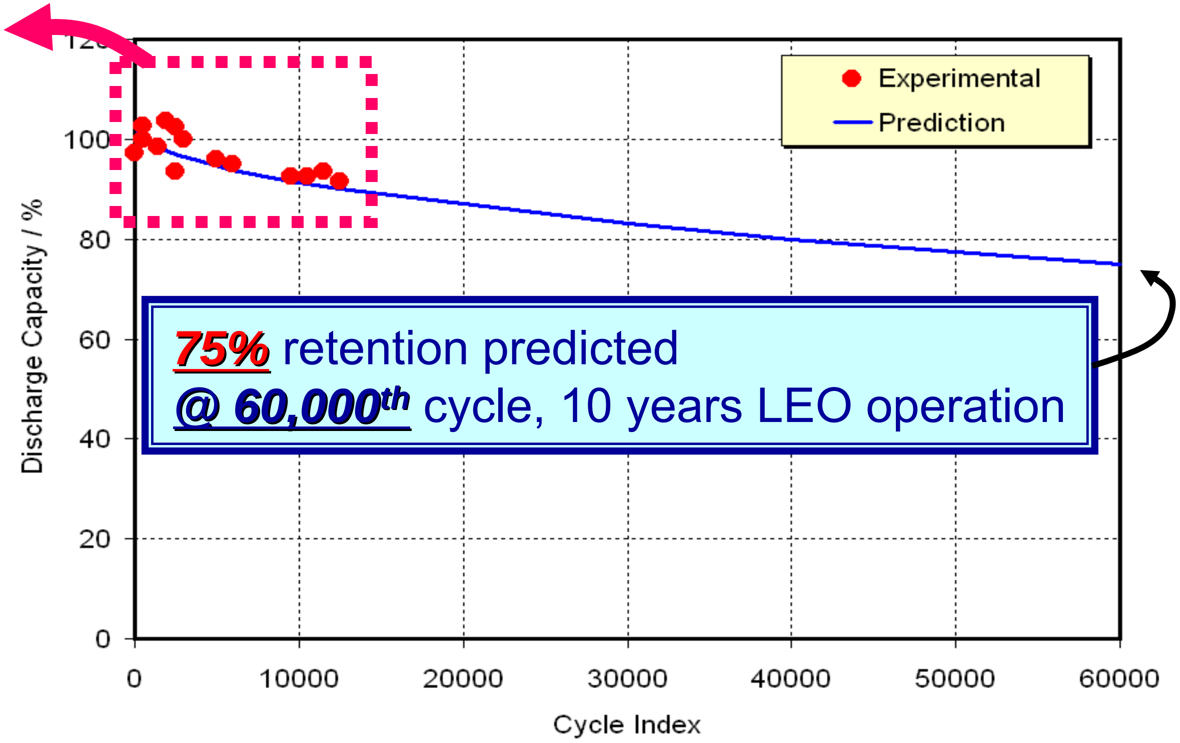
QL075KA Cell: Cycle Life
40% DOD Cycle @ R.T.

Capacity retention equation *)

(Discharge capacity retention) = 100 - k x $\sqrt{N_{cycle}}$

*) k: constant to determine capacity fading rate
N_{cycle}: charge and discharge cycle index





Powering Life.

Zero Volt^{TM} Capability
Cycle Performance after 0V Storage (17 months) (200mAh model cell)

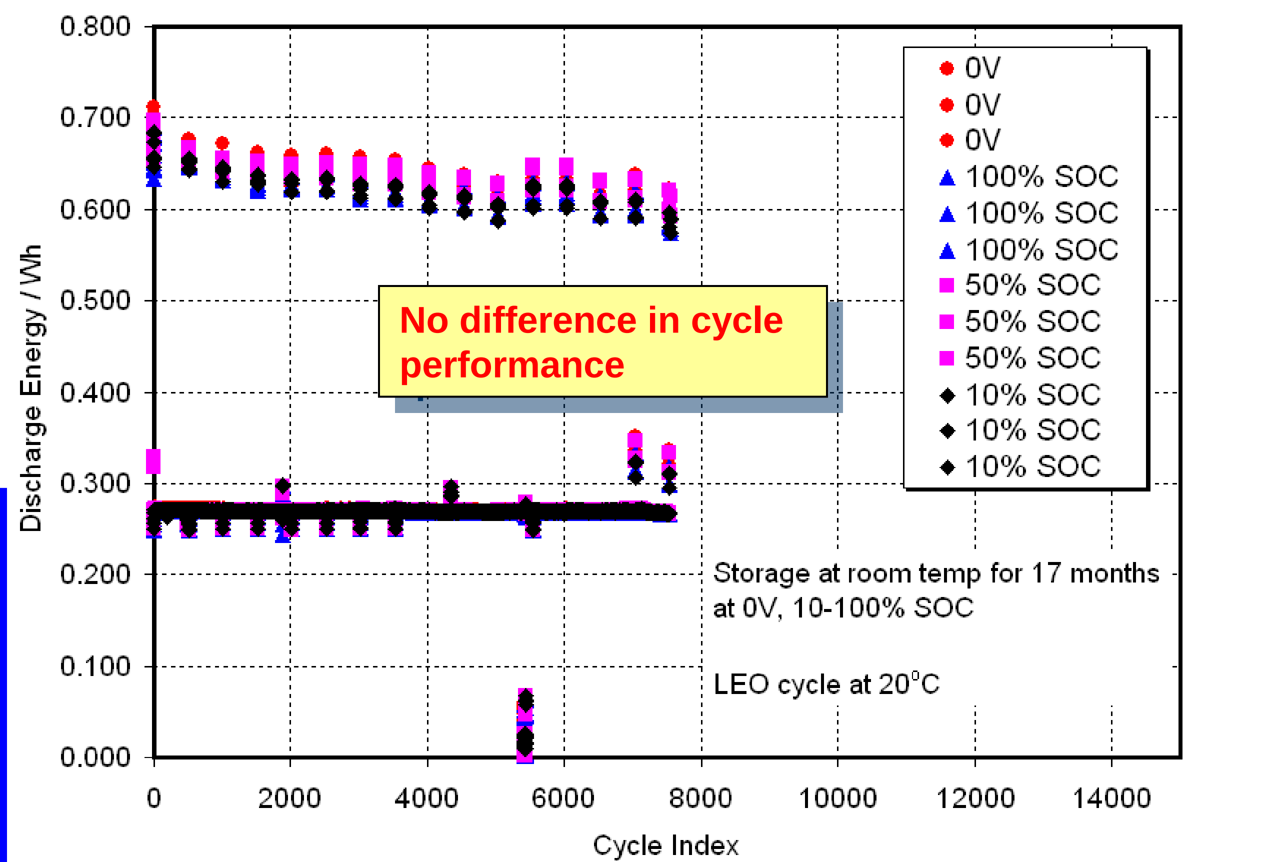
Storage Condition
For 17 months,
- 100% SOC (3 cells)
- 50% SOC (3 cells)
- 10% SOC (3 cells)
- 0V (3 cells)

(at room temperature)

Cycle condition
- LEO cycle (40% DOD)

Capacity check
- 100% DOD
  at every 500 cycles

(at 20°C)



Powering Life.

QUALLION

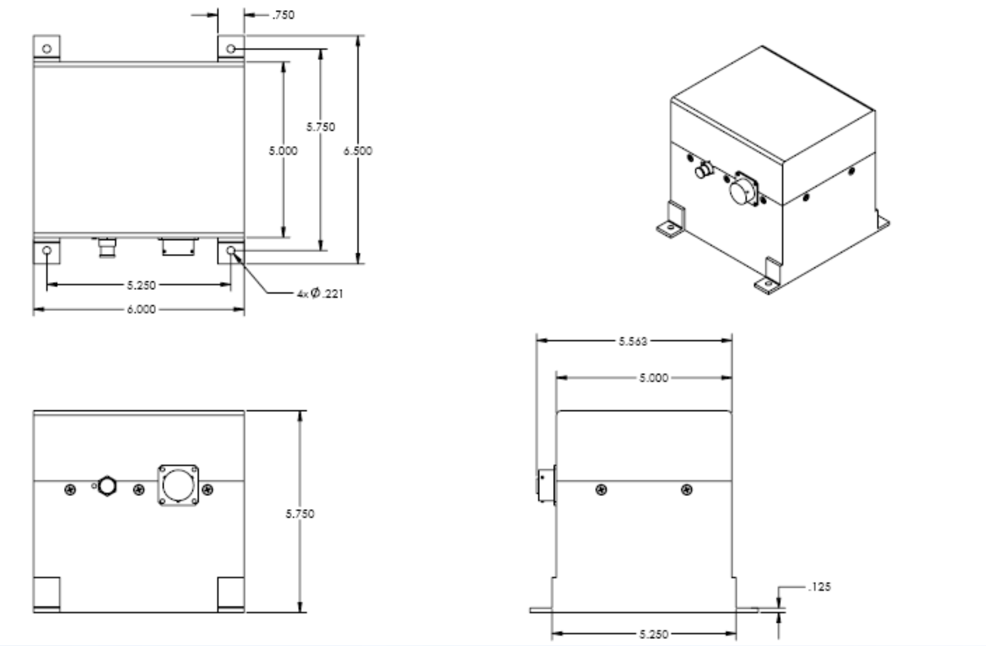
Matrix™ Battery, QL038KM for Little Bird, MH-47 ,MH-60 and U2

24V Lithium-ion (Lead Acid Replacement)

- 38 Ah capacity
- 0.912Kwh (100wh/kg)
- 9.75^{L}x8.125^{W}x5.3^{H} inch
- 24 lbs

Powering Life.

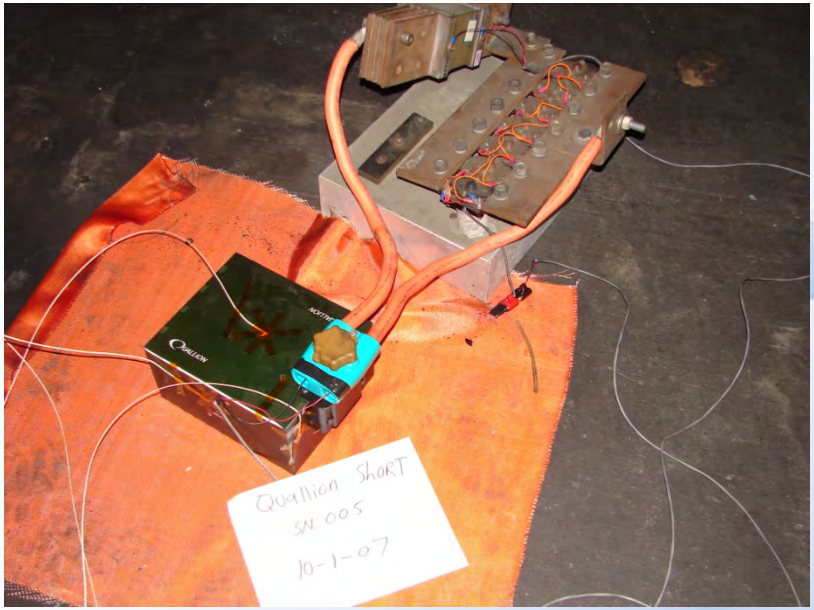
24V, 9.5Ah Matrix Battery^{TM} for C-17 Aircraft EBPS

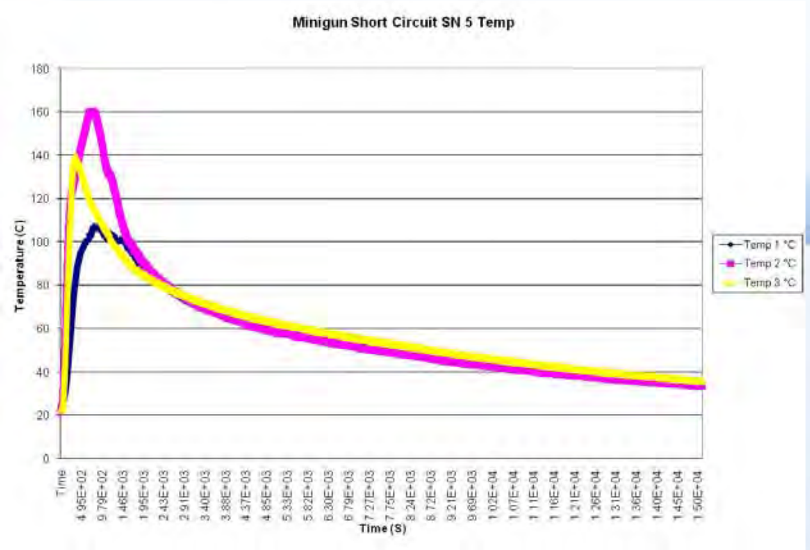


- **Qualification Program to Replace Current Ni-Cd System**
  - **Low maintenance and long life**
  - **Fully integrated charge control electronics, battery management electronics & BIT/SOC capability**
  - **-65ºF to 160ºF (with heaters)**
  - **Less than 8.5lbs**
  - **Full charge in 75 minutes over 21V to 32V input range**
  - **Plug N Play**

Powering Life.

QL038KM External Short Test
5 mohm external short with BMU disabled
Passed with no flame or explosion

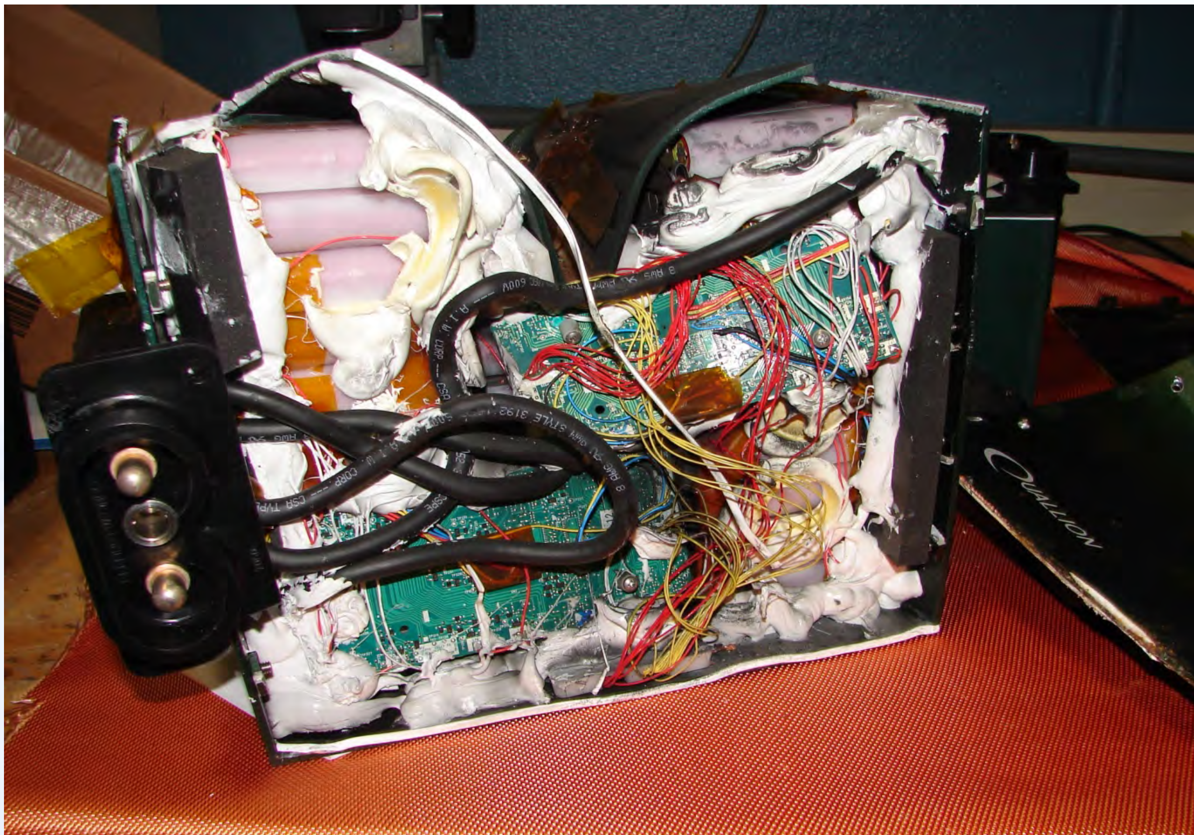




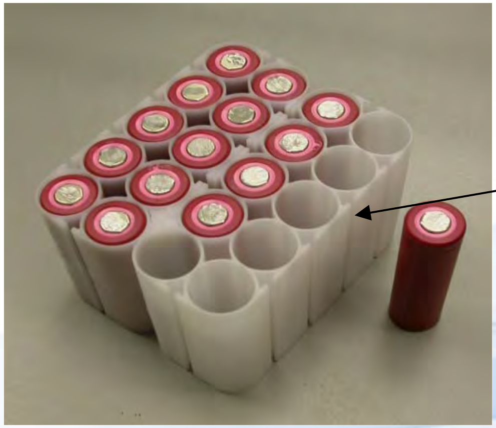
Powering Life.

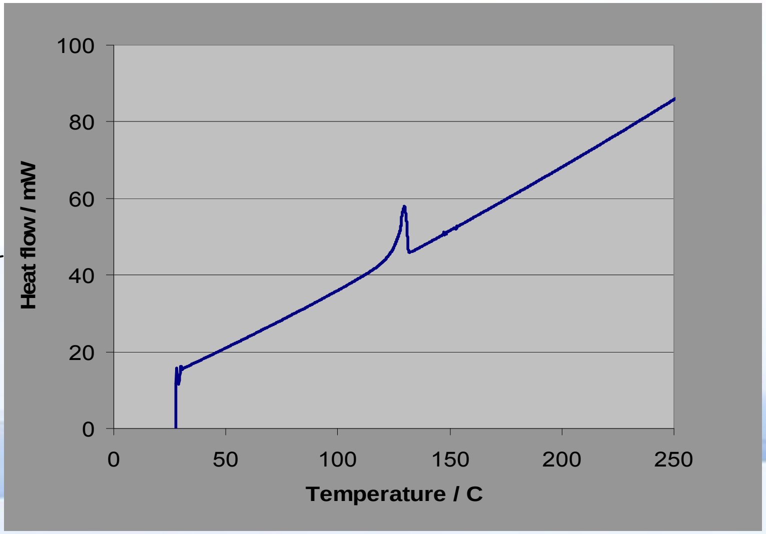
QUALLION

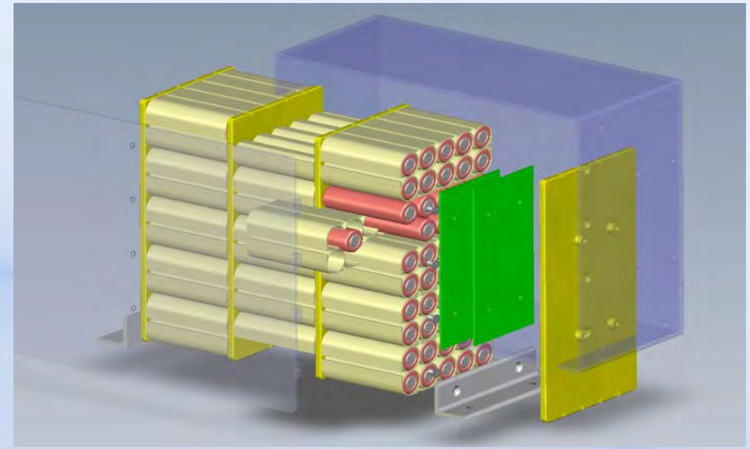
QL038KM Crush Test
Unit fully charged to 29.4V
Passed with no explosion of fire



Quallion Unique Safety Technology; HAM™ (Heat Absorption Material)







Powering Life.

Demonstration of HAM™ Technology

Test Battery-

Sanyo 18650W cell, 10 cells in Parallel connection.

Capacity- 15.0 Ah

Overcharge test condition-

Charge battery pack @6A to 12V, hold voltage @12V till temperature dropping

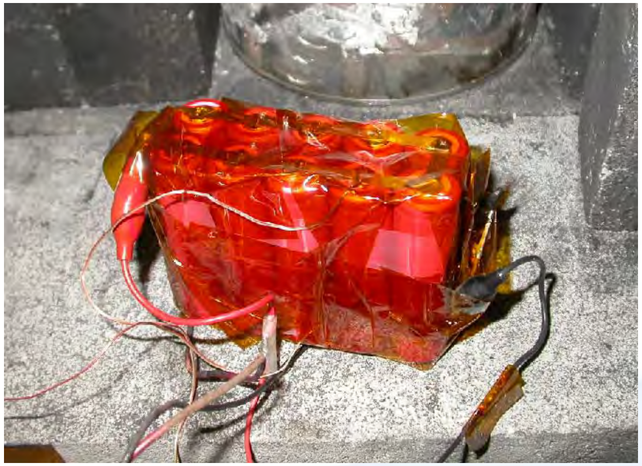
Without HAM sleeve

With HAM sleeve

Powering Life.

QUALLION

Battery Failed without HAM™



Connection

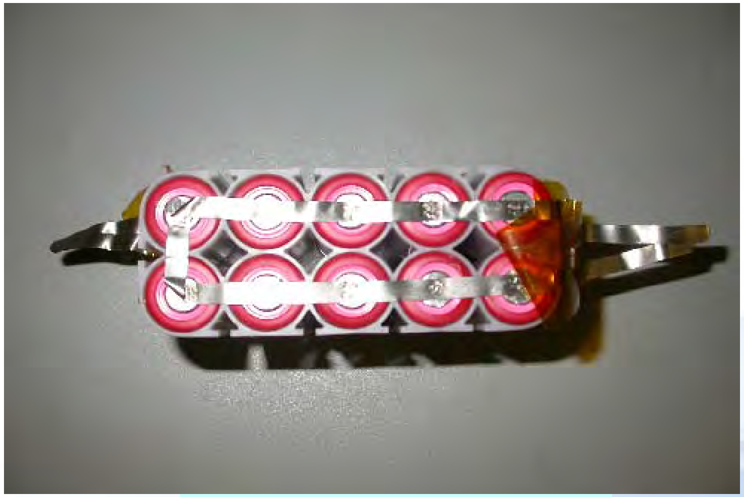
Insulation

After Test

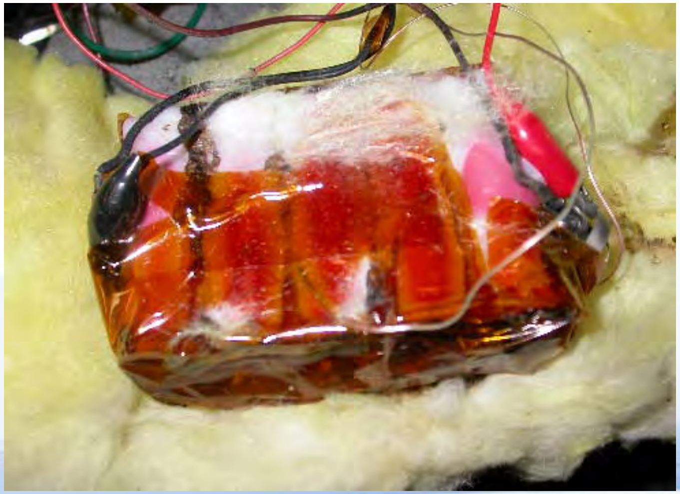
Powering Life.

Battery was Safe with HAM^{TM}

HAM® melted and latent heat stopped thermal run away



Connection



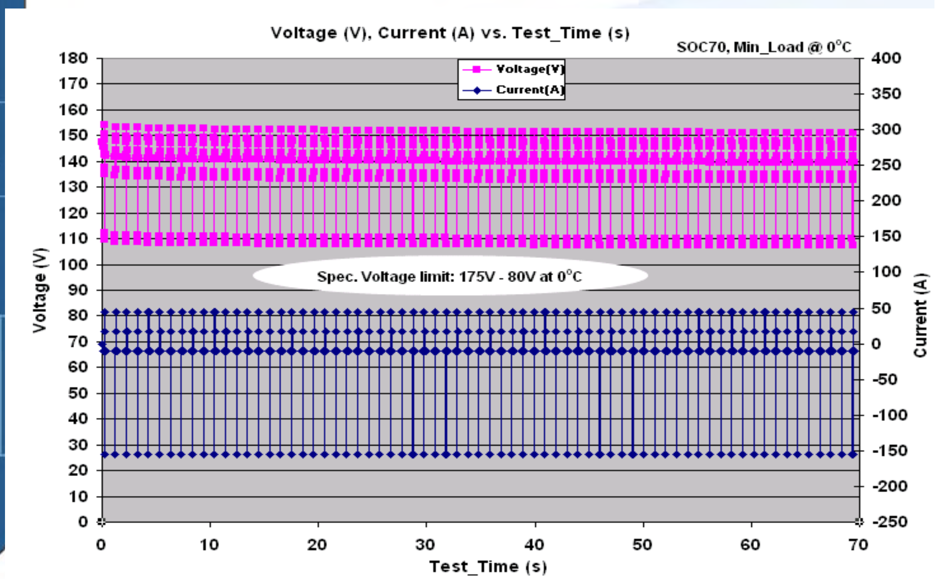
After Test

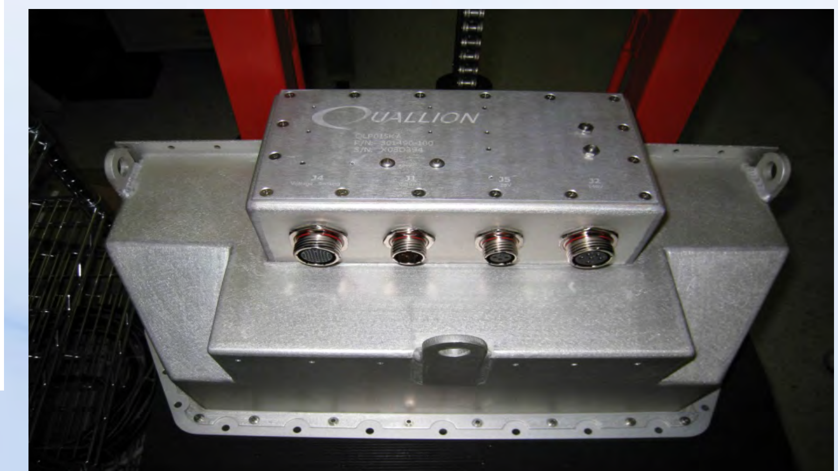
Insulation

Powering Life.

140V, 28V Battery for the NASA Launch Abort System (LAS) for ARES I

- 140V, 15Ah & 28V, 1.5Ah Lithium-ion Pack
- (378) Commercial 18650 High Power Cells
- 140V Battery is capable of over 220A peak discharge current and 50A peak charge current



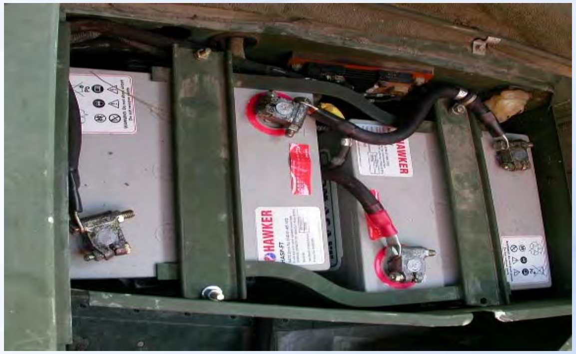


- 70% SOC @ 0°C,140V Battery Mission Profile

Powering Life.

Quallion 24V, 1250A Capable Matrix™ Battery Pack for HMMWV

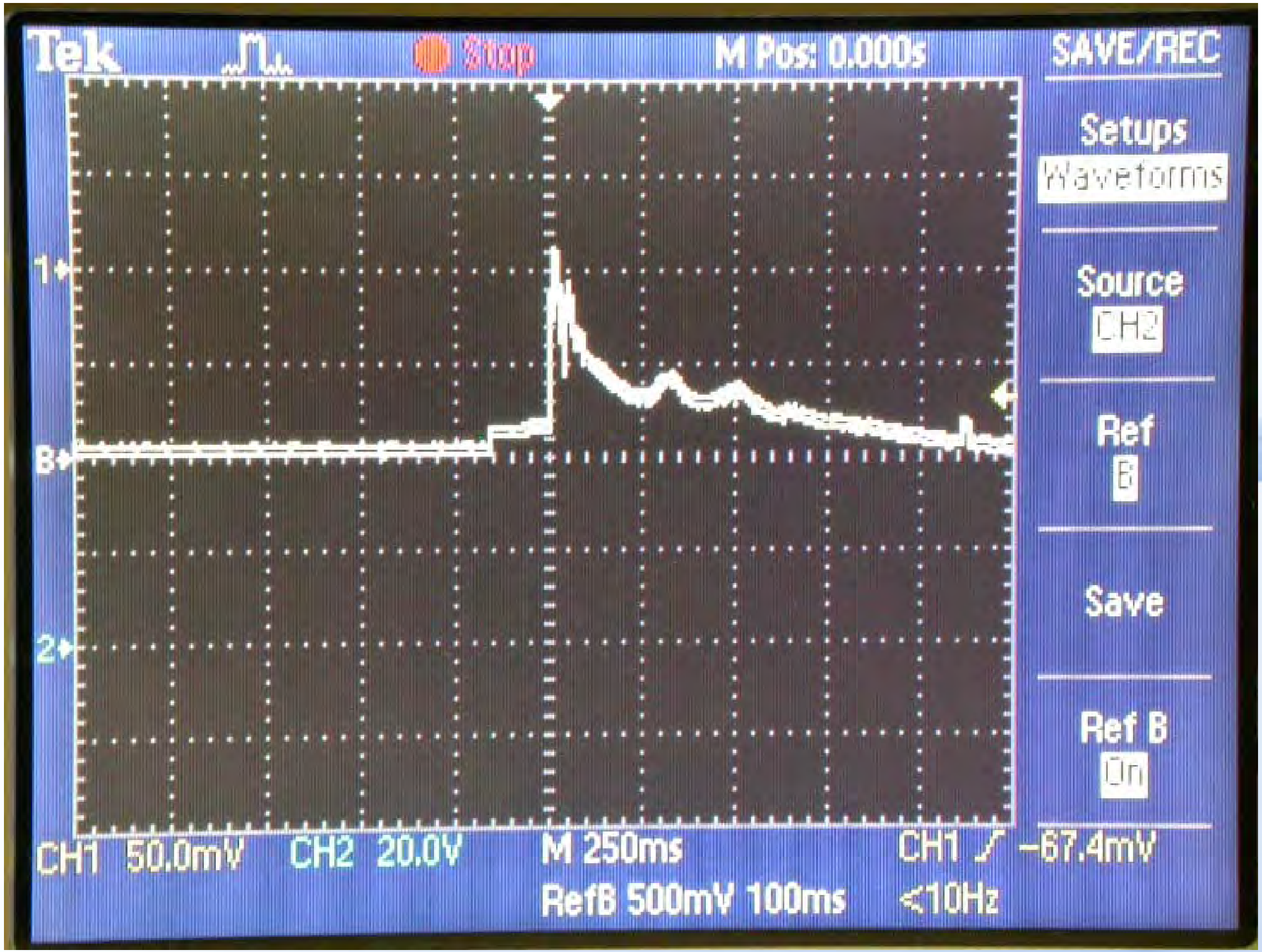
Less than ½ SLAB Weight and Deep Discharge Capable



**Current Lead-Acid Battery
24V, 65Ah, 120lb (2 batteries in series)**

**Quallion Drop-in Li-ion APU
24V, (78Ah, 98.8Ah, 156Ah), 52lb**

Engine Start Test (Max Current 1100A) at SOC 70%



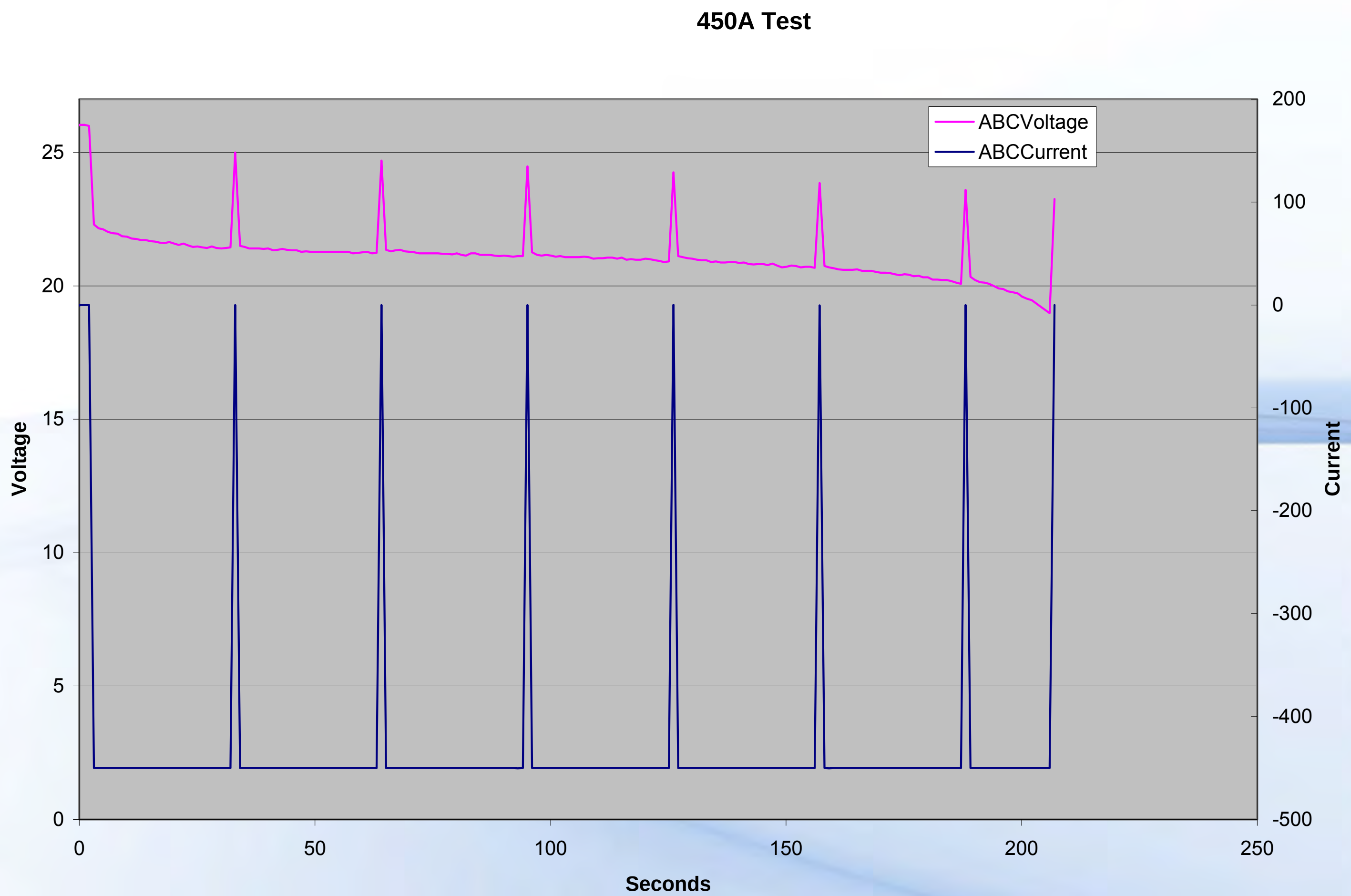
Scale: 500mV 100ms

Current: Discharge

- Peak current ~ 1100A in first 20ms
- Two peaks 500A during the first 200ms – similar profile as the lead acid battery

Powering Life.

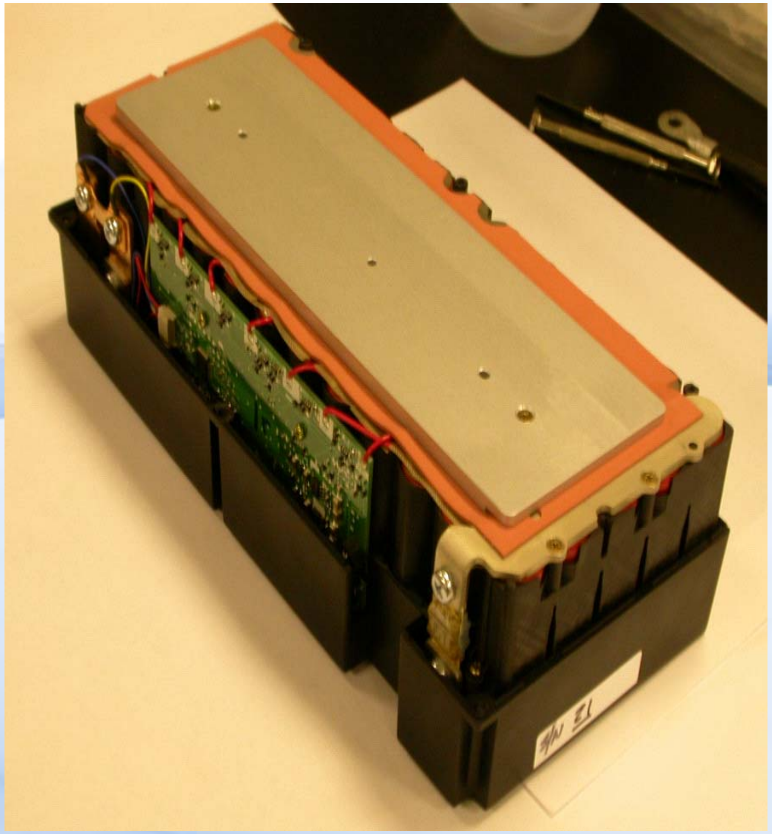
450A-30 Seconds Pulse Discharge Test at SOC 40%



Powering Life.

QUALLION

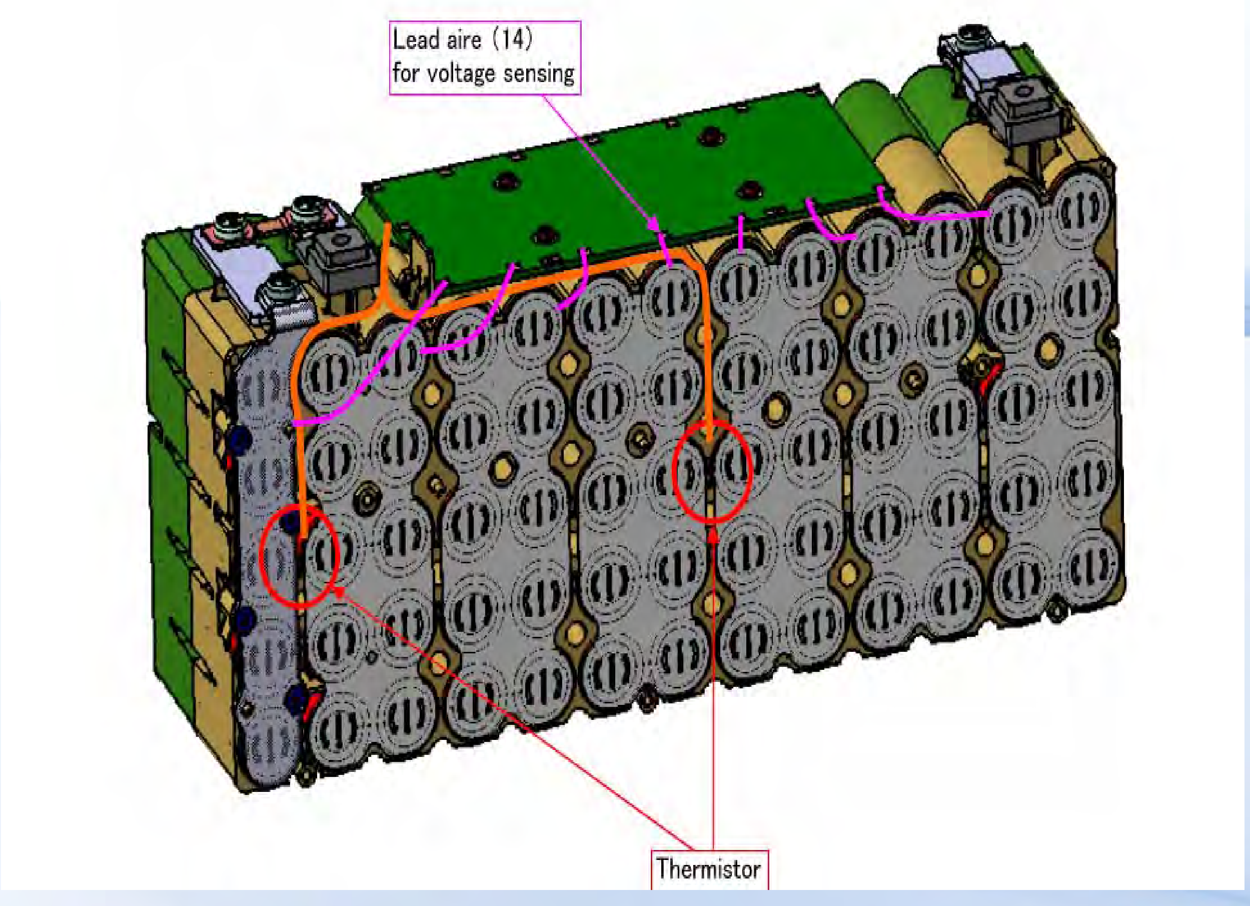
Quallion Matrix™ Module
48V, 9.5Ah, 0.456Kwh*, 78x115x260mm



* Standard Module (Whr and W capability varies in energy module and power module)

Powering Life.

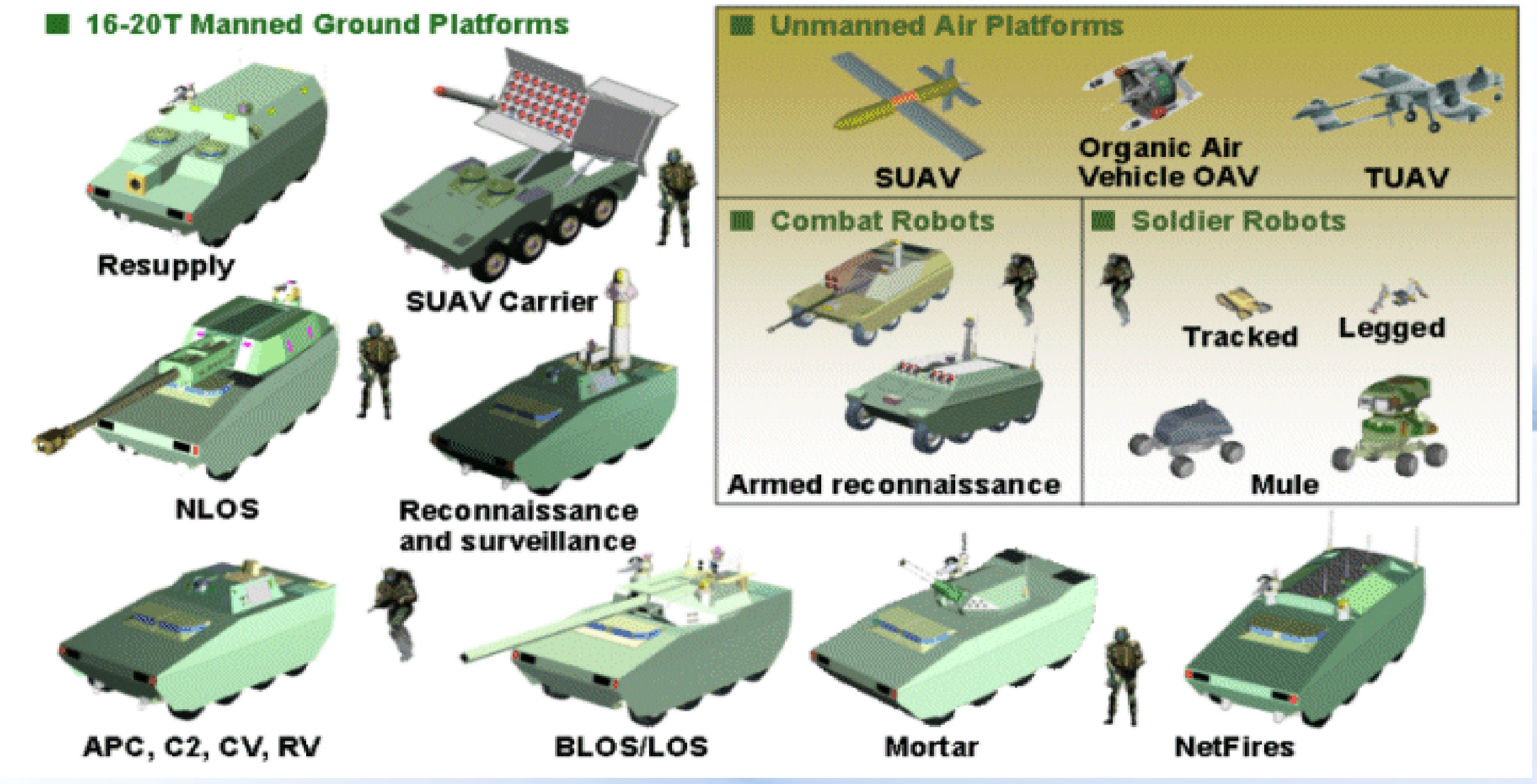
Voltage Sensing, Current Measuring and Temperature Monitoring



One Mechanical Configuration can bring Multiple Performance Varietals

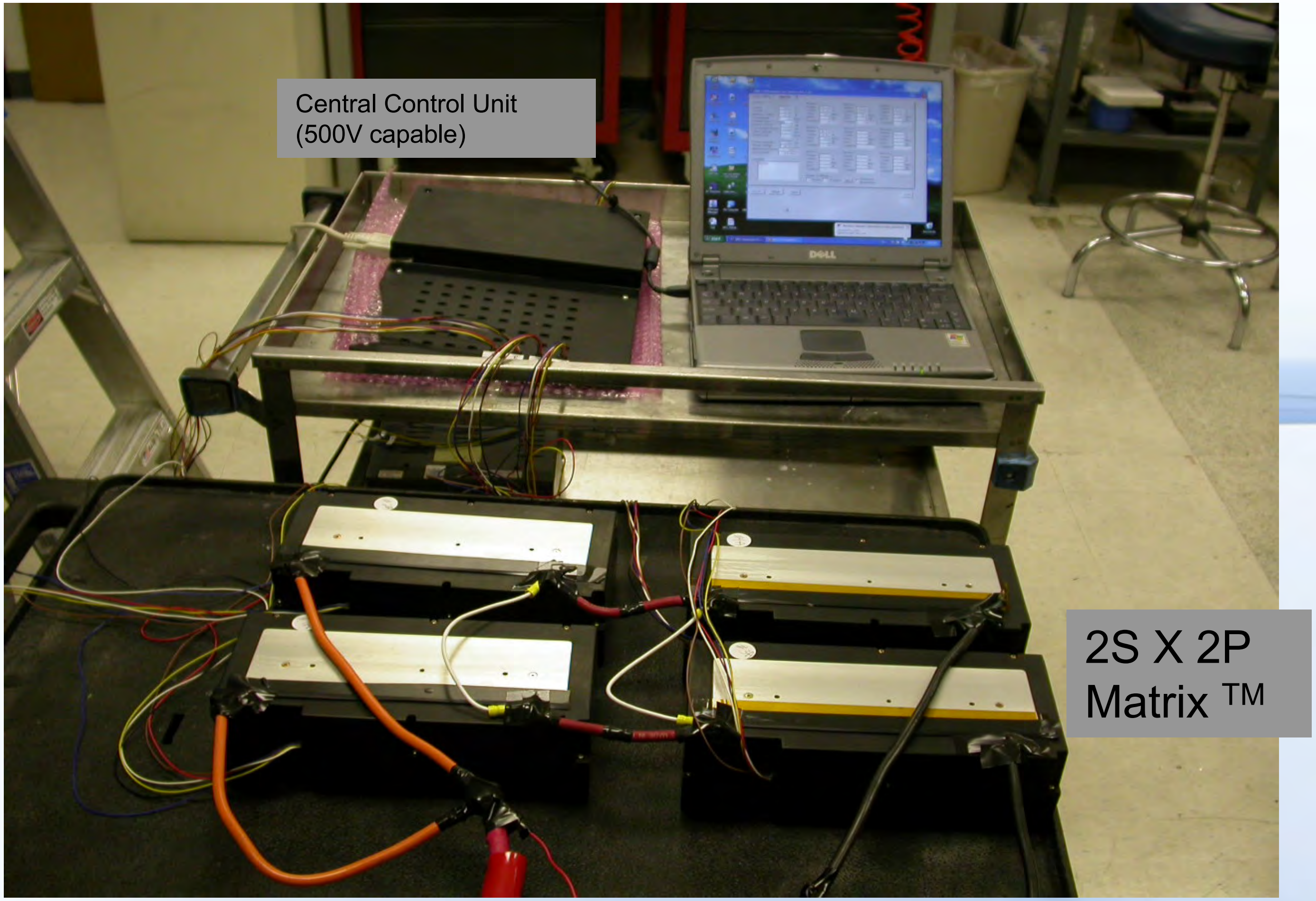
Cell							MBD pack				
Model Name		Capacity (mAh)	Weight (g)	1KHz AC Impedance (mili ohm)	Wh/kg	W/kg	Wh	KW	Max. discharge current (A)	Kg	Remark
18650 F3		2500	47	45	197	390	600	1.2	25	4.3	Highest Energy
18650 F1		2100	47	58	165	330	500	1	21	4.2	High Energy
18650 Y		1900	43	40	162	970	460	1.4	29	4.1	Energy/Power Balance Model
18650 W		1500	44	28	125	1600	360	3.6	75	4.2	High power
18650 SA		1200	41	25	108	2200	289	4.8	100	4	Highest Power

Modular Design for Flexible Performance, Flexible Shape and Inexpensive Cost



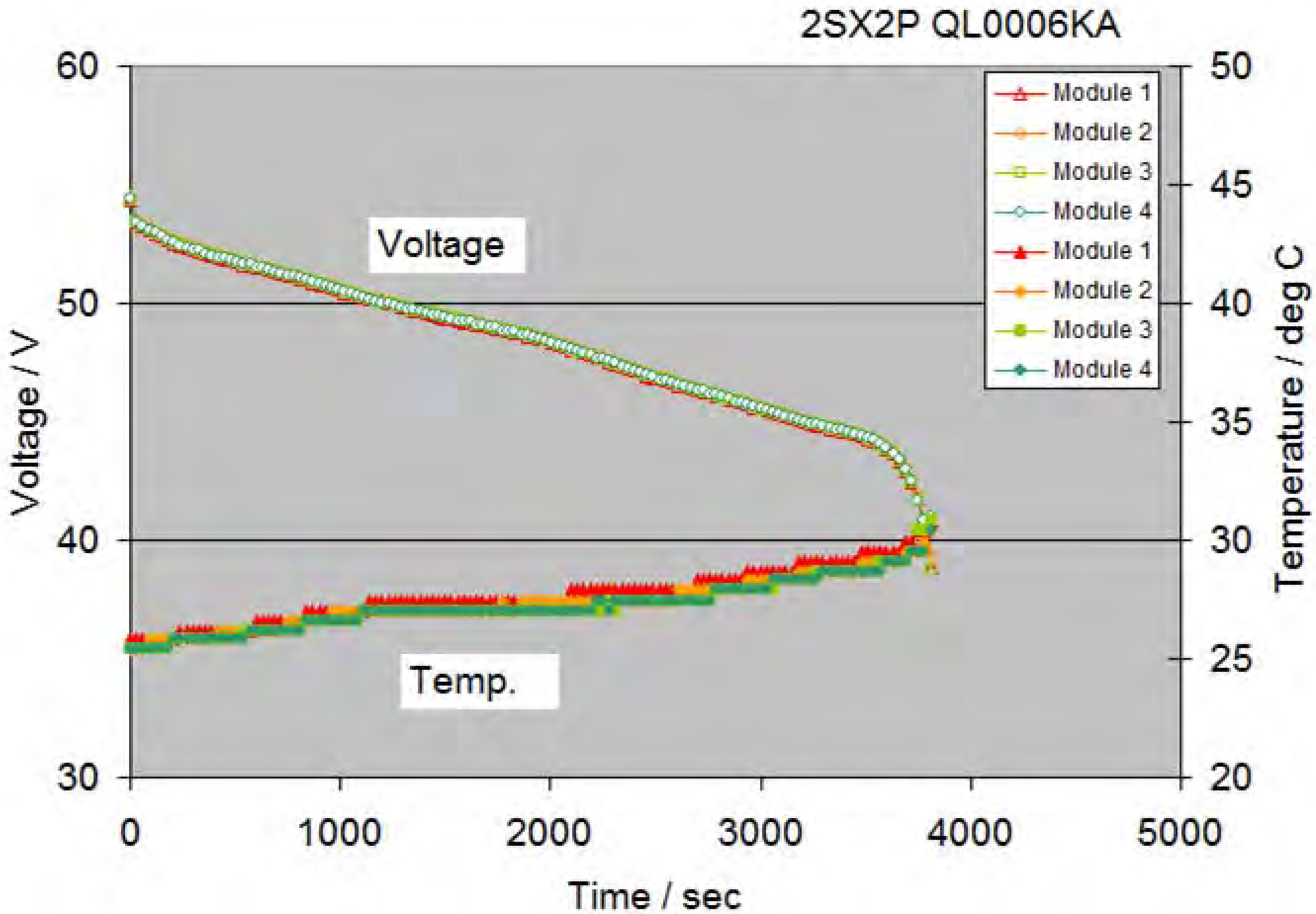
Powering Life.

96V -1.83Kwh Matrix^{TM} System



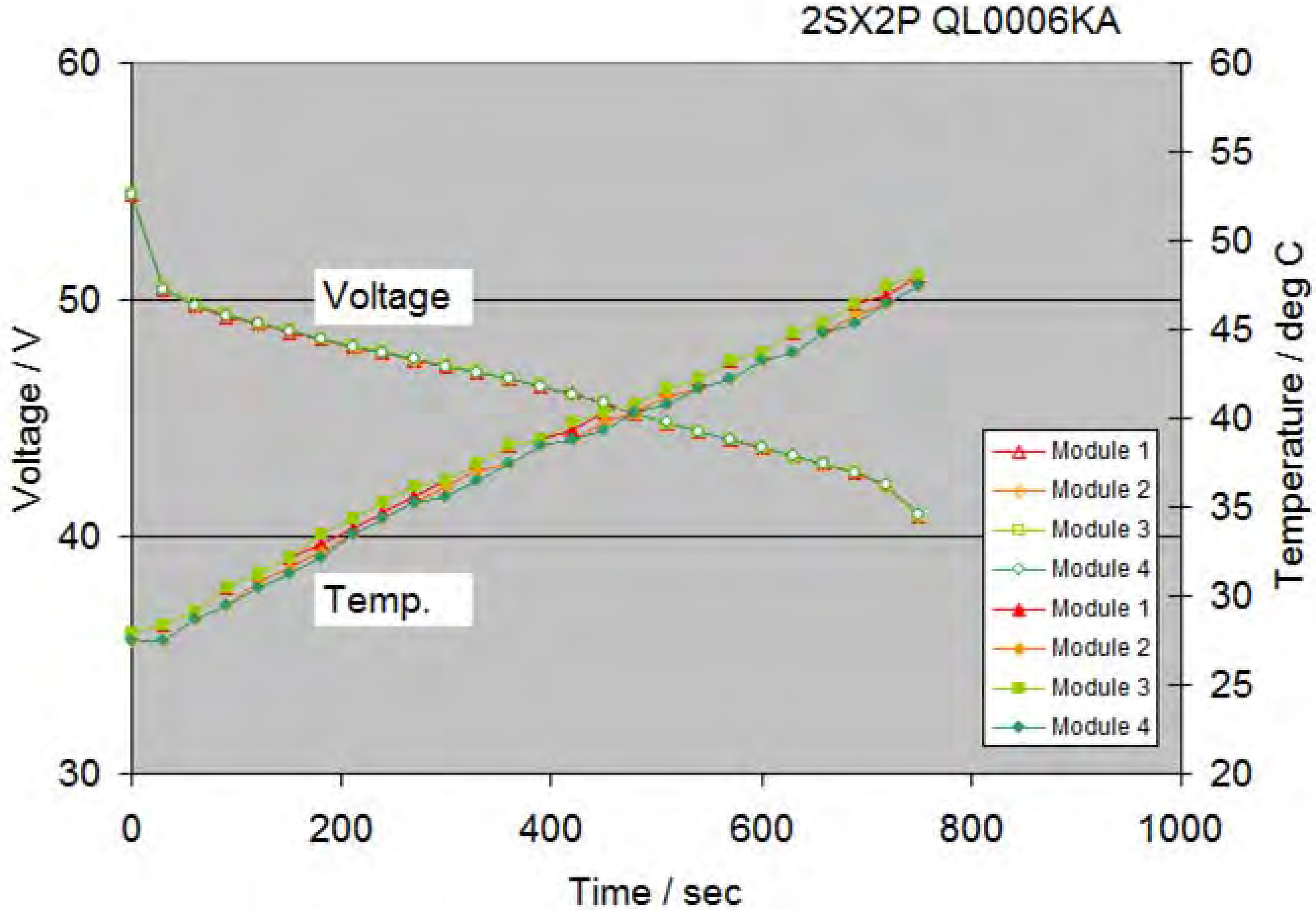
Powering Life.

1C Discharge Curves



Charge : 1C 109.2V CCCV C/20CA cutoff at R.T.
Discharge : 1C to 78V at R.T.

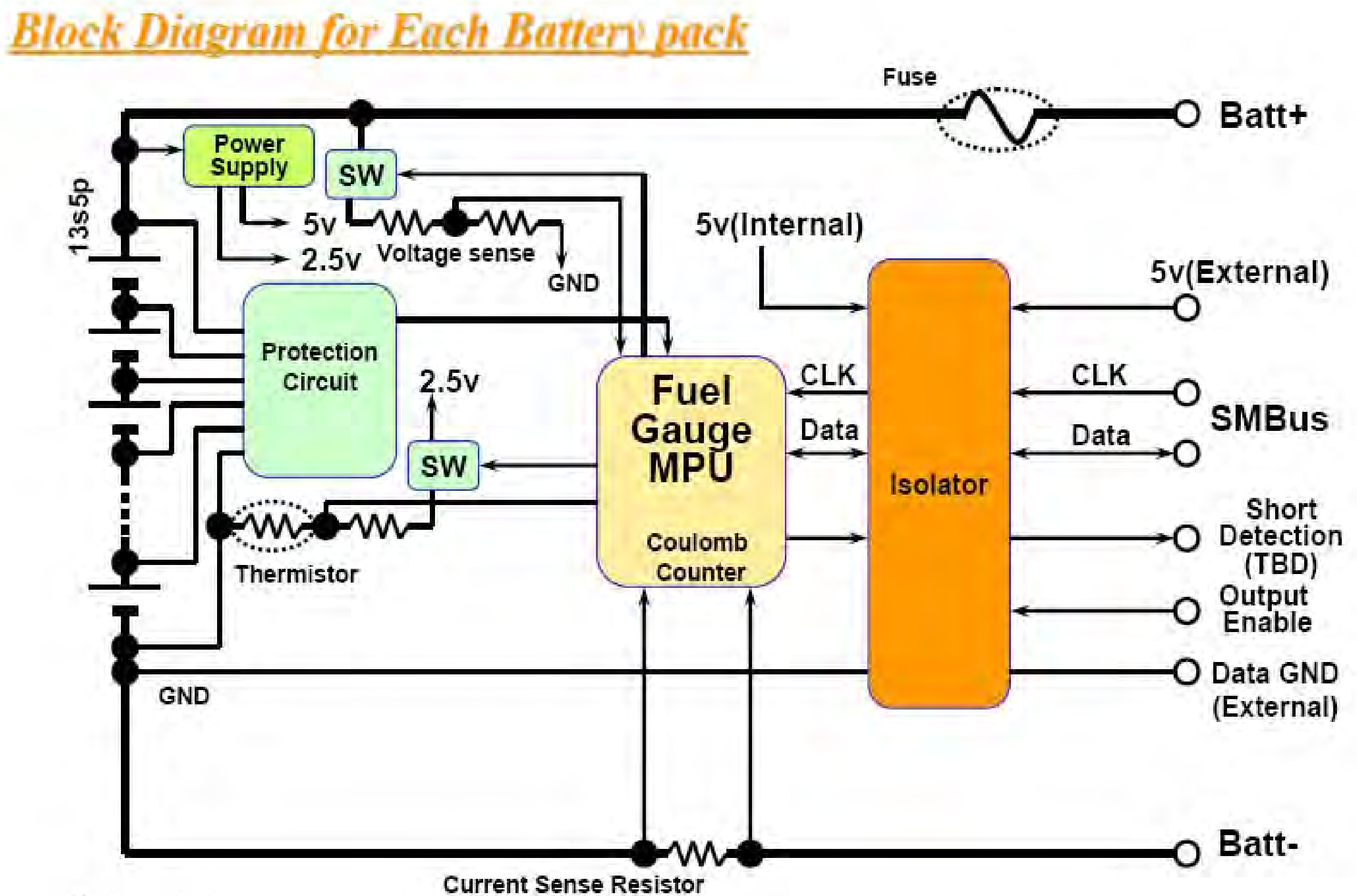
5C Discharge Curves



Charge : 1C 109.2V CCCV C/20CA cutoff at R.T.
Discharge : 5C to 78V at R.T.

Very small temperature deviation in the packs

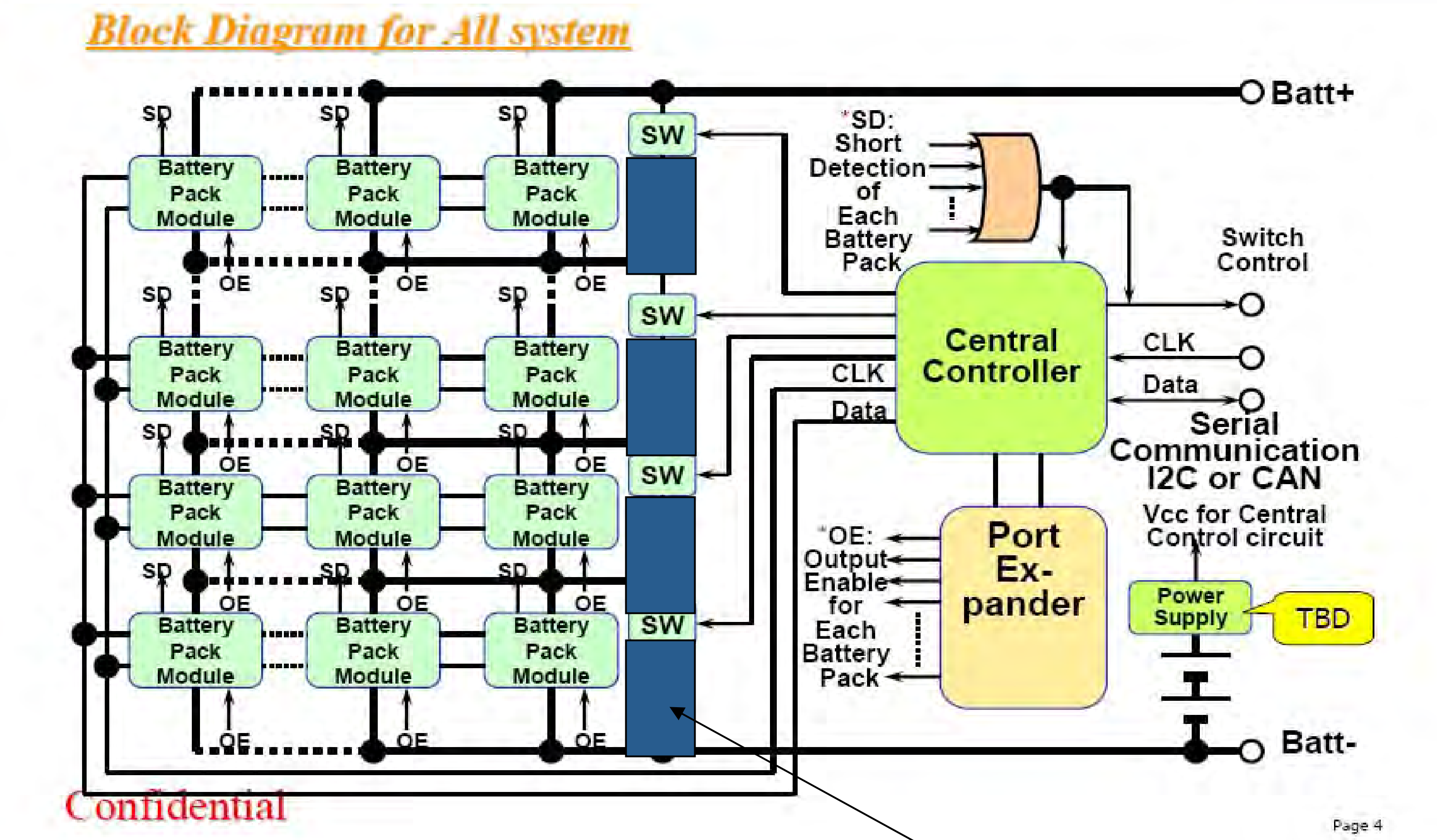
BMU in the Matrix™ Module



Powering Life.

QUALLION

Matrix^{TM} Battery System with Matrix^{TM} Module



Balancing Circuit

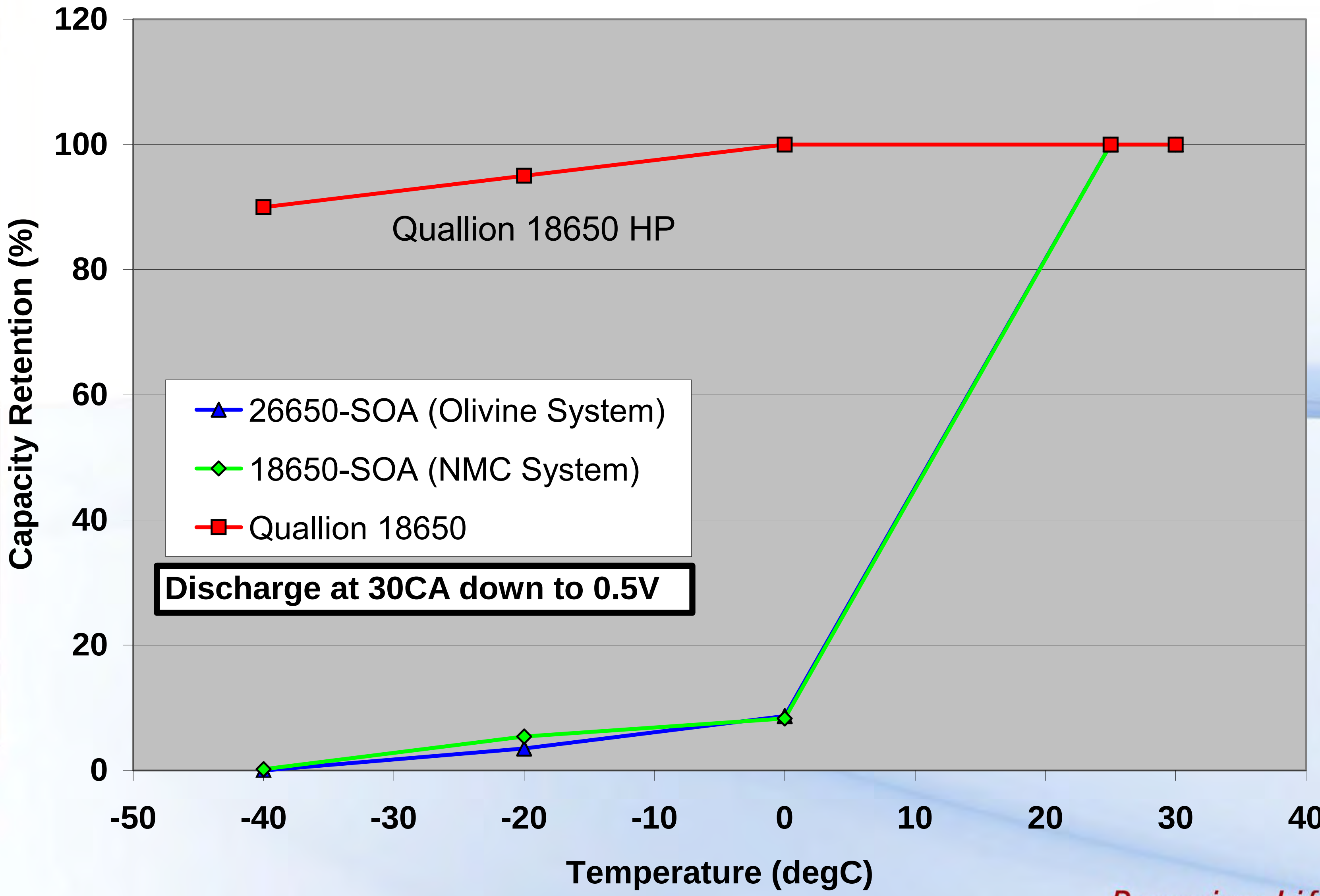
Powering Life.

Quallion Unique High Power and Low Temperature Capability: 18650 HP

At -40°C, 30C rate discharge capable

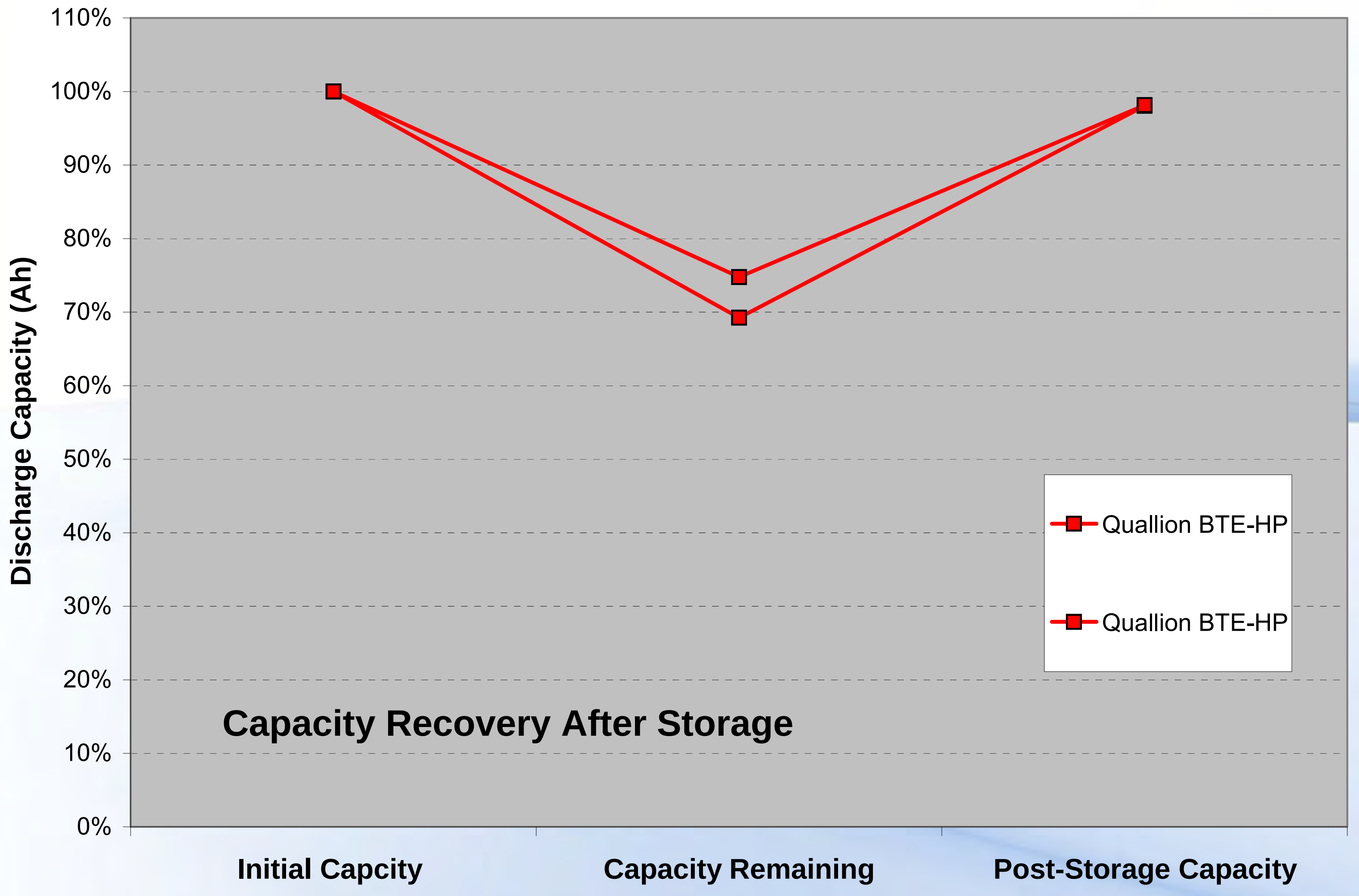
- Electrical Characteristics
  - Nominal Capacity = 900 mAh
  - Operating Range = -40°C to +71°C
  - Chemistry = NCA/MCMB
- Physical Characteristics
  - Diameter = 18.1 mm
  - Height = 65.4 mm
  - Volume = 66.7 cc
  - Weight = 39 g
- Heritage Materials
  - Active materials are the same as Quallion SATELLITE cells
  - USG T3 program enables Quallion to produce Cathode NCA and Anode MCMB in-house by 2012

30C Discharge Data Comparison

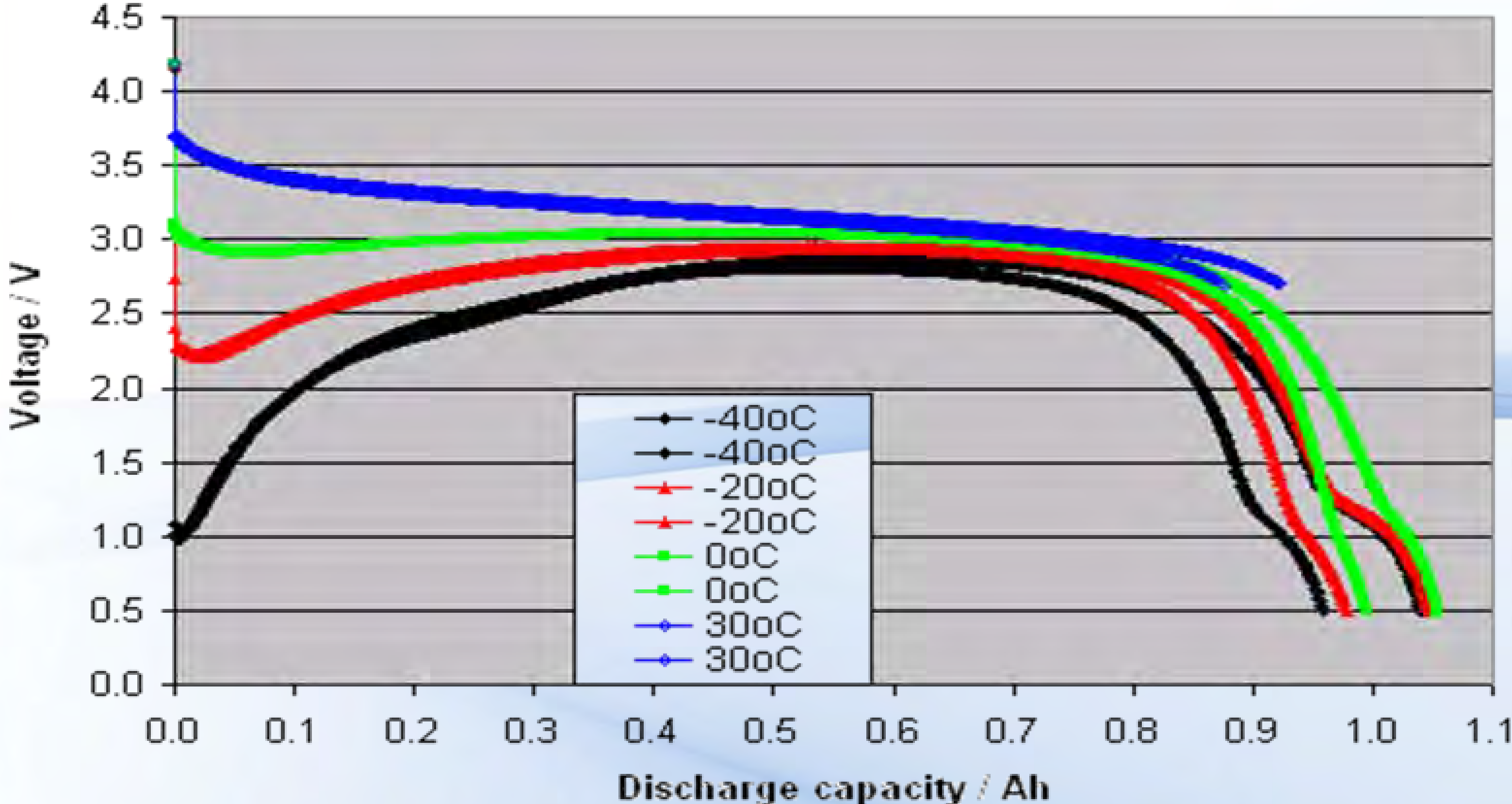


Powering Life.

Storage of Quallion HP Cell at +71°C/2 Weeks



Discharge Temperature data of Quallion HP Cell at 30C Rate

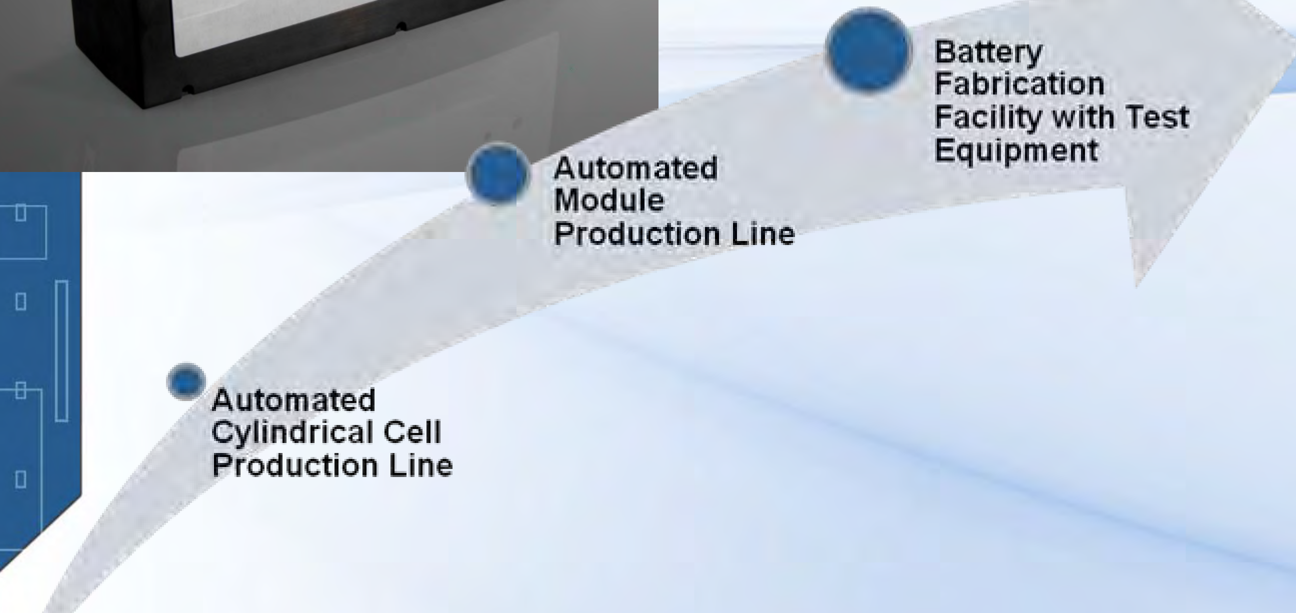


Charge : 1C, 4.2V CCCV C/20 cutoff at RT

Discharge : 30 C to 0.5 V at Different temperature

Powering Life.

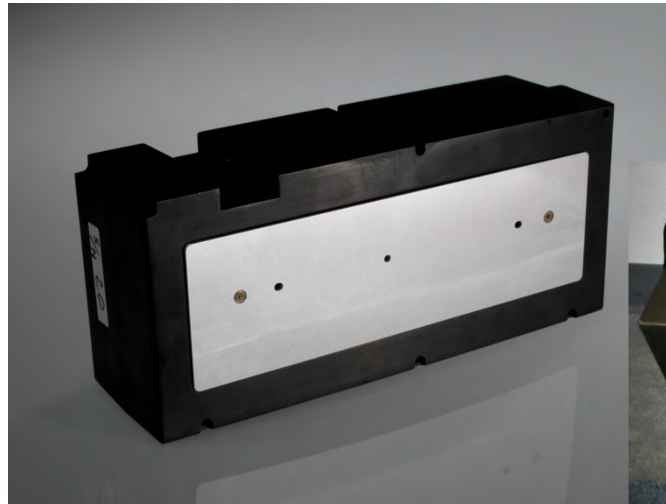
Matrix^{TM} Technology: Modular Design for Flexible Performance, Flexible Shape and Inexpensive Cost



Cost Competitive Battery Solution

COTS cell (non-domestic, most inexpensive)

QUALLION



Quallion: US Domestic Battery Company with Unique Material, Cell and Battery Capability

Powering Life.

EaglePicher™

Development of a "Half-Sized" BA-5590 with Li/CFx Cells

Gregg C. Bruce

EaglePicher Technologies

Presented at:
2009 Joint Services Power Expo
May 5th – 7th, 2009
New Orleans, Louisiana

Topics

- Introduction
- EP-X590 and EP-X295 Batteries with Li/CFx Cells Development
- "Half-Sized" BA-5590 Li/CFx Battery Development
- Conclusions

Introduction

- EPT has carried out a development program to enable Li/CFx to be used in applications that require moderate or high rates.
- The goal has been to increase rate capability and improve low temperature performance.
- Efforts initially focused on a D cell format and evaluation in EP-X347 (2 D cells), EP-X380 (2 D cells), EP-X590 (10 D cells), EP-X295 (5 D cells) and the “Half-Sized” BA-5590 battery.
- Extensive performance, safety and transportation testing has been successfully completed.
- The EPT Li/CFx D cell has safely passed all the requirements of the UN Transportation testing protocol.

EaglePicher™

Introduction

- **EPT has delivered the following CFx Cells and Batteries for evaluation:**

Organization	Cell Size, Ah	No. of Cells/Batteries	Date
USAF	D Cell 15.5-Ah	20 Cells	08/05
US Army	D Cell 15.5-Ah	60 Cells	08/05
US Army	EP-XX47	10 Batteries	08/05
US Navy	D Cell 15.5-Ah	10 Cells	10/06
US Army	EP-X380	15 Batteries	04/07
US Army	EP-XX47	20 Batteries	05/07
US Army	D Cell 15.5-Ah	10 Cells	06/07
US Army	EP-X590	5 Batteries	06/07
US Navy	EP-X590	2 Batteries	11/07
Canadian DND	EP-X590	4 Batteries	12/07
Canadian DND	D Cell 15.5-Ah	10 Cells	12/07
NASA Goddard	D Cell 15.5-Ah	8 Cells	12/07
Natick	EP-X295	2 Batteries	04/08
US Army	EP-X295	30 Batteries	05/08
US Navy (Crane)	EP-X295	6 Batteries	08/08
US Army (Natick)	EP-1/2 5590	30 Batteries	12/08
US Navy (Crane)	EP-X590	10 Batteries	01/09
US Army	EP-1/2 5590	20 Batteries	02/09

Electrical Performance (D Cell)
Lithium Battery Chemistries at 20°C and 2A

Cell Chemistry	Capacity (Ah)	Weight (g)	Volume (cc)	Specific Energy (Wh/kg)*	Energy Density (Wh/l)*
Li/SO_2	7.5	80	47.3	262.5	444.0
Li/MnO_2	10.5	113	47.3	260.2	621.6
Li/CFx	15.5	87	47.3	463.2	852.0

*Li/SO_2 and Li/MnO_2 based at 2.8V and Li/CFx based at 2.6V

Military Batteries - EPT CFx cells

- **EPT has been working on the "EP-5590" format with three approaches:**
  - **EP-X590 (10 D cells) twice the capacity of the BA-5590.**
  - **EP-X295 (5 D cells) same capacity, 59% of the size, 58% of the weight of the BA-5590.**
  - **Half Sized EP-5590 (5 smaller cells) same capacity of the BA-5590.**
- **The CFx EP-X590 battery was 7.3% heavier but delivered two times the capacity of the SO_2 BA-5590.**
- **The CFx EP-X295 battery was 59% of the size and 58% of the weight and delivered close to the same capacity as the SO_2 BA-5590.**
- **The "Half-Sized" BA-5590 with CFx cells delivered 82% of the capacity of a BA-5590 in 50% of the volume and 50% of the weight. Future optimization is on-going.**

EP-X295, EP-X590 and "Half-Sized" BA-5590 Batteries

EP-X590 Batteries - EPT CFx D Cells

- **EaglePicher has made a limited number of EP-X590 batteries with CFx D cells.**

- **EaglePicher evaluated the Li/CFx D cells in the EP-X590 batteries in a similar fashion to a Industry/Government Li:MnO_2/Li:SO_2 evaluation with the exception of the 2A discharges.**

- **The batteries delivered the capacity projected by cell characterization.**

EP-X590 with EPT CFx D Cells Electrical Performance

Test Protocol	Test Temp.	Capacity (Ah)	Running Time (hrs)	Voltage Delay	Specific Energy (Wh/kg)	Energy Density (Wh/l)
Standard ASIP	-20ºF	10.21	17.17	1 hour	109.3	127.5
Standard ASIP	95ºF	31.16	61.84	Not Observed	393.9	459.3
Heavy ASIP	70ºF	30.77	30.28	Not Observed	382.2	445.6
Heavy ASIP	130ºF	31.25	31.71	Not Observed	400.2	466.7
RCU (0.825A)	-20ºF	20.51	24.73	3.83 minutes	216.9	252.9
RCU (0.825A)	95ºF	31.31	37.95	Not Observed	391.0	456.0

Standard ASIP = 20W, 1 minute: 4.6W, 6 minutes: 6W, 3 minutes
Heavy ASIP = 20W 1 minute: 6W, 1 minute

Military Batteries – EP-X295 Battery

- **EPT internally developed the EP-X295 battery.**
- **The EP-X295 is 59% of the volume and 58% of the weight of the BA-5590.**
- **The battery was manufactured in limited quantities for evaluation by Military users.**
- **The EPT EP-X295 battery has successfully passed all the requirements of the UN Transportation testing.**

EP-X295 SINCGARS Profile with Storage

Storage	Test (°C)	Voltage Delay	Capacity (Ah)	Run Time (hours)	Wh/l	Wh/kg
None	21°C	None	14.8	28.6	361.1	345.8
None	-20°C	21 minutes	8.1	14.1	176.6	169.1
None	54°C	None	15.4	30.5	385.0	368.7
7 Day DC	21°C	None	14.8	28.4	358.1	343.0
7 Day DC	-20°C	21 minutes	7.5	13.0	163.7	156.7
7 Day DC	54°C	None	15.0	29.8	376.8	360.8
28 Day DC	21°C	None	15.8	28.7	375.2	359.3
28 Day DC	-20°C	31 minutes	6.9	12.0	151.5	145.1
28 Day DC	54°C	None	15.4	30.5	385.0	368.7

SINCGARS (Standard ASIP) = 20W, 1 min.: 4.6W, 6 min.: 6W, 3 min.
Baseline BA-5590 at 21°C provides 247.6 Wh/l and 227.8 Wh/kg.

EP-X590 and EP-X295 Batteries with CFx Cells - Conclusions

- Under the SINCGARS Test Protocol the CFx EP-X590 battery ran for 61.35 hours and the EP-X295 ran for 28.6 hours.
- The BA-5590B/U Li/SO_2 battery tested under identical conditions ran for total of 32.50 hours, specification is 30.5 hours.
- Maximum temperature reached was 41^{o}C for the EP-X590 and 53^{o}C for the EP-X295 under the SINCGARS Test Protocol at 21^{o}C.
- The EP-X590 battery is 7.3% heavier but delivers close to two times the capacity of the SO_2 BA-5590. One CFx battery weighing 1030g versus two SO_2 batteries weighing 1920g (960 g each).
- The EP-X295 battery will be 58% of the weight of the Li/SO_2 BA-5590 and deliver 88% of the capacity and 94% of the specified mission requirement.

Background - Goals

Performance Specifications:

- "Half Sized" EP-5590 Li/CFx Battery
- 200 Wh at the SINCGARS radio duty cycle of (4.6W : 6.0W : 20W, 6 minutes:3 minutes:1 minute)
- 1.1lb max (400 Wh/kg)
- Dimensions: see drawing below
- 16.8V max, 10V min
- Connector: BA-5590 type
- Fuel gauge
- Operational Temp: -20°C to 55°C
- Storage Temp: -40°C to 70°C
- Prototypes deliverables will be evaluated on electrical performance and their ability to meet IATA, MIL-PRF-47491B, and Safety Assessment Report (SAR) testing. SAR required in FY09 for Soldier use.

“Half-Sized” BA-5590 with Li/CFx Cells

EaglePicher™

EP-X590 and “Half-Sized” BA-5590 Batteries

Baseline Performance

- **The “Half-Sized” BA-5590 with Li/CFx cells is designed so that the two batteries can fit into the BA-5590 battery enclosure.**

- **The performance goal is quite rigorous since the battery is exactly half the size of the BA-5590 but the connector is unchanged. Therefore, the volume available for the cells is less than 50% of the space available for the cells in the BA-5590 battery.**

- **The “Half-Sized” BA-5590 with Li/CFx Cells weighs 50% of that of the BA-5590.**

EaglePicher™

Baseline Performance – Cell

- Due to the volume for the cells in the “Half-Sized” BA-5590 being reduced when compared to the BA-5590 a new cell was developed.
- The Electrical Characterization of the cell is shown below:

Temperature (°C)	Discharge Rate (continuous)		
	0.5A	1.0A	2.0A
-20	N/A	6.40-Ah	6.24-Ah
21	13.37-Ah	13.47-Ah	12.78-Ah
55	13.90-Ah	13.35-Ah	13.49-Ah

Baseline Performance

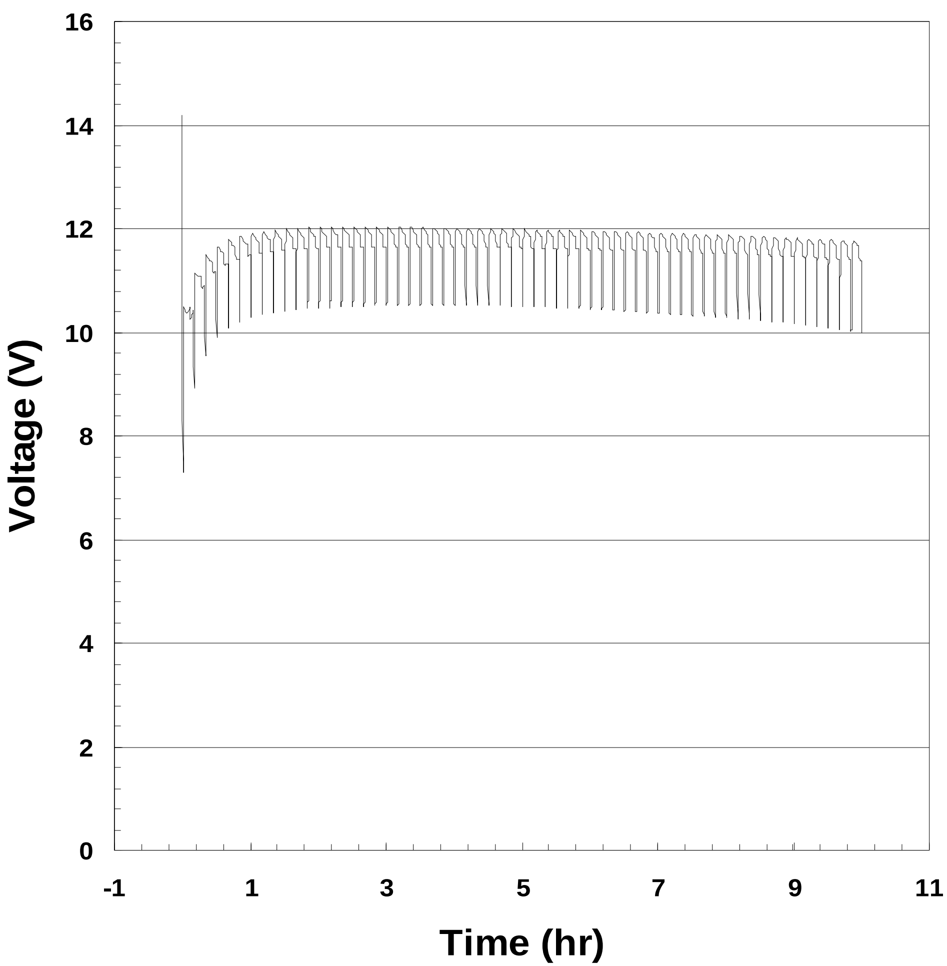
“Half-Sized” BA-5590 with Li/CFx Cells

- The development of the battery focused on the SINCGARS Test Protocol.
- The batteries were characterized at -20°C, 21°C and 55°C as specified.
- In addition the battery was also discharged at -29°C to determine performance limitations.
- In all cases the battery discharged at every temperature with some Voltage Delay noted at -20°C and -29°C.

"Half-Sized" BA-5590 with Li/CFx Cells

EaglePicher™

SINCGARS Test Protocol (– 29ºC)



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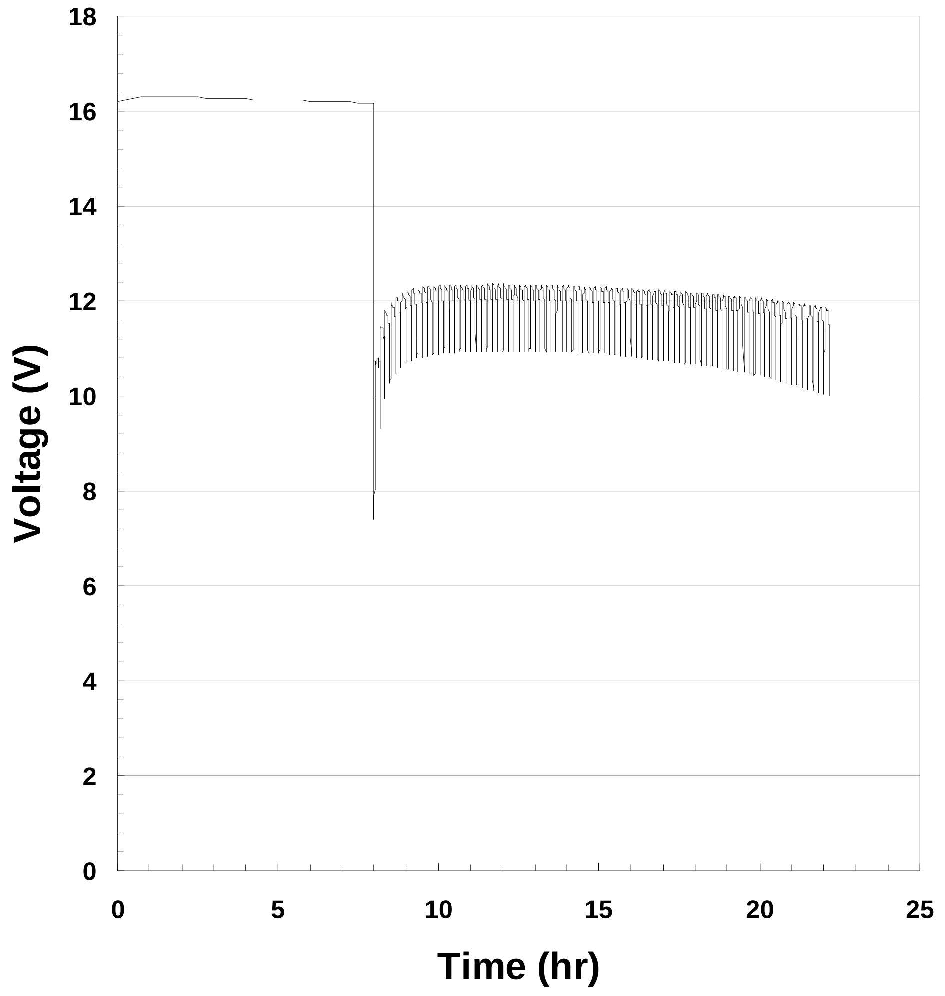
SINCGARS Test Protocol (– 20^{o}C)



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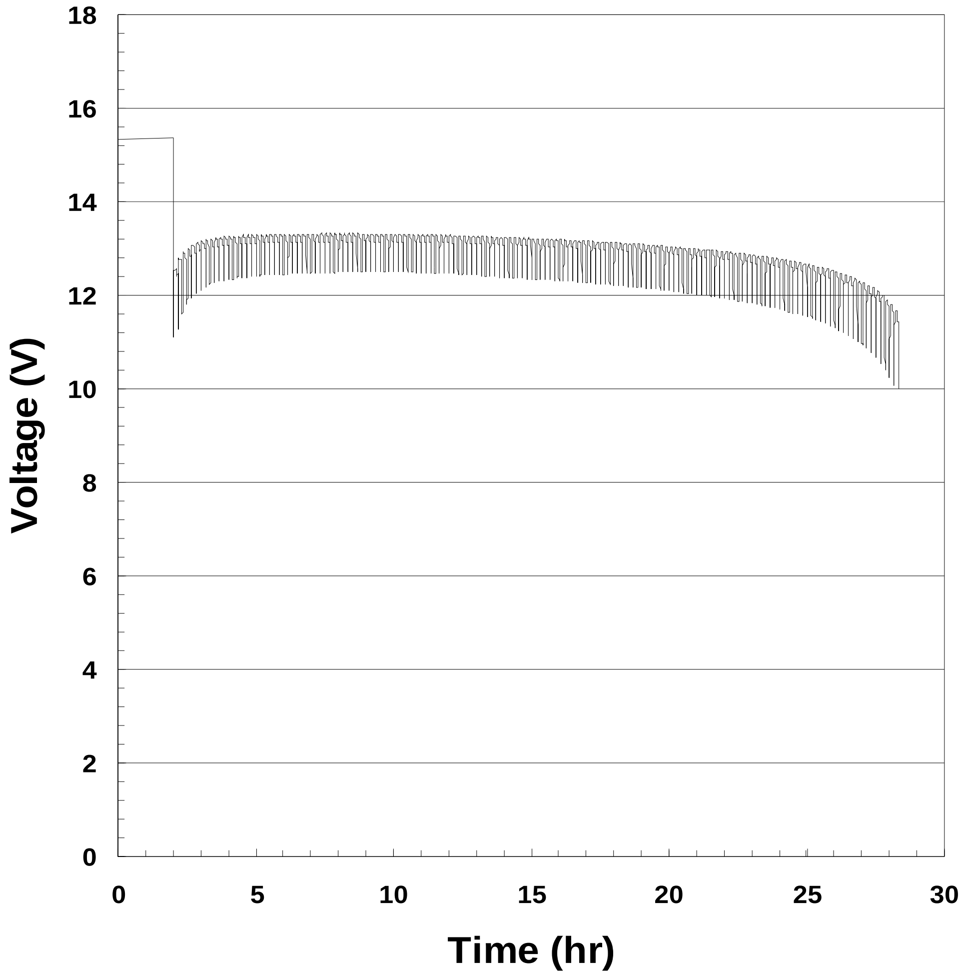
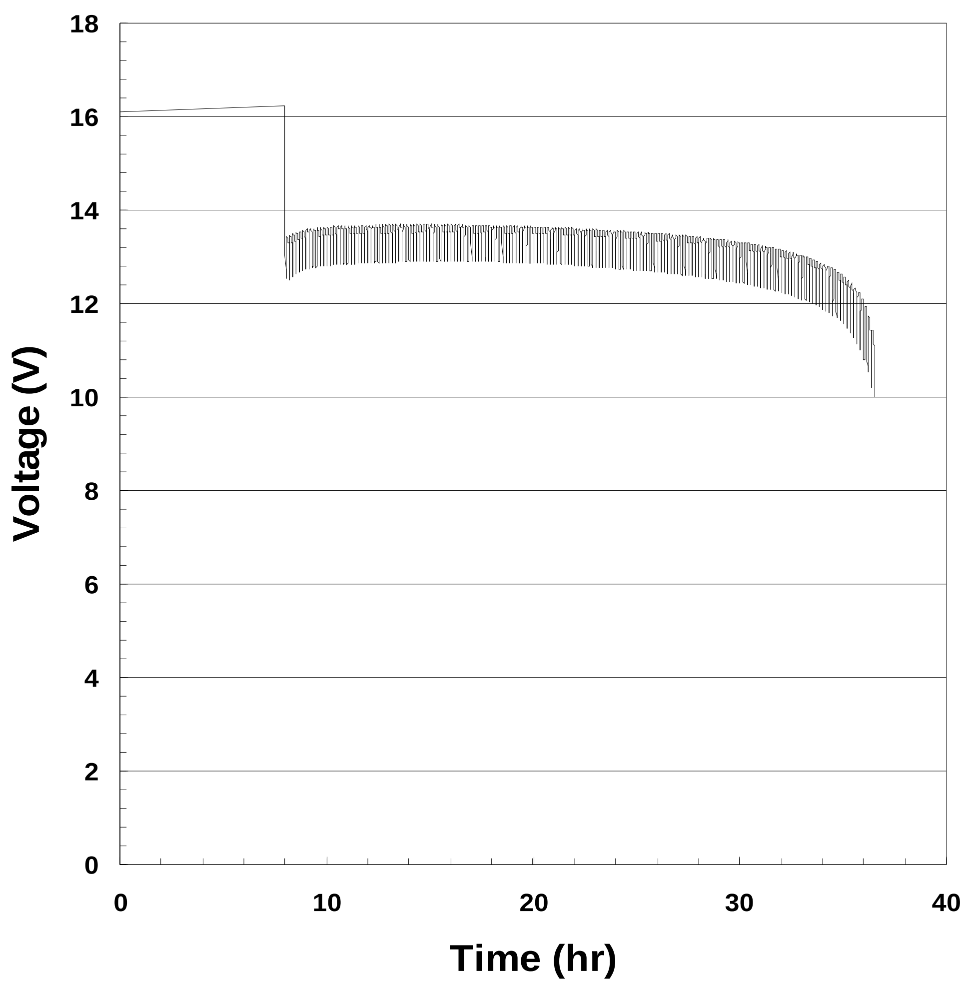
SINCGARS Test Protocol (21ºC)



“Half-Sized” BA-5590 with Li/CFx Cells

EaglePicher™

SINCGARS Test Protocol (55°C)



“Half-Sized” BA-5590 with Li/CFx Cells Electrical Performance – SINCGARS Protocol

Temp. (°C)	Voltage Delay	Capacity (Ah)	Discharge Time	Watt Hours	Wh/l	Wh/kg
-29°C	30.6 min.	5.3-Ah	9.1 hours	59.5	136.41	122.68
-20°C	20.3 min.	7.6-Ah	13.4 hours	88	201.75	181.44
21°C	0	13.6-Ah	26.2 hours	172.3	395.02	355.26
55°C	0	14.1-Ah	28.0 hours	183.8	421.39	378.97

Baseline BA-5590 at 21°C provides 247.6 Wh/l and 227.8 Wh/kg.

“Half-Sized” BA-5590 with Li/CFx Cells - Conclusions

- There are still performance issues associated with the CFx batteries when tested at low temperature.
- The voltage delay was greater than allowed.
- The performance of the EPT Li/CFx batteries have demonstrated the potential of the electro-chemistry.
- The “Half-Sized” Ba-5590 battery delivered 355.26 Wh/kg at 21^{o}C and 378.97 Wh/kg at 55^{o}C.
- On-going developments have shown 400 Wh/kg is within reach.
- The CFx batteries provided by EPT will allow the user to select the proper capacity as governed by the mission and not have to carry unwanted weight.

“Half-Sized” BA-5590 with Li/CFx Cells Recent Developments

- **Recent Internally Funded Research and Development at EPT has shown that the cell impedance can be greatly reduced to limit or eliminate Voltage Delay under Low Temperature conditions.**

- **The lower cell impedance will also reduce thermal issues at higher discharges rates (2A). The thermal issues are not an issue under the SINCGARS Test Protocol.**

- **Presently, different cell designs are under investigation to increase Specific Energy.**

2009 JSPE - Saft

Advanced Lithium Power Sources – Real World Experience

5 May 2009

saft

Real World Experience – Key Topics

- Saft Background
- Improved Target Acquisition System
  - Lithium Battery Box
- Battery Life
  - Expectations vs. Experience
  - Life Limiting Factors
- Fielded Lessons
  - Expecting the Unexpected
- New Developments

Saft Global Manufacturing Network

- SDD is a division of Saft America, Inc. – a subsidiary of the Saft Group, headquartered in Bagnolet, France.
- Saft is a multinational company specializing in the manufacture and development of high tech batteries for industry.

saft

Space and Defense Division, Cockeysville, MD

Dedicated to manufacturing advanced Li-ion cells and batteries for Space and Defense applications

Type of Cell	VL4V	VL12V	VL22V	VL34P	VL52E
	Very High Power			High Power	High Energy
Dimension					
Diameter (mm)	34	47	54	54	54
Case length (mm)	156	152	174	174	200
Mass (kg)	0.33	0.64	0.96	0.94	0.99
Capacity (Ah)	5.5	12	22	33	52
Specific Energy (Wh/kg)	50	74	84	120	200
Energy Density (Wh/L)	138	175	200	280	430
Power (W/kg) 18 sec pulse at 50% SOC	3600	6000	6350	1900	N/A
Continuous Discharge Rate	60C	100C	100C	15C	1C

Improved Target Acquisition System (ITAS)

- Saft supplies the battery for Raytheon's Improved Target Acquisition System used with the TOW Missile.
- Battery powers weapon sight / targeting unit (ITAS)
- More than 1500 batteries have been fielded for combat use. Systems in Iraq and Afghanistan (TRL-9).
- Raytheon has recognized Saft with the Supplier Excellence Award three years in a row due to our performance on this program.

Raytheon

saft

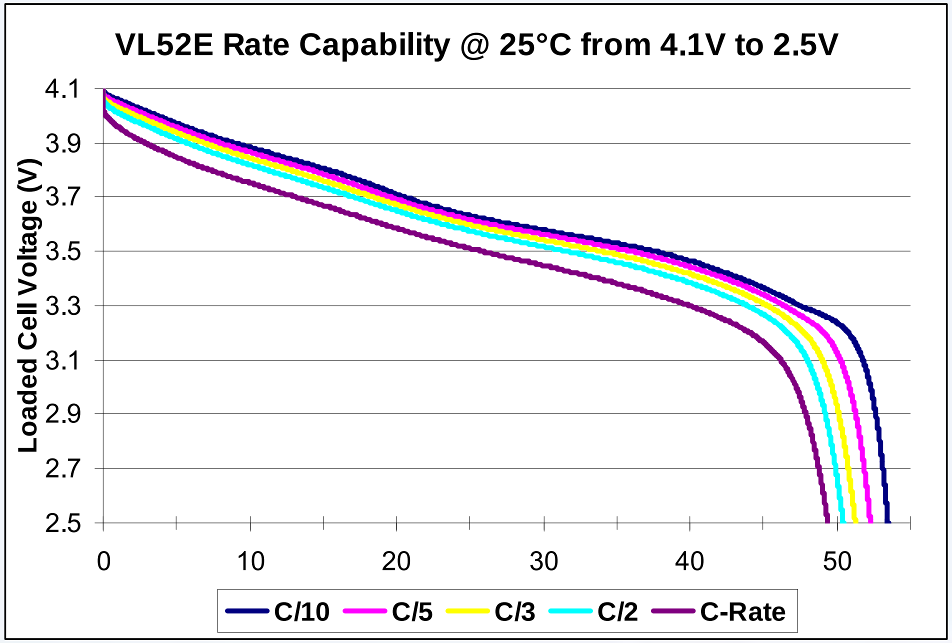
ITAS – Lithium Battery Box

- Production began in 2004 – the first production for a large Lithium-ion system.
- Improvements over former AgO/Zn technology:
  - Increased Operational Readiness
    - No activation charge needed
  - Charging time < 6 hours
  - Operating time > 16 hours
  - Total life > 3-5 years
  - Reduced service cost
- Only required field maintenance is periodic charging
- Battery specs:
  - 28 V, > 80 Ah
  - 65 lbs
  - Energy = 2.5 kWh

ITAS cell pack: 8S, 2P configuration

ITAS - High Energy Cell Design

Characteristic	Units	Value
Mass	kg	1.0
Volume	L	0.48
Charge Voltage	V	4.1
Capacity (4.1V-2.5V, 25°C, C/7)	Ah	52
Specific Energy (4.1V-2.5V, 25°C, C/10)	Wh/kg	185
Energy Density (4.1V-2.5V, 25°C, C/10)	Wh/L	385
Peak Discharge Current (RT, Complete)	A	52
1kHz AC Impedance	mΩ	0.8
Terminal-to-Terminal Length	mm	208
Diameter	mm	54



VL 52 E

ITAS - Battery

- Robust
  - Shock
  - Vibration
  - UN Transportation
  - Waterproof to 36” but floats
  - EMI, EMC, NBC qualified
- Designed for one man lift
- Ergonomic Connector access
- Simple user interface
- Designed for 36” drop cold
  - 32 drops for qual – no leaks
- Made to fit the space in HMMWV behind passenger seat

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ITAS - Flange Panel Front Controls

- Two Mil spec connectors with connector covers
- BIT lights (BAT, ELEC)
  - BAT = Cell Pack
  - ELEC = Electronics
- Display Intensity Control
  - On (low) / On (high) / Off
- Charge Indicator
- State of Charge LEDs
- Power Switch integral 35A Circuit Breaker
- Override Switch

Battery Life

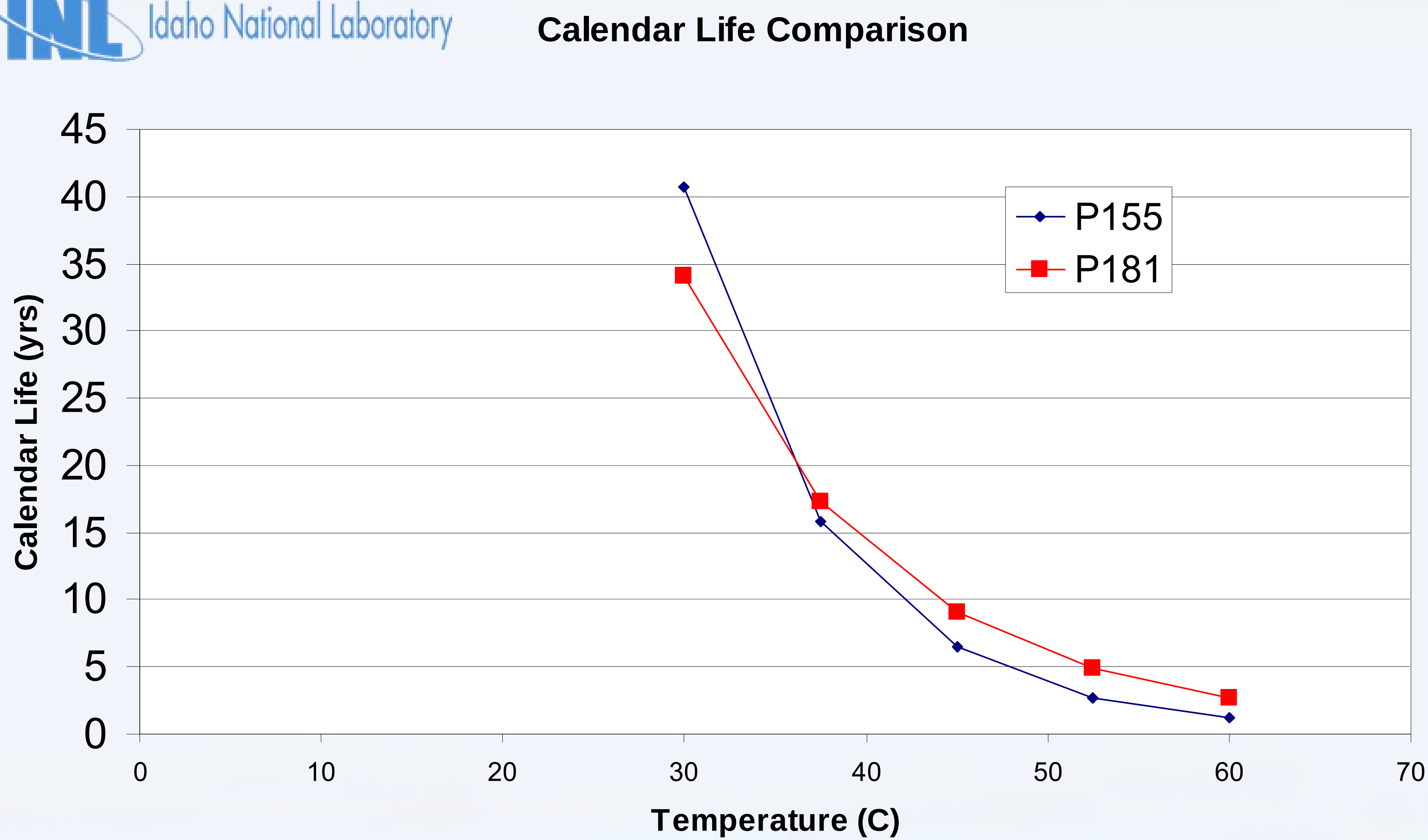
- Battery life based on few major factors
  - Fundamental Electrochemistry – Specific chemistry gives life potential
  - Calendar Time / Temperature – Lower temperature gives longer life
  - Discharge Depth and Rate – Shallower / slower cycles give longer life
- Methods to determine life take time – cycles and calendar time
- Two data sources – Lab / Field

Battery Life - Definitions

- Battery life defined for given application
  - Typically when battery delivers 80% of new capacity
- Lithium-ion - General Life / Technology
  - No memory effect as in some other chemistries
  - Does have low rate self discharge
  - Self discharge will vary from cell to cell
  - Overcharge is chief systems concern

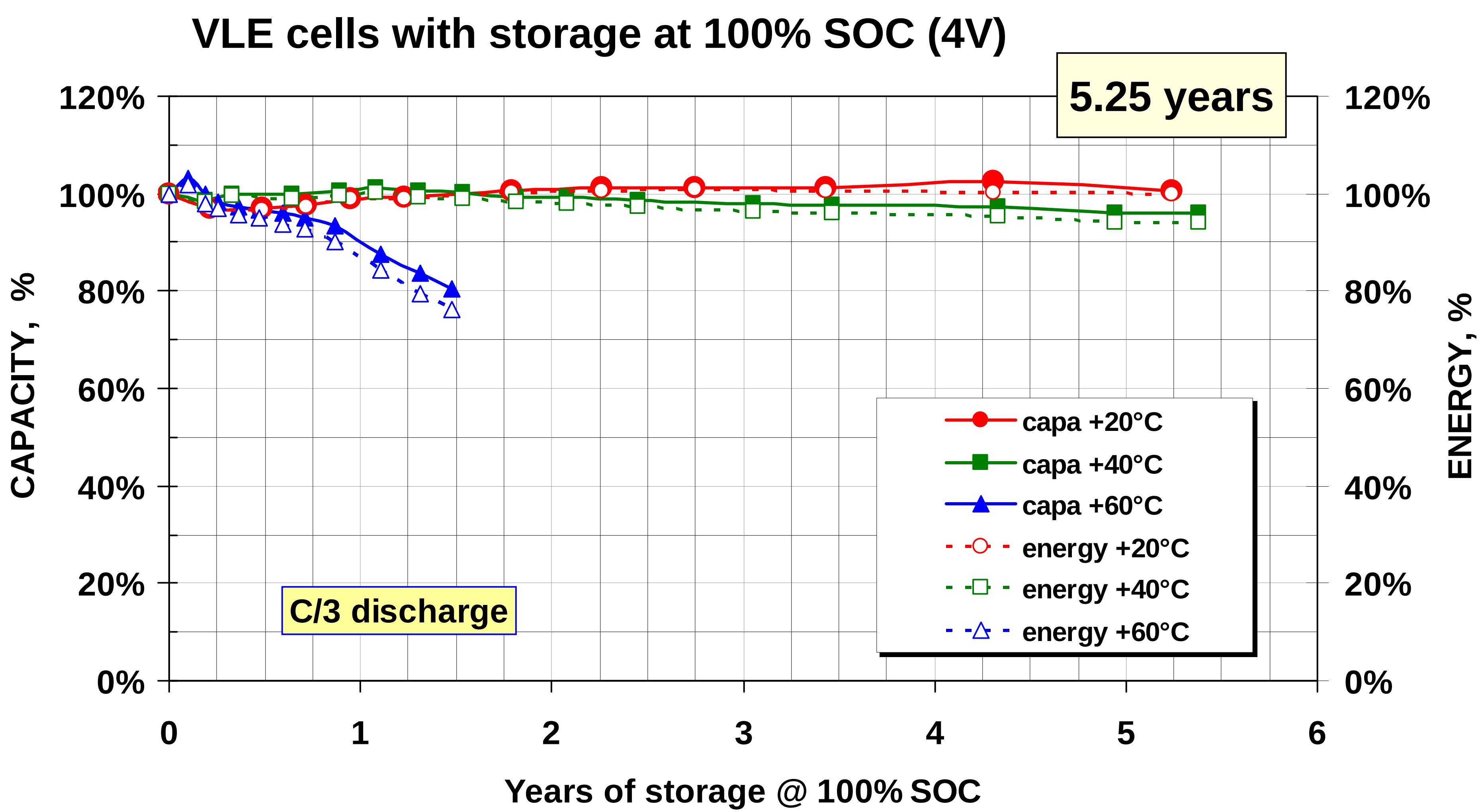
Battery Life - Saft Lithium Ion (NCA)

Idaho National Laboratory



saft

Battery Life - Calendar Stability at Temperatures

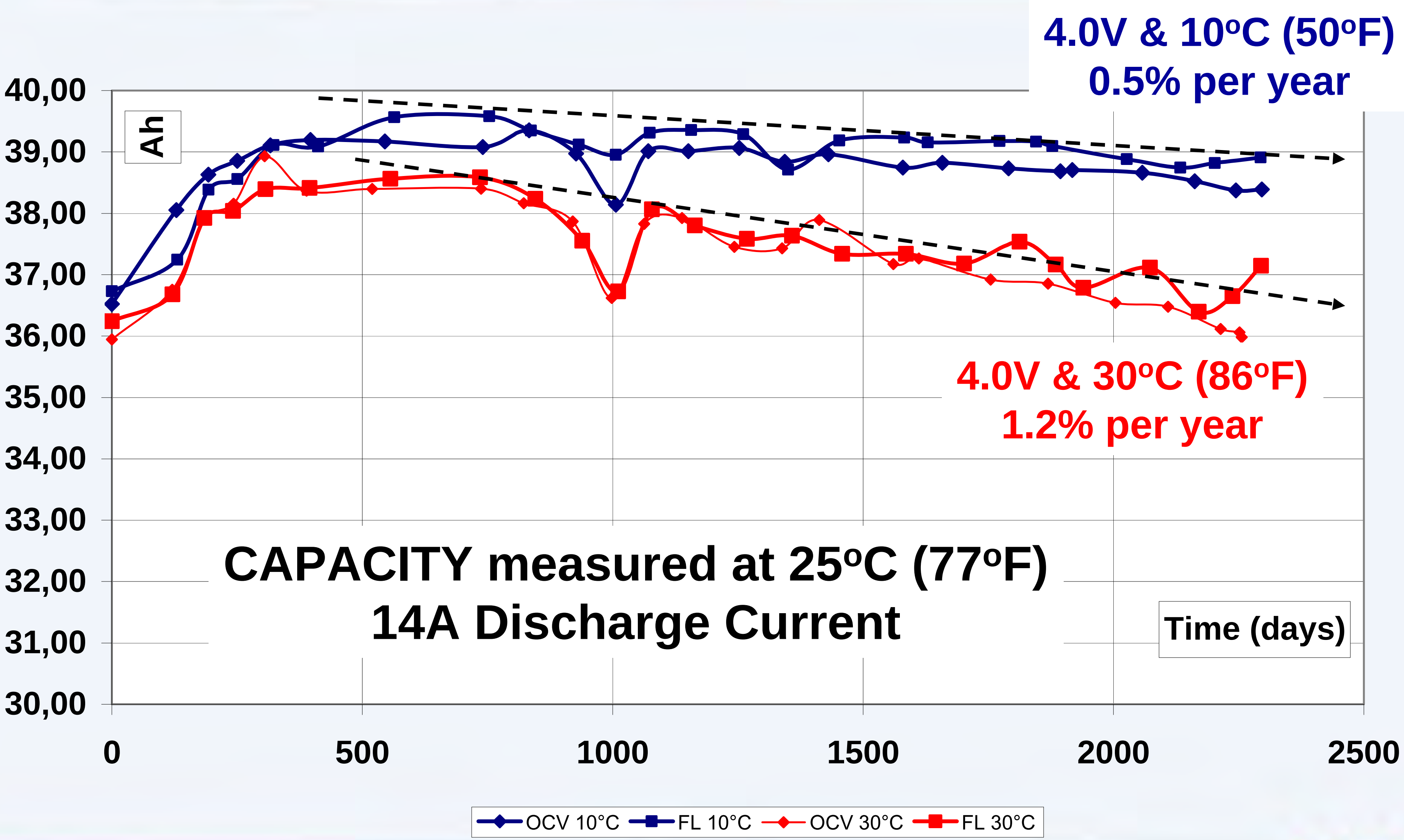


Battery Life - VES140 Cell for Space

- Space program calendar life testing of Li-ion cells
  - Cells were very similar to ITAS cells
- Actual > 6 years of storage performed
- Storage done at several different voltages and two different temperatures – 10°C and 30°C on float and on Open Circuit Voltage
- Capacity and impedance measured periodically

Storage Condition	Capacity Loss per Year	Remaining Runtime after 10 Years (20 hours at start)
	Based on 6.8 years testing	Best Estimate Projection
4.0V and 10°C (50°F)	0.5%	95% / 19 hours
4.0V and 30°C (86°F)	1.2%	88% / 17.6 hours

Battery Life - VES140 Cell for Space



Battery Life – Fielded Batteries

- Batteries SN0064 and SN0187 tested at Saft after 3+ Years uncontrolled use (transit, operational use, etc)
- Battery Capacities were 90.7 Amp Hours and 93.3 Amp Hours
  - Battery test
    - ITAS simulation discharge at room temperature (C/18 rate)
    - Capacities were above nameplate capacity for new units
  - Original Cell Capacities were checked
    - Manufacturing data from July and December 2004.
    - Capacities were roughly 45 Amp Hours at medium discharge rate (C/3 rate) – Equivalent to 90 Amp Hours in a battery
- Very low capacity loss after 3+ years uncontrolled use – Roughly 3% in July 2004 unit / No loss in December 2004 unit

Battery Life – Limiting Factors

- Electrochemistry – Not the limiting factor?
  - Life of more than 4 years (and counting) demonstrated
- Connectors – Mate / Unmate Cycles
  - Expected number of cycles for MIL-38999
- Interior Components – Foam / Adhesives
  - Degrade over time
- Physical Abuse
  - Case damage
  - Lack of charging

Fielded Lessons – Alternate Uses

- Supporting the Warfighter!

Warfighter

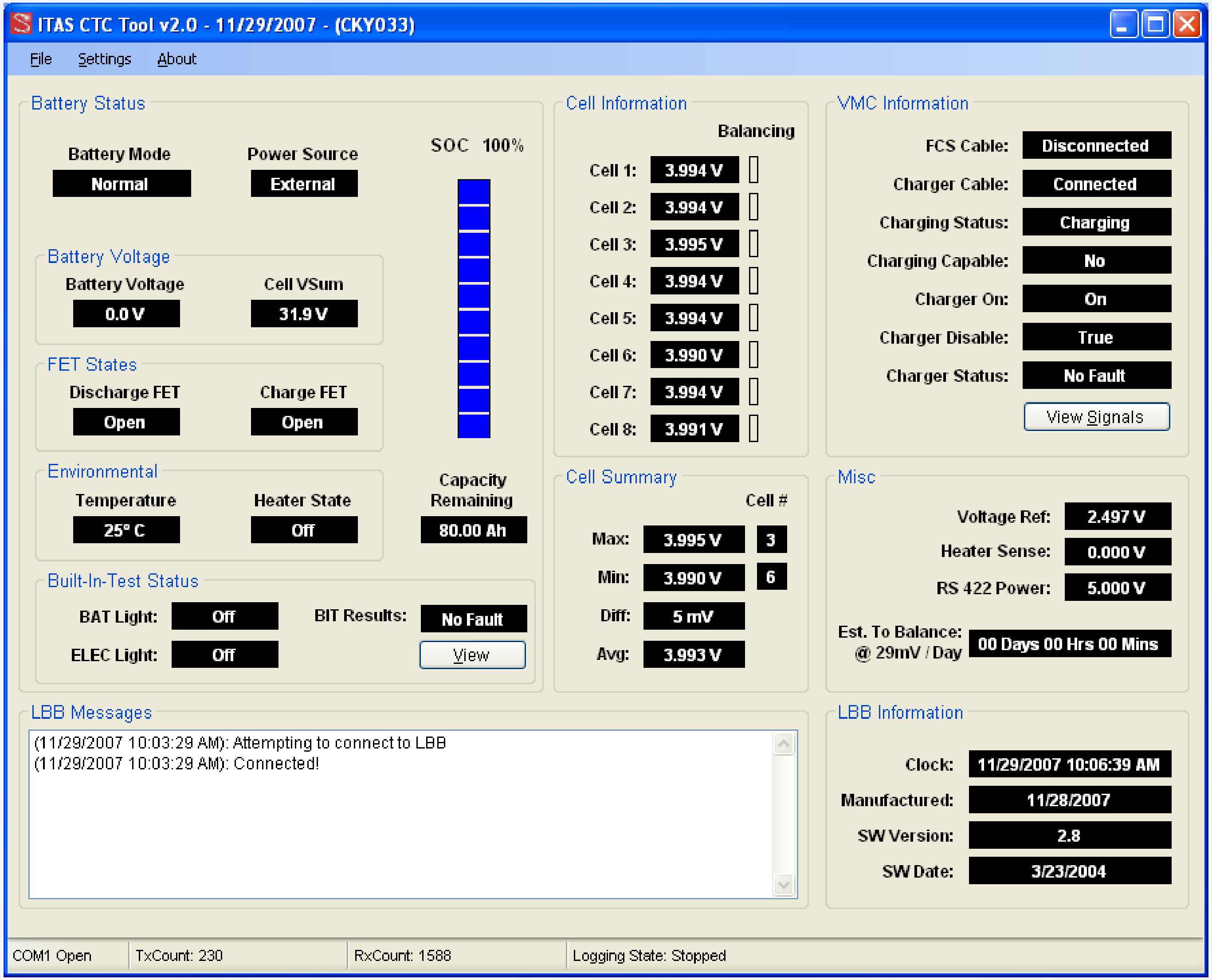
ITAS LBB
(in supporting role)

Fielded Lessons – Systems Function

- ITAS LBB contains complete system functionality
  - Overcharge Protection (Primary Function)
    - Multiple Layers
    - Fully independent circuits
  - Cell Balancing
  - Communication with maintainer
- Lesson: Overcharge protection has been a complete success
  - No failure – ever!
- Once circuit is in place, what other features can be enabled?

saft

Fielded Lessons – Systems Function



Fielded Lessons – Logistic Challenges

- Battery Charging
  - Only maintenance needed!
  - Once every 6 months
    - Baseline recommendation
    - Consult Raytheon FSR's for best practice
  - Lesson: Lead cause of battery return
- Cell Balance
  - Handled by LBB system
  - Lesson: Challenge for battery availability
- Solution – Training and Setting Expectations
  - Article in "The Preventive Maintenance Monthly" (August 2008)
  - Sharing current information

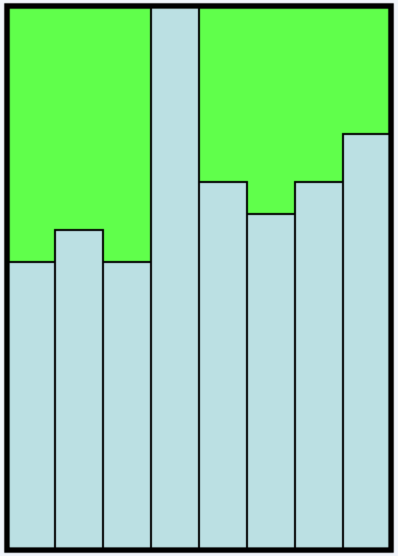
Fielded Lessons – Logistics - Charging

- Batteries self discharge over time and ensuring a maintenance charge is applied remains a challenge.
- Largest return issue (by far)
- Education of user has helped
- Continued storage at low SOC can lead to irreversible cell damage and require cell replacement

Fielded Lessons – Logistics - Balancing

- Differences in self-discharge rate lead to voltage differences in the cell packs
- Normal self-discharge in cells from 0.2 to 2.0 mV/day
- Balancing function during charging corrects for unequal self-discharge – No user intervention needed.
- Balancing rate during charge is ~30 mV / day
  - Takes time to bring a pack back into alignment

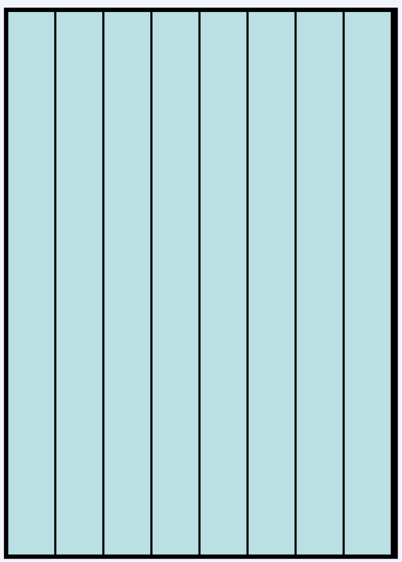
Fielded Lessons – Logistics - Balancing



- Delta Voltage: Difference between max / min cells
- Charging must stop when max cell reaches upper limit (4.1 V)
- Other cells not fully charged

(*green* = wasted capacity)

Fielded Lessons – Logistics - Balancing



- Balancing selectively discharges high cells to match lower ones
- Charging is allowed to continue
- Cells charged more uniformly
- Balancing capability is a key feature of the ITAS LBB. Allowing time for the balancing to work will improve performance.

Fielded Lessons – Battle Damage

- Enemy Fire
  - At least three batteries in separate incidents
  - Batteries smoked, vented
  - Not the end of the world!
- Overwhelming Damage
  - Bridge collapsed onto one battery

New Developments

- Advanced Lithium Power Source
  - Development from the ITAS LBB – Performance Heritage
  - On board AC and DC charging – Convenient Charging
  - Lower Voltage range
  - Wider variety of applications – Simple integration

VL52E Cells (7S2P)

Charger

  - Available Fall 2009

Conclusions

- Saft's High Energy Technology is ideal for use in deployed situations as a high reliability power source.
  - The robust cell design allows for high charge and discharge power, low heat generation, and excellent cold temperature performance, all with extended cycle and calendar life.
- Saft's System approach and integrated control electronics provide an unsurpassed total solution for today's field demands
  - 100% performance of charging safety system has been a key success.
- Large Format Lithium-ion batteries are a success in today's battlefield!

Conclusions (continued)

- *Saft would like to thank US Army Close Combat Weapons Systems (CCWS) and Raytheon for their continued support and team based approach in providing the best possible power solutions for the US Military.*
- *Saft would also like to thank our customers for continued feedback on battery system performance. This insight allows us to continually update and improve our energy storage solutions.*

Questions?

Contact Information

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Battery Requirements
for
Application of
Lithium Ion and Lithium Polymer
To
Achieve Standardization
and Improved Reliability

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Manager AIR-4.4.5.2 Electrical Power
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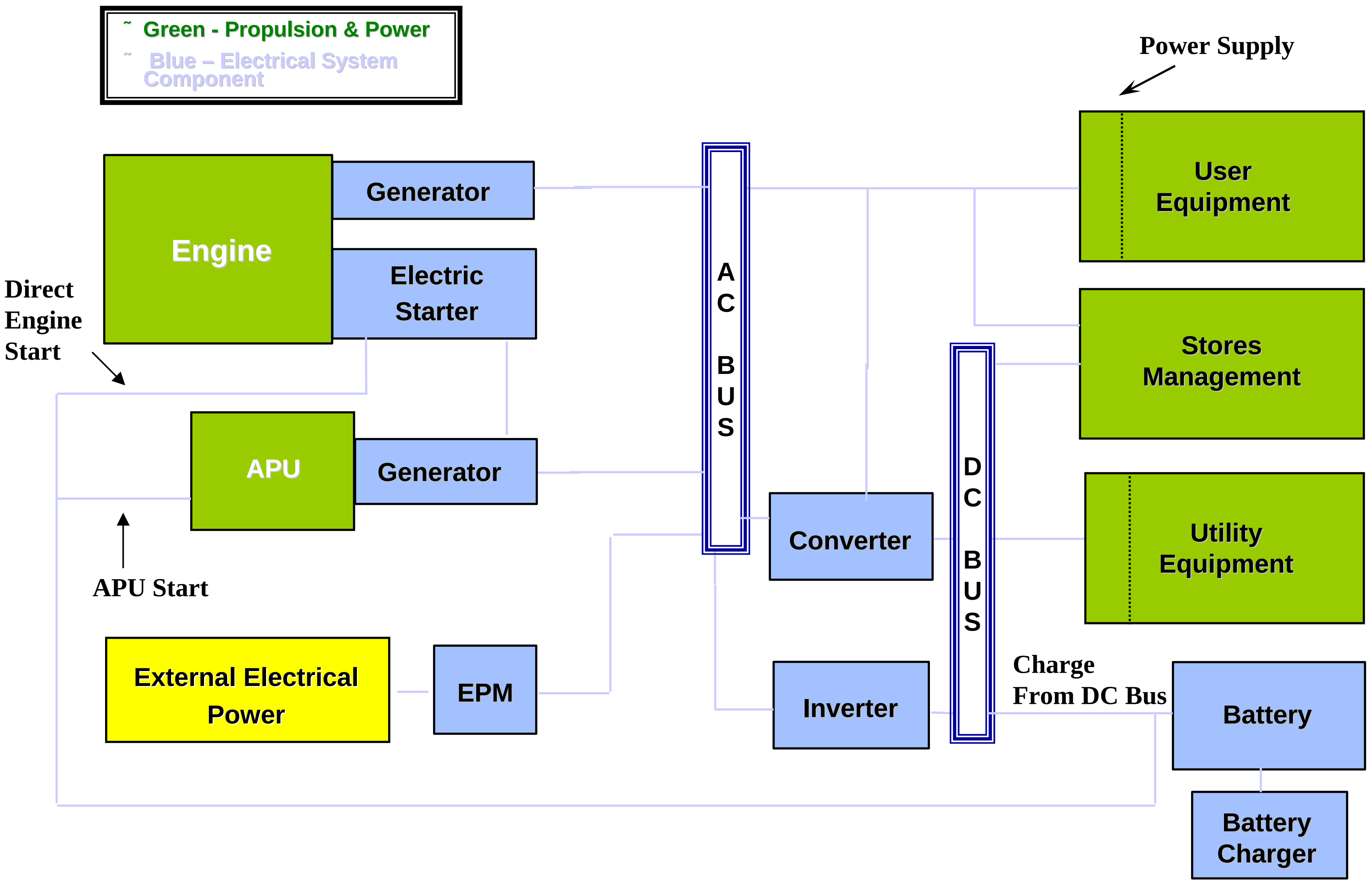
Phone: 301-342-0810

Agenda

- Aircraft Battery Functions
- Present Batteries
- Present Reliability
- Battery Technology Development Underway
- Specification Requirements
  - Direct Current Buss Charging
  - Safety
  - Service life and logistics
- Cost of Ownership
  - Present Battery Costs
  - Lithium Battery Costs
- Technology Development to Address These Costs
- Standardization Opportunity that Could Address Costs
- Planned Demonstrations

Aircraft Battery Functions

NAVAIR



Present Navy Battery Applications & Chemistries

- Presently there are 22 Navy aviation platforms
- Sealed Lead-Acid batteries are presently used on 15 platforms
  - Advantages
    - No scheduled Maintenance for 2-3 years of service life
    - Floats on DC Bus
  - Disadvantages
    - Higher weight than other chemistries
    - Requires heater blankets at cold temperature to assure proper charge
    - Environmental concerns
- Nickel-Cadmium batteries used on 7 platforms
  - Advantages
    - Higher energy density than Lead-Acid
    - Lighter weight
  - Disadvantages
    - Requires periodic maintenance
    - Environmental concerns

Present Reliability

Aircraft	System	Mean Flight Hours Between Failures	MMH/K Flight Hours
MH-53E	Sealed Lead-Acid D8565/1-2	65834	43.2
CH-53E	Sealed Lead-Acid D8565/1-2	5607.1	24.6
F/A-18D	Sealed Lead Acid D8565/4-1	3117.6	26.7
F/A-18F	Sealed Lead Acid D8565/14-1	635.0	171
AH-1W	Nickel-Cadmium M8565/10-1	182.2	159.9
UH-1N	Nickel-Cadmium M81757/16-1	401	97.3

Data Represents Period from 7/08 to 12/08

MIL-PRF-29595A Lithium

NOTE: This draft, dated 20 September 2007, prepared by Crane Division, Naval Surface Warfare Center, Code 6093, Crane, IN, as agent for the Naval Air Systems Command (Code AIR-4.4.4.2), has not been approved and is subject to modification. DO NOT USE PRIOR TO APPROVAL. (Project 6140-XXXX)

METRIC

MIL-PRF-29595A
DRAFT
SUPERSEDING
MIL-B-29595(AS)
1 June 1994

PERFORMANCE SPECIFICATION

BATTERIES AND CELLS, LITHIUM, RECHARGEABLE, AIRCRAFT, GENERAL SPECIFICATION FOR

This specification is approved for use by the Naval Air Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the general requirements for secondary (rechargeable) storage batteries of lithium electrochemistry including, but not limited to, lithium-ion, gel-polymer lithium-ion, and lithium polymer. Potential applications for these cells and batteries are: aircraft, aircraft support equipment, items installed in aircraft, and items carried aboard aircraft. The rechargeable batteries are generally used for medium current engine starting/utility applications, have non-removable covers, and are designed for maintenance-free operation (see 6.14.8).

Comments, suggestions, or questions on this document should be addressed to: Commander, Naval Air Warfare Center Aircraft Division, Code 491000B120-3, Highway 547, Lakehurst, NJ 08733-5100 or emailed to thomas.omara@navy.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at http://assist.daps.dla.mil.

AMSC N/A | FSC 6140

MIL-PRF-29595A Lithium Rechargeable Battery Specification Cover Page

MIL-PRF-29595A Lithium (cont)

- Additional specification requirements for Lithium
  - Direct Current Buss Charging (2 Hour Charge)
    - Electronics
      - Shunts current around fully charged cells
      - Cell Balancing
      - Control inrush current
  - Service Life and Logistics
    - Electronics
      - Prevent complete rundown of battery
      - BIT display
  - Life Cycle Requirements – 600 cycles 100% DoD with 28.25 CP charge for 2 hours
    - 100 cycle (-18°C / 0°F)
    - 100 cycles (43°C / 110° F)
    - 100 cycles (24° C / 75° F)
    - Repeat previous 3 steps

MIL-PRF-29595A Lithium (cont)

- Safety
  - Electronics
    - **EMI**
    - Inhibits charge at cold temperature or heater blankets
    - Prevent overcharge of cells
    - Prevents under-discharge
  - Additional Safety Tests
    - S9310-AQ-SAF-010 Technical Manual Requirements
      - Short Circuit Test
      - Overcharge/Discharge Test
      - Over-discharge/Charge Test
      - High temperature Test
      - Electrical Safety Device Test
      - Aging Safety Test
    - Discharge at maximum operational temperature

Technology Development

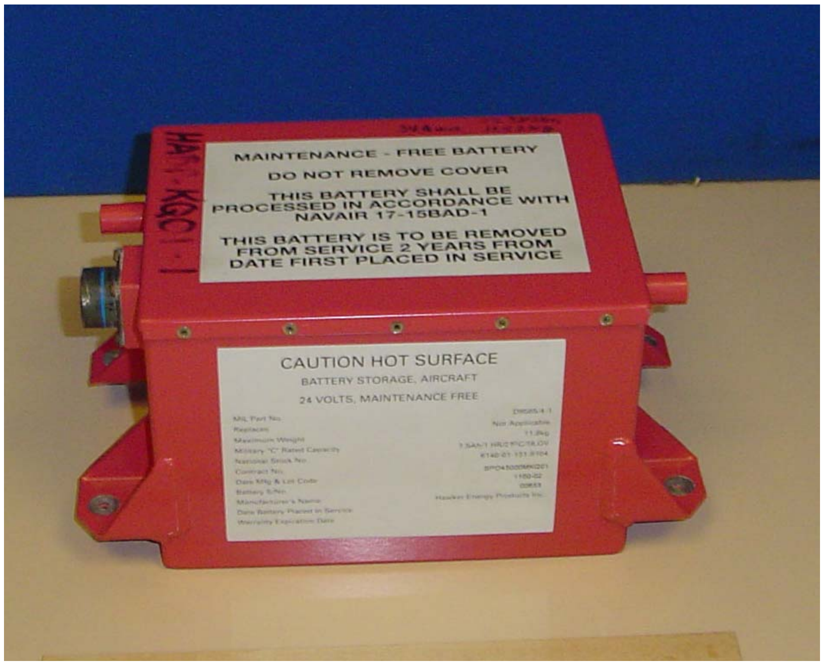
- Intelligent Battery Charger
  - Eagle Picher
    - Automated charger setup by part number
    - Return sulfated batteries to RFI
  - GEM Power
    - Working to develop “universal” intelligent battery charger
    - Charger will determine battery chemistry (i.e., Lead-acid, Ni-Cd, Li-ion), state of charge and select correct charging algorithm
    - Unit to include battery diagnostics/prognostics capability
- STTR
  - Topic N07-T002 – “Aircraft Battery Diagnostic and Prognostic System”
  - Entered Phase II with contract award to GEM Power in November 2008
  - Goal is to develop passive battery diagnostic and prognostic capability to be incorporated into the aircraft health management system

Technology Development (cont)

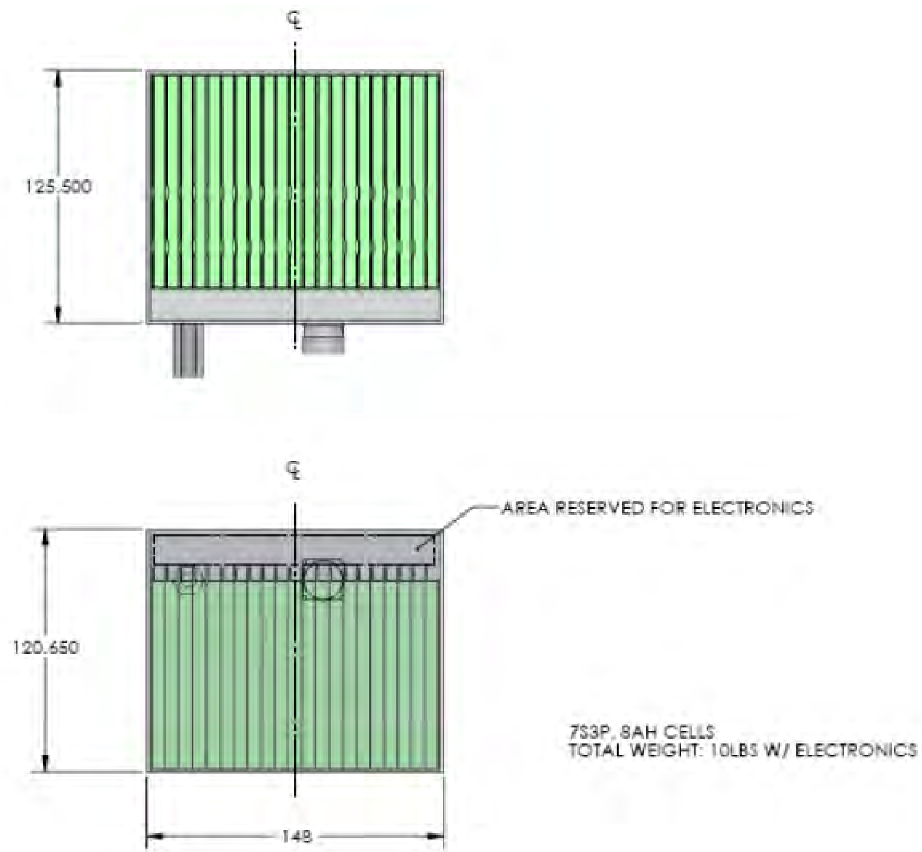
NAVAIR

- Battery Developments
  - Lithium Polymer – Kokam America
    - F/A-18C/D (present battery 24 Volt, 7.5 Ah, 332 in cu., 26 lbs)
      - 24 Volts
      - 25 Ah
      - 332 in. cu., 13 lbs
      - 3 string of 7 cells
    - AH-1W (present battery is 24 Volt, 35 Ah 1026 in. cu., 85 lbs)
      - 24 Volts
      - 50-60 Ah
      - 1026 cu. In., 55 lbs
      - 2 strings of 7 cells
  - Lithium-ion – SAFT
    - N-UCAS
      - 24 Volts
      - 55 Ah
      - GlobalHawk design - 14 cylindrical cells – 2 strings of 7 cells (1115 cu. in., 49 lbs)
      - N-UCAS design – 7 prismatic cells in series
      - 662 cu. In., 43 lbs

F/A-18 Battery



Present D8565/4-1 SLAB



Kokam Proposed Lithium Polymer Design

Test	Sample	1	2	3	4
1. Dimensions	All	The batteries mounting holes were not in complains. See note 1.			
2. Strength of Vent Tubes	All	OK	OK	OK	OK
3. Color & Marking	All	No marking labels were on the batteries. See note 2.			
4. Weight	All	16.65 lbs	15.85 lbs	15.7 lbs	lbs
5. Initial Capacity Discharge	All	0:53:51 22.45ah	1:09:25 28.94 Ah	1:07:45 28.30 Ah	1:08:16 28.45 Ah
6. Capacity Discharge	All	1:09:07 28.82ah	1:09:23 28.92 Ah	1:04:40 26.96 Ah	1:08:09 28.40 Ah
7. Emergency Loads @ Ambient	2	N/A	1:10:44 28.58ah	N/A	N/A
8. Emergency Loads @ -20°F	2	N/A	1:05:56 26.36ah	N/A	N/A
9. Emergency Loads @ 0°F	3	N/A	N/A	1:07:26 26.96ah	N/A
10. Emergency Loads @ 23°F	2	N/A	1:08:00 27.19Ah	N/A	N/A
11. Emergency Loads @ 131°F	1	1:11:24 29.44Ah	N/A	N/A	N/A
12. Start-up Loads @ 131°F	3	N/A	N/A	3/9/2009	N/A
13. Start-up Loads @ -20°F	2	N/A	3/11/2009	N/A	N/A
14. Start-up Loads @ Ambient	2	N/A	1.08Ah	N/A	N/A
15. Half-Hour Charge @ 0°F	2	N/A	3/13/2009	N/A	N/A
16. Half-Hour Charge @ 59°F	3	N/A	N/A	1:04:42 26.97Ah	N/A
17. Half-Hour Charge @ 131°F	2	N/A	3/16/2009	N/A	N/A
18. Hour Charge @ -40°F	2	N/A	1:03:56 26.65Ah	N/A	N/A
19. Life Cycling *(600 cycles)*	4	N/A	N/A	N/A	in progress
20. Hour Discharge @ 120°F	2	N/A	3/18/2009	N/A	N/A
21. Discharge while Inverted *(62.5 amps for 5 min)*	2	N/A	5.2Ah	N/A	N/A
22. Altitude *(60,000 ft)*	3	N/A	N/A	3/3/2009	N/A
23. Mechanical Shock	3	N/A	N/A		N/A
24. Temperature Shock *(160°F, -70°F)*	2	see note 2.	N/A	N/A	N/A
25. Temperature Rise & Float	2	N/A	OK 1:13:55 30.83Ah	N/A	N/A
26. Vibration *(62.5 amps for 3 min)*	2	N/A	OK 3.12Ah	N/A	N/A
27. Humidity *(10 days)*	3	N/A	N/A	see note 2.	N/A
28. Salt Fog *(2 days)*	3	N/A	N/A	OK 25.15V	N/A
29. Ground Storage @ 122°F *(30 days)*	3	N/A	N/A		N/A
30. Shelf Life *(18 months)*	4	N/A	N/A	N/A	
31. Deep Discharge Recovery *(122°F for 7 days)*	2	N/A	see note 5.	N/A	N/A
32. Physical Integrity @ 185°F	1	1:01:22 25.59Ah	N/A	N/A	N/A
33. Final Examination	All				

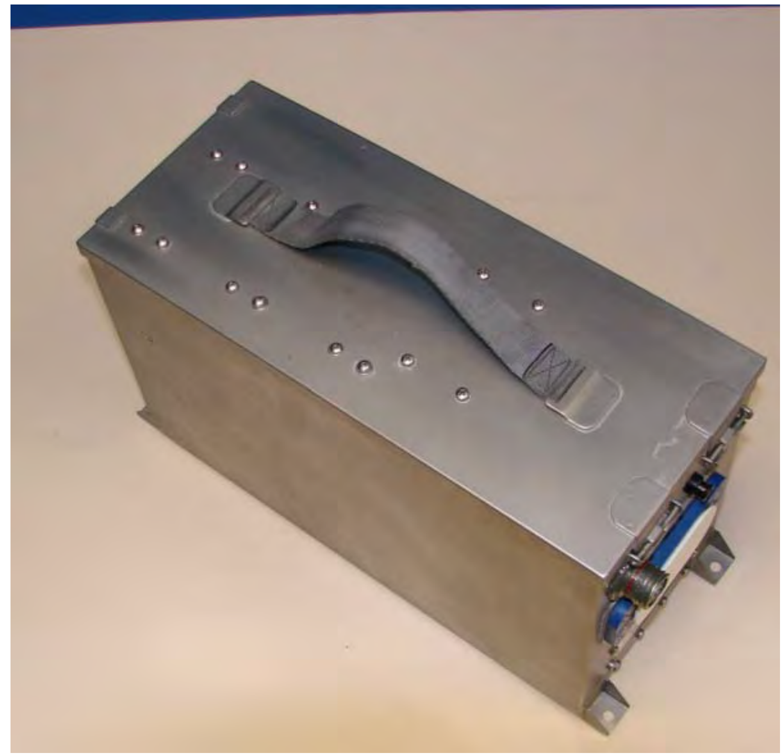
AH-1W Lithium Battery

NAVAIR

External and Internal Views of AH-1W Lithium Polymer Batteries for the AH-1W by Kokam

GlobalHawk & N-UCAS Battery

GlobalHawk Battery



N-UCAS Battery

Cost of Ownership

- Present Battery Cost
  - Valve Regulated Lead Acid
    - Cost from $800 (F/A-18) to $2500
    - Service Life of 2-3 Years
    - No scheduled maintenance
  - Low Maintenance Nickel-Cadmium
    - Cost from $1200 to $7600 (AH-1W)
    - Five year service life
    - One year maintenance cycle

Cost of Ownership (cont)

- Lithium Batteries
  - Present Lithium Aircraft Batteries
    - B-2 - $57K
    - JSF – Projected cost $100-150K (270V & 28V)
  - Projected Navy Lithium Battery Cost
    - Kokam America
      - AH-1W - $7600
      - F/A-18 - $2500
    - SAFT
      - N-UCAS Flight Certification Units - $25K

Technology Development to Address Cost Issues

- SBIR Topic N08-017 Thermally Stable Lithium Batteries
  - Increased temperature operating range
    - To 71º C Operating
    - To 85º C Exposure
  - Resulting in:
    - Increased service life
    - Increased storage life (Logistics)
    - Improved safety
  - Phase I Option awarded in April '09 to Yardney Technical Products
- STTR Topic N07-T002 Aircraft Battery Diagnostic and Prognostic System
  - Phase II awarded Nov. 2008
  - Diagnostics and prognostics
    - Goal to incorporate hardware/software into aircraft
      - Maintenance Computer
  - Benefit
    - Improved safety
    - Removal at end of service life (instead of arbitrarily scheduled service life)

Technology Development to Address Cost Issues (cont)

- **STTR Topic N04-029 - Prognostic Health Management of Primary 28V & Secondary 270V JSH Lithium (Li)-ion batteries**
  - Phase II awarded October 2008 to Global Technology Connection
  - Goal is to develop Prognostic Health Management (PHM) for both Lithium batteries used on the JSF
  - Technical approach is to develop battery life models for each battery

Technology Development to Address Cost Issues (cont)

- Battery Developments
  - Kokam America
    - Nano-technology for Lithium Polymer
      - Quick recharge
      - Reduced need for certain electronics
      - Improved power capability
      - Extend shelf and service life
      - Improved safety
  - SAFT America
    - N-UCAS Development
      - Improved operational temperature range
      - Lower Self-discharge
        - Longer shelf life
      - Improved electronics
      - Stacked prismatic design

Planned Demonstrations

- AH-1W Lithium Polymer Battery (Kokam America)
  - FY09 – Qualification Testing at NSWC Crane
  - FY10 – Safety Testing at NSWC Crane
  - Late FY10 – Flight Testing at NAS Pax River
- F/A-18 Lithium Polymer Battery (Kokam America)
  - FY09 – Qualification Testing at NSWC Crane
  - FY10 – Safety Testing at NSWC Crane
  - Late FY10 – Flight Testing at NAS Pax River
- STTR Topic N07-T002 Aircraft Battery Diagnostic and Prognostic System
  - Phase II – Demonstration/Evaluation of prototype unit
    - Prototype box for evaluation – Late FY09
    - Testing at Boeing's FIRST Lab – Early FY10
  - Phase III – Integration of system into aircraft (Onboard) – Late FY10

Standardization Opportunities To Address Cost

Battery	System	Width (in)	Depth (in)	Height (in)	Capacity (Ah)
D8565/17-1	SLAB	4.5	5.3	2.5	1/3
8565/1-2	SLAB	3.9	8.5	3.7	1.5
8565/6-1	SLAB	6.8	6.3	3.3	1.5
81757/14-1	Ni-Cad	4.5	11.2	4.7	5.5
8565/4-1	SLAB	6.7	11.5	5.7	7.5
8565/11-1	SLAB	9.8	8.4	7.8	10
8565/18-1	SLAB	12.1	5.7	5.5	10
8565/14-1	SLAB	7.1	13.9	6.6	15
8565/9-1	SLAB	10.0	10.7	8.9	24
8565/7-2	SLAB	11.6	11.7	9.1	24
81757/15-1 81757/15-3	Ni-Cad	10.0 10.0	10.7 10.7	8.9 8.9	25 25
8565/5-1 8565/5-2	SLAB	12.2	11.8	10.4	30
81757/16-1	Ni-Cad	11.9	10.5	10.4	35
D8565/15-1	SLAB	10.0	10.7	8.9	35
8565/10-1	Ni-Cad	9.7	13.8	7.6	35
81757/18-1	Ni-Cad	6.5	11.0	10.3	55
29595/TBD	Li-ion	7.7	9.9	8.8	55

Lithium Battery 1 (D8565/17-1 through 81757/14-1)

Lithium Battery 2 (8565/4-1 through 8565/9-1)
Kokam Battery Development 1

Lithium Battery 3 (8565/9-1 through 8565/10-1)

Lithium Battery 4 – High Rate
Kokam Battery Development 2

Li Battery 5
SAFT NUCAS

New Opportunities for Safety

NAVAIR

- NAVAIR 4.4.5 has submitted 2 new SBIR topics that are undergoing review for pre-release for solicitations in 27 July 2009
  - Non-Flammable Electrolyte for Lithium-ion batteries
  - Fire Suppression Systems for Lithium-ion Batteries

* www.acq.osd.mil/sadbu/sbir/solicitations

Questions?




SFC's Direct Methanol Fuel Cells: Lightweight, Portable Power for Soldiers in the Field

SFC
SMART FUEL CELL

Christian Boehm
Director Defense Division

Joint Service Power Expo 2009

Agenda

I. **SFC – The Company**

II. Fuel Cell Technology

III. Man Portable Power Solution

IV. Other Application

Smart Fuel Cell AG & Inc.

Company facts

- Founded in 2000
- Sole company with commercial DMFC products
- Location: Munich, Germany
  Atlanta, GA, USA
- 105 employees
- ISO 9001:2000 certified
- Listed company since 2007

Products

- DMFC fuel cell systems
- Power Manager
- Methanol cartridges

SFC Markets & Products

Core Markets

Leisure - Comfortonomy

Remote Industrial - Dependability

Defense - Weight Saving

Products

EFOY

Fuel cartridges

EFOY Pro

Fuel cartridges

FC-250

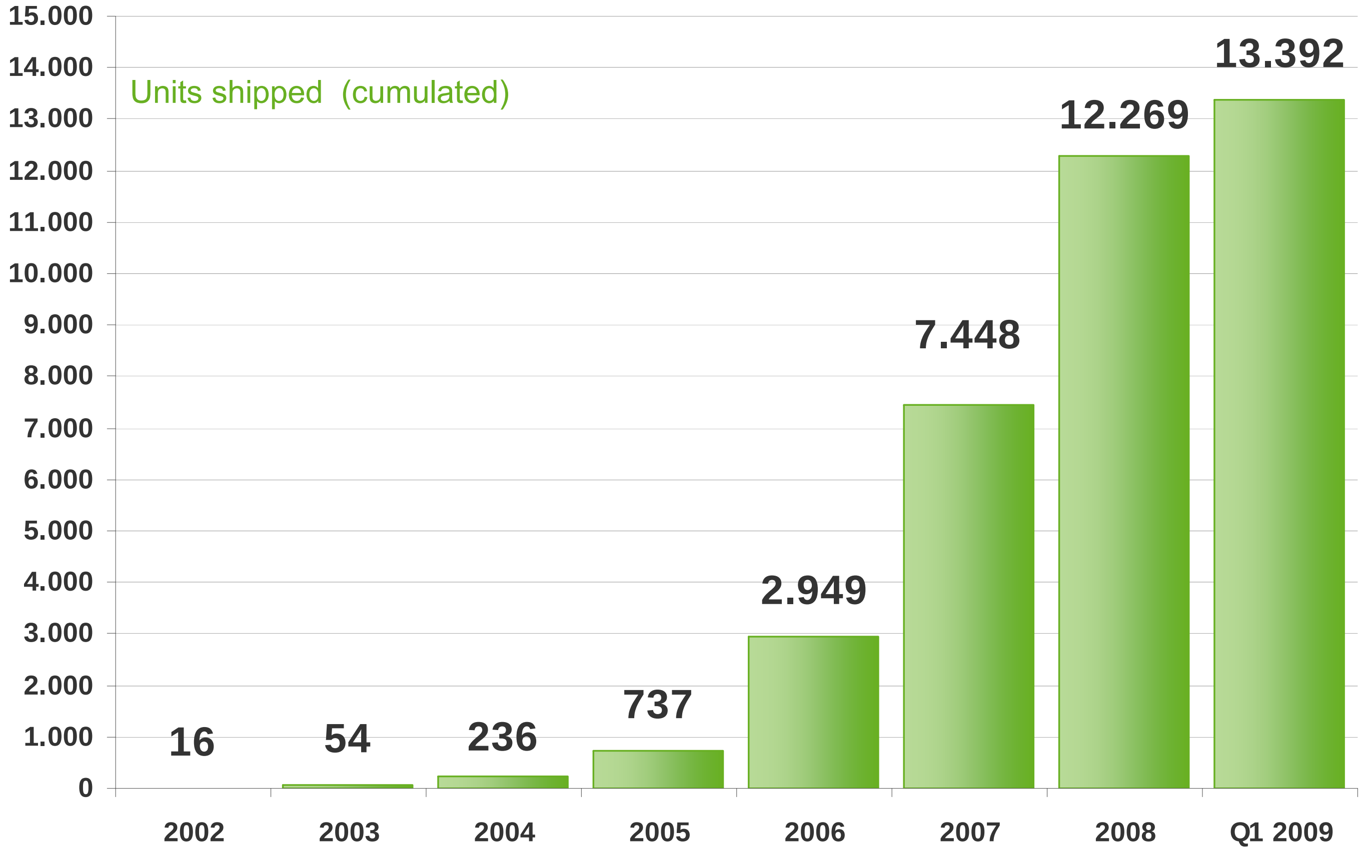
Emily

Jenny

Power Manager

Substantial Market Traction

- over 13,000 shipped fuel cells
- over 100,000 shipped fuel cartridges
- 5 million operating hours in user hands



References Defense

BMVg / BWB

Portable DMFC-Solution

Vehicle backup power

PEO Soldier

US-Army Defense Acquisition and Challenge Program

FFW

Future Force Warrior

ATEC

US-Army Test and Evaluation Command

AFRL

Battery renewable integrated tactical energy system (BRITES)

AFSOC

Power Managers & Jenny for Air Force Special Operations Command

NATO-members:

Finland, Netherlands, Norway, South Africa, Sweden, Switzerland, UK

NIAG Study for vehicle APU

Agenda

SFC SMART FUEL CELL

I. SFC – The Company

II. **Fuel Cell Technology**

III. Man Portable Solution

IV. Other Applications

The Fuel Cell Technology

Conventional generator

Liquid Fuel → 1 → Thermal energy → 2 → Mechanic energy → 3 → Electric energy

Direct-methanol fuel cell (DMFC)

Liquid fuel → One step – direct conversion → Electric energy

- High efficiency
- Low temperature
- Very low emissions
- No wear out

Storage of 10 kWh of Energy

	Methanol	Hydrogen	Lithium Batteries	Lead acid batteries
				
weight:	8 kg	85 kg	110 kg	270 kg
volume:	10 l	60 l	120 l	

Methanol combines superior energy density with easy handling, shipping and low cost.

Agenda

I. SFC – The Company

II. Fuel Cell Technology

III. **Man Portable Solution**

IV. Other Applications

SFC Man Portable Fuel Cell Solution

Challenges:

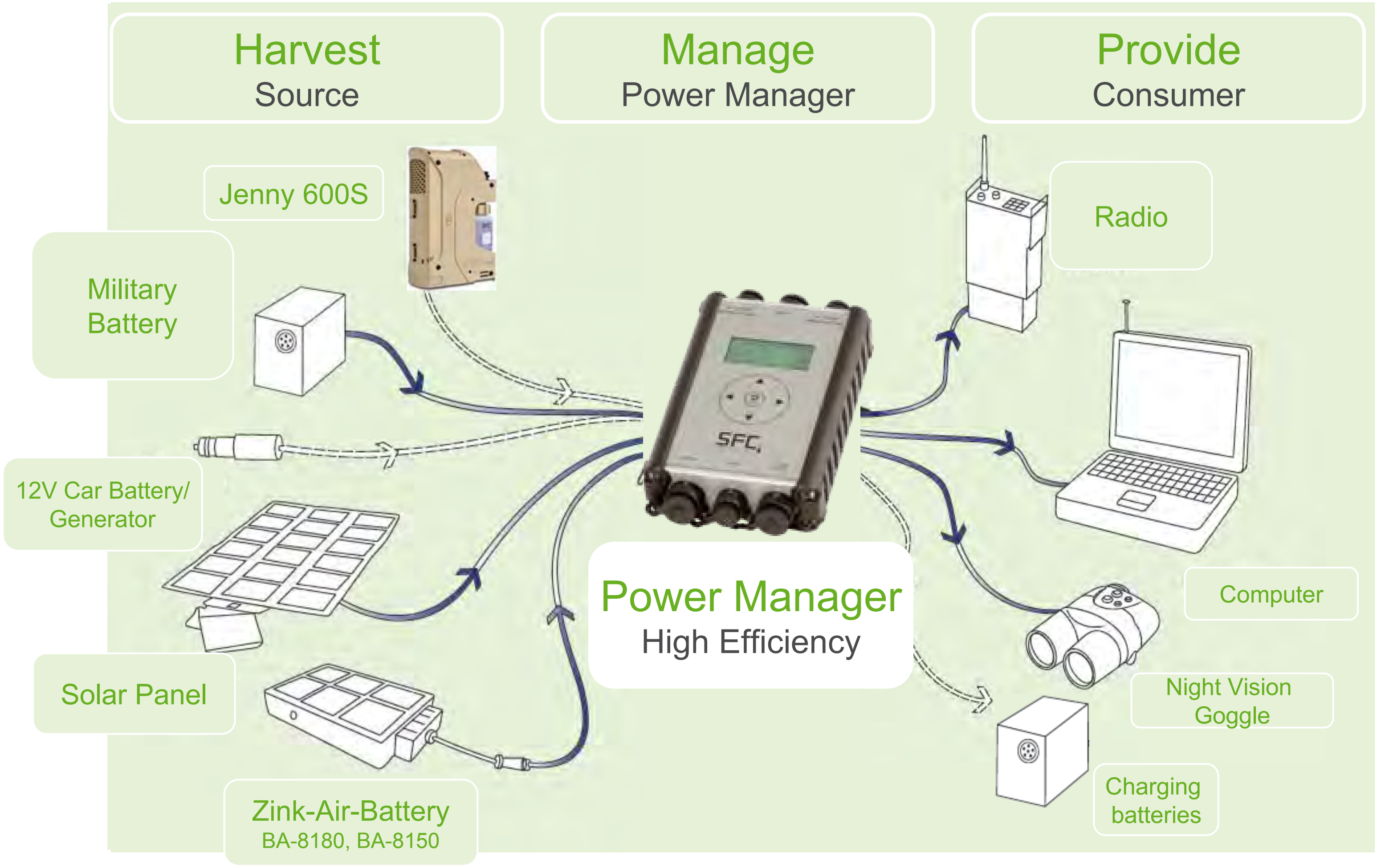
- The longer the mission the heavier the soldier's weight
- Limited mission capability due to increased weight
- Far away from any logistic institution
- No resupply during the mission duration

SFC Solution for remote / dismounted power supply

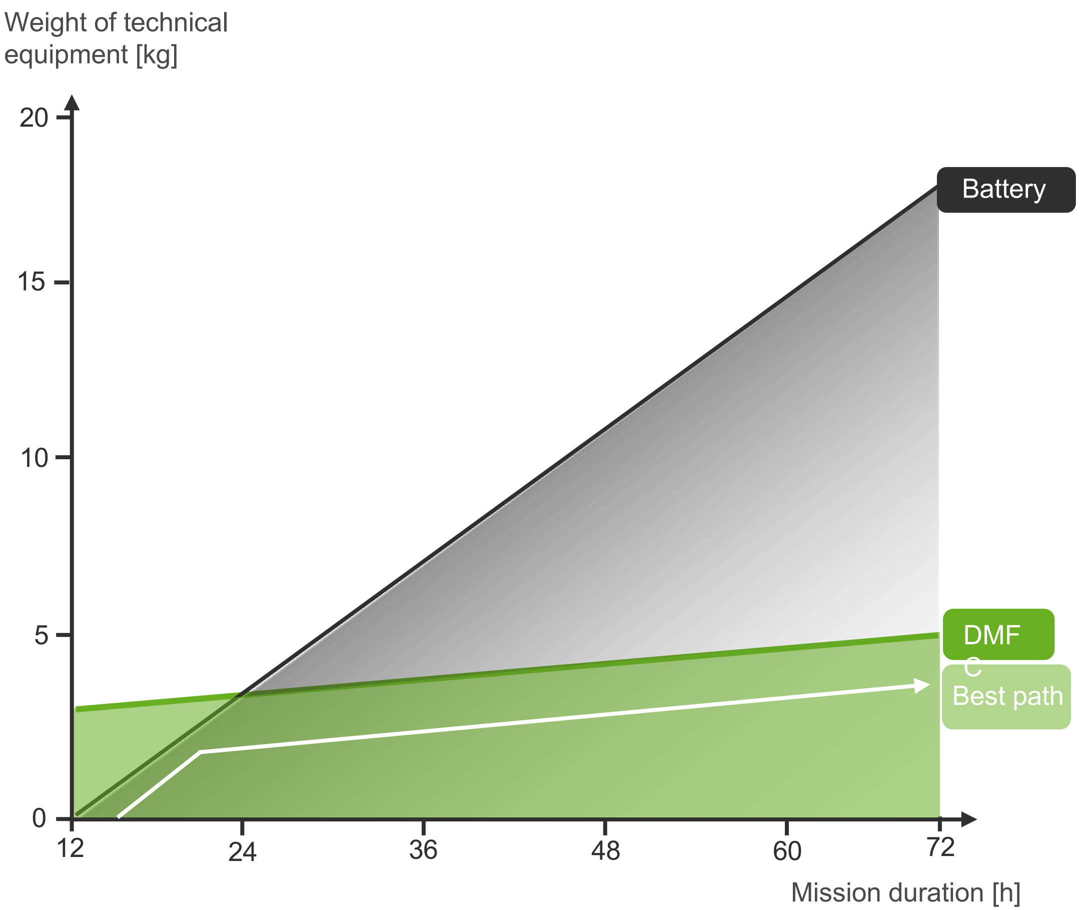
- Power Manager
- Jenny 600S

over 1,000 fielded

Portable Power Architecture



SFC Man Portable Power



SFC Fuel Cell System

and hybrid battery

up to 80%*

weight reduction

on a 72+ hrs Mission

*compared with conventional rechargeable battery packs

Advantages:

•more power, less weight

•elimination of spare batteries

Winner of the wearable Power Prize Competition

1st Place!!

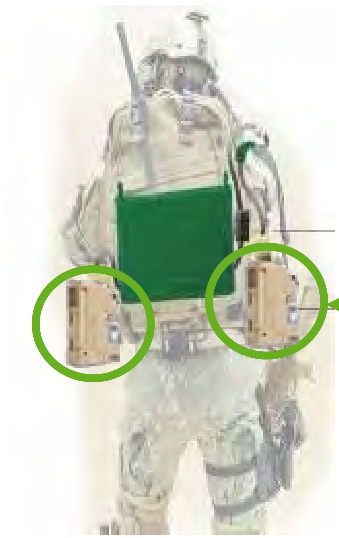
M-25

3rd Place!!

Jenny 600 S

SFC Smart Fuel Cell AG 16

AFSOC: JENNY 600S and Power Manager Solution



- 16 hours operation with 0.7 litre methanol at 50 watts
- over 50% weight reduction in a 72 hours mission compared to BA 5590 batteries
- Harvesting power from all different power sources

US Air Force Ground Airman Example

	weight	energy	volume
Baseline	35.5 lbs	2500 W·hr	11 L
Spiral 1	26.9 lbs	2620 W·hr	9.5 L
	24% Reduction		14% Reduction
Spiral 2	~17-18 lbs	≥2500 W·hr	6.4 L
	50% Reduction		33% Reduction

SFC solution

Power supply for German Mountain Infantry

Automatic battery charging

Fuel cell attached to the IdZ system

- 16 hours operation with 0.35 liter methanol at 25 watts
- Automated, stand alone battery charging

Mission advantages

- Power Source for portable, mobile and stationary reconnaissance systems
- Endless power for night vision devises
- Reliable power for targeting systems
- Power radio communication
- Higher Mobility due to reduced weight
- No battery resupply/ recharging in the field

Agenda

I. SFC – The Company

II. Fuel Cell Technology

III. Man Portable Solution

IV. **Other Applications**

ATEC uses SFC Fuel Cells for Test Instrumentation

100 hours operation

@ 250 Watts

with 28 liters fuel

- Reduced costs: replace one cartridge in every 4 days, no disposal fees
- Reduced weight: (24 kg) 53 lb fuel replaces (581) 1280 lb battery
- Invisible testing: Stand alone, automatic and quiet operation

Mobility

- Efficient power on board vehicles
- Fuel saving
- Independent of fossil fuels
- Undetectable / silent watch
- No connection to the engine power necessary
- Easy to install

Special Purpose Vehicles

- Reliable energy for all devices on board / mobile office
- Fully automatic recharge, maintenance free, easy integration
- No data loss due to empty batteries, no extra depot tours for recharges
- Unlimited mission times
- Inconspicuous, no emissions, no noise

Remote sensors, cameras, etc.

Unattended operation for weeks

Hybridized with solar power and rechargeable battery

Remote control available

Visit our Booth 210!

SMART FUEL CELL

Christian Boehm
Director Defense Division

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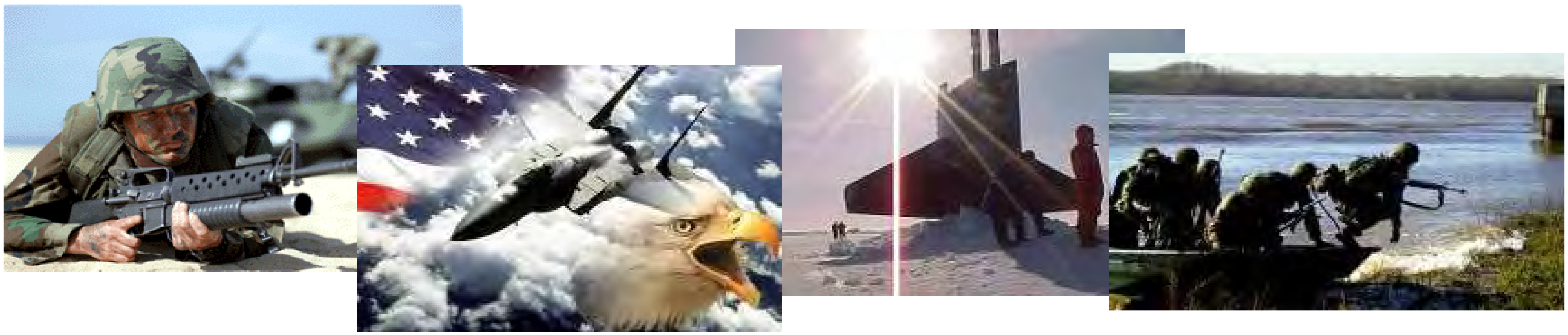


DLA's H_2 Demonstration Project at Defense Depot Susquehanna, PA
- *Lessons Learned* -

May 5, 2009

Ken Burt – NSWC-Crane
Bob Skinnell – DDSP

DLA's Hydrogen and Fuel Cell Program: MHE Pilots

DLA Goals:

- Be an ***<u>early adopter</u>*** and ***<u>principal demonstrator</u>***
- Foster competition in the marketplace and provide a market demand
- Support improved Technology and Manufacturing Readiness Levels
  - Exercise the supply chain
  - Test under real world conditions
  - Provide feedback to manufacturers
- Highlight the business case for fuel cells

Improve fuel cell readiness by funding R&D efforts in areas that are near commercialization

DLA's Hydrogen and Fuel Cell Program

4 Fuel cell forklift demonstration projects

Approach:

- Pilot multiple H_2 generation, dispensing and fuel cell technologies to power Material Handling Equipment (MHE) in warehouse operations
- Analyze operational data to establish an operational business case

Collaborators:

3 Leading Fuel Cell Mfg, 2 Leading Hydrogen Mfg, DLA/DOE/NSWC Crane/NREL with multiple Prime Contractors

Funding (Congressional):

FY07: $10M FY08: $13M FY09: $8M (Projected)

Locations:

DDSP: 40 forklifts, delivered (cryogenic) H_2, indoor dispensing
DDWG: 20 forklifts, onsite natural gas reformation for H_2, mobile refueling
DDJC: 20 forklifts, electrolysis for H_2, Power Purchase Agreement (Solar)
Ft. Lewis: 19 forklifts, 1 bus, wastewater digester gas H_2, mobile refueling

Duration: 2 years each

Business case analysis based on performance and cost data collect by NREL

Lessons Learned: Project Development

- **Work closely with host activities to identify, define & understand project goals/objectives**
  - Identify realistic technology/manufacturing goals/targets/expectations
  - Define program deliverable requirements
  - Generate MOA with participants to establish and document responsibilities
- **Allow program objectives to the drive procurement strategy**
  - BAA/PCA/RFI/RFP
- **Track and implement improvements made along the way in future development**
- **Identify technical team as early as possible for the selection process**

Lessons Learned: Contracting Phase

- Clearly identify all requirements/objectives/selection criteria within solicitation material
- Allow ample time for proposal submittal
  - 45-60 days minimum recommended
- Provide site visits and open Q&A opportunities
  - One or more site visits
- Review and award contracts to solicitation requirements
  - Provide step by step review instructions

Be patient: the contract award process takes time!

Lessons Learned: Permitting & Site Approval Process

- Again, Be Patient
  - Lack of detailed codes/regulations slows approval process for state/Federal/site permitting
- Share Lessons Learned
  - Share permitting process with DOD activities considering hydrogen pilot programs
  - Share permitting process with commercial sector generating codes and standards


Yale

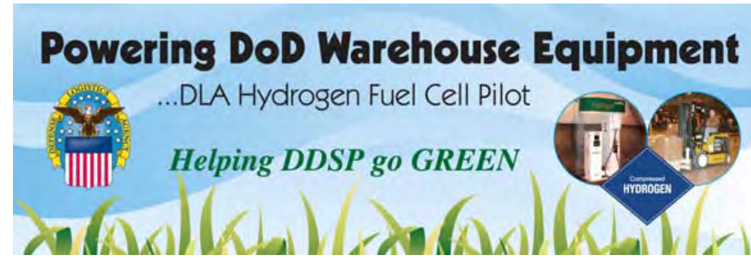
Hydrogen Power at DDSP

- DDSP's Operations:
  - New Cumberland, PA
  - Move 770,542 NSNs worth $9.0B
  - H_2 operations in 1.7 mil sq ft. warehouse
  - 1200 various types of MHE

- Anticipated advantages of fuel cell powered operations:
  - Longer operations at full power (constant voltage)
  - Time savings on battery management vs. fueling
  - Reduced hazmat handling concerns

Hydrogen Power at DDSP

- ***Ribbon Cutting – February 10th, 2009***
- Features:
  - 40 fuel cell MHE integrated in fleet
  - Dual indoor dispensing system
  - Outdoor storage and compression for delivered liquid H_2
- Funding: $5.3M
- Performers:
  - Air Products - infrastructure and integration
  - Plug Power (20 new units)
  - East Penn/Nuvera (20 retrofit units)



First two months:
1474 kg
2205 Transactions

One of the largest uses of H_2 for fuel cells in the US!

Lessons Learned: Develop Buy-In

- Socialize early
  - Bring the right people to listen <u>and</u> talk
    - Share experiences with follow-on sites
  - Involve all the right parties early
    - Command
    - Union representation
    - Users
    - Fire Department – work closely, get them involved, educate them especially when H_2 is new
    - Physical security
    - Public affairs/legal

Lessons Learned: Develop Buy-In

Socialize safety – Instill confidence!

- Dispel "Hindenburg" misperceptions
- Hand out brochures
  - Highlight benefits but recognize safety concerns
- Hold regular meetings to keep people in the loop as implementation progresses
- Focus on system safety features
- Provide awareness training for all employees
- Heavily promote response procedures

Lessons Learned: Site Prep

- Permitting
  - –Introduce contractor and safety/environmental staff early
  - –Environmental impact reviews were easy because contractor was experienced

- Coordinate and test alarm system operations (early!)
- Set fuel cell factory settings (voltage limits) to match user requirements
- For retrofits, carefully select equipment and uses
  - Some vehicles are harder than others to retrofit

Lessons Learned: Operations Support

- Working with contractors
  - Response time on repairs has to be fast
  - One single point of contact to maintain control (particularly important working with gov't and multiple contractors)
  - Use local contractors when possible
  - No accidents is key to maintaining confidence

Lessons Learned: Training

- Training
  - Content specific to those being trained
  - Training needs to fit group size
    - Break into small groups when hands on is needed
  - Complicated by having more than 1 fuel cell type

- Physical aspects of fuel cells
  - Getting used to refueling
  - Running out of fuel because users are used to battery slowing down

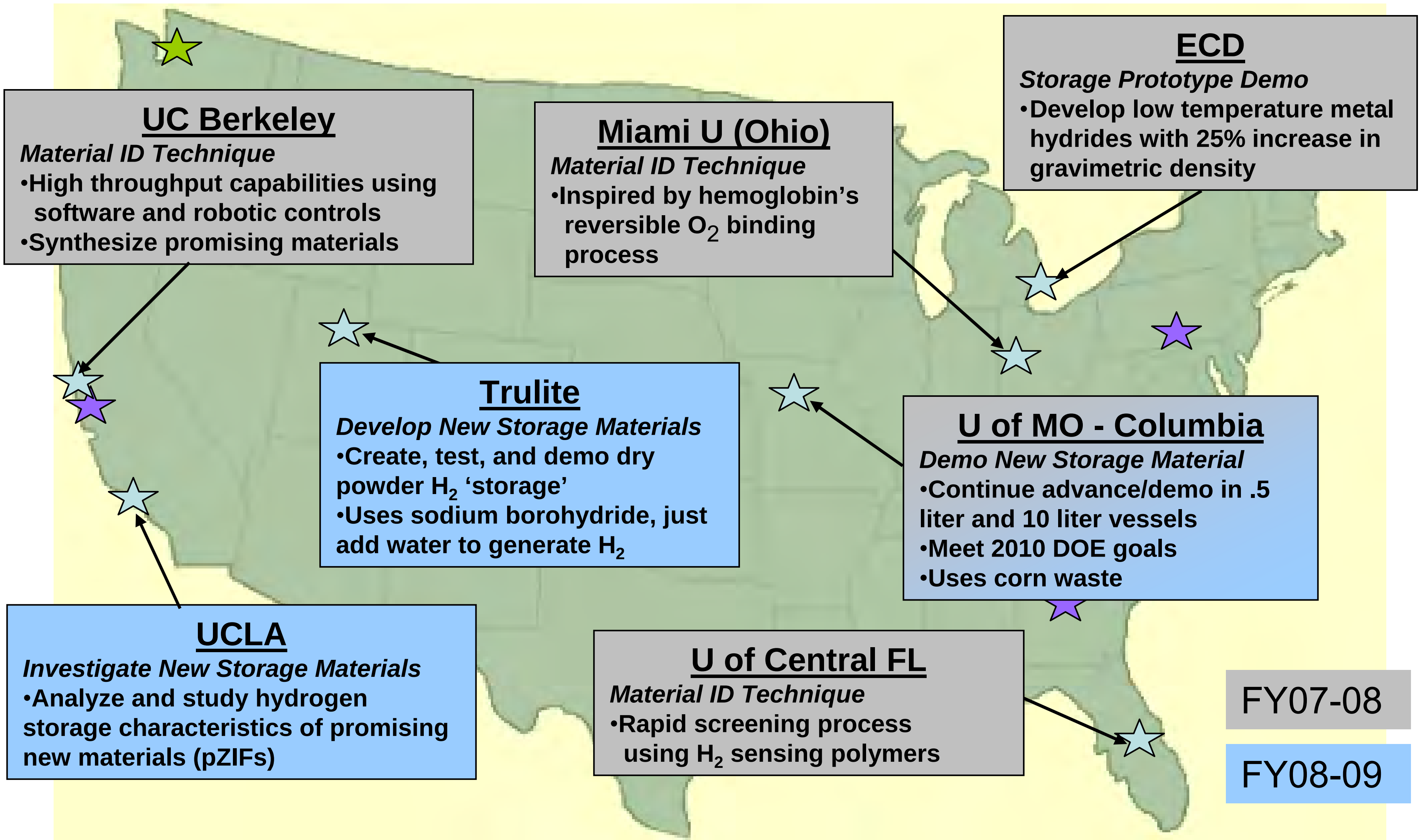
Lessons Learned: Operations

- Infrastructure
  - Limited early startup
    - Break in equipment and the people
  - Two dispensers; mobile refueler as backup
    - Indispensible! Critical for startup because break-in ran in to more issues than anticipated; must maintain productivity and buy-in
  - Recommend getting infrastructure up as soon as possible – lots of unanticipated bugs
  - Indoor dispensing is key (buy-in, utilization)

DEFENSE LOGISTICS AGENCY

NAVSEA WARFARE CENTERS CRANE

Other DLA Initiatives: Solid H_2 Storage R&D



Hydrogen and Fuel Cell Program: Future Planning

Spiral Development

- H_2 fuel cell stock selectors at DDWG
- Expand the technical requirements and/or capacity of ongoing DLA demonstration projects
- Focus on improving value proposition and 'green' hydrogen production

Solid Hydrogen Storage

- Continue teaming with DOE and other military Services for early stage R&D

Extended Range Utility Vehicle

- Phase I: Design novel H_2 storage to extend range of fuel cell utility
- Phase II: Construct and integrate the technology at DDWG

Low cost/green H_2 production, storage, and delivery

Contact Information

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RDECOM

CERDEC
US ARMY – RDECOM

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

CERDEC Fuel Cell Team: Soldier and Man Portable Fuel Cell Evaluation and Field Testing

2009 Joint Services Power Expo – New Orleans, LA – 5 May, 2009

Mike Dominick, Elizabeth Ferry, JJ Kowal, Marnie de Jong, Jon Novoa

Who We Are

- DoD — Department of Defense
  - DA — Department of the Army
    - AMC — Army Materiel Command
      - RDECOM — Research, Development, and Engineering Command
        - CERDEC — Communications-Electronics, Research, Development and Engineering Center
          - C2D — Command and Control Directorate
            - Army Power Division
              - Power Sources Branch
                - Fuel Cell Development Team

Outline

- Army Power and CERDEC Fuel Cell Team Missions
- Sensor and Soldier Power
    - Potential Benefits
    - Recent Testing results (Akermin, AMI, Ultracell, Samsung)
- Man Portable Power
    - Potential Benefits
    - Recent Testing Results (Protonex, Idatech)
- Recent Exercises and Demos
    - Wearable Power Challenge, 2008
    - Medical Readiness Training Exercise, 2008
    - Cobra Gold, 2009
    - Rapid Fielding Initiative, Current

Mission: **Conduct research, development, and system engineering leading to the most cost-effective power, energy, and environmental technologies to support Army's soldier, portable, and mobile applications.**

ATOs

ATO R.LG.2009.01

Mobile Power

Transitional Hybrid Power Source, Log-fueled
Waste Heat Recovery
Power Centric Mobility applications

ATO D.CER.2008.08

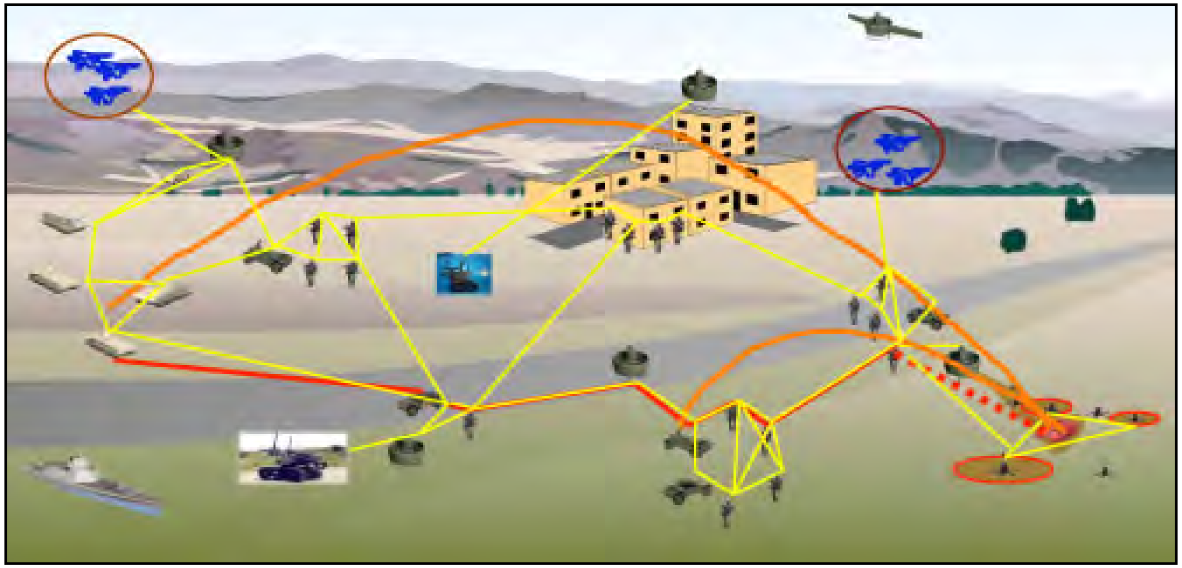
Power for Dismounted Soldier

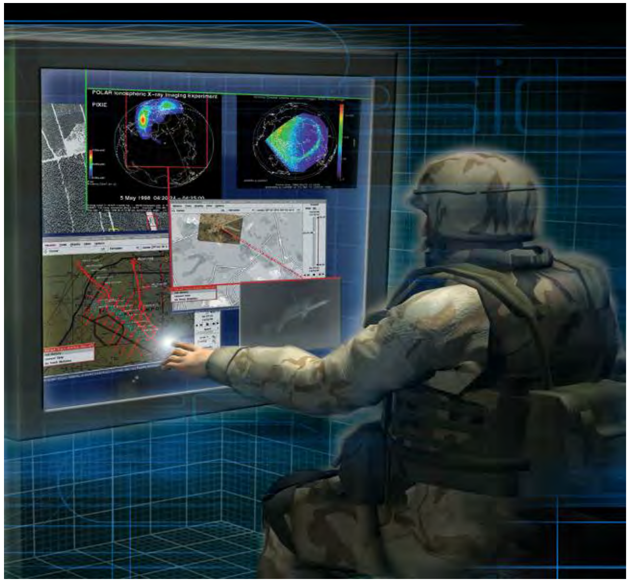
Half-Sized BA5590 Li/CFx Battery
Half-Sized BA5590 Li-Air Battery
Soldier Conformal Rechargeable Battery
Soldier Hybrid Methanol Fuel Cell Power Source
Soldier Hybrid Fuel Cell Power Source
Portable Hybrid Power Sources & Chargers, JP-8 fueled

Mission: Rapidly develop and transition suitable fuel cell technologies to applications where they are most needed.

Fuel Cells for Sensors and Soldier Power

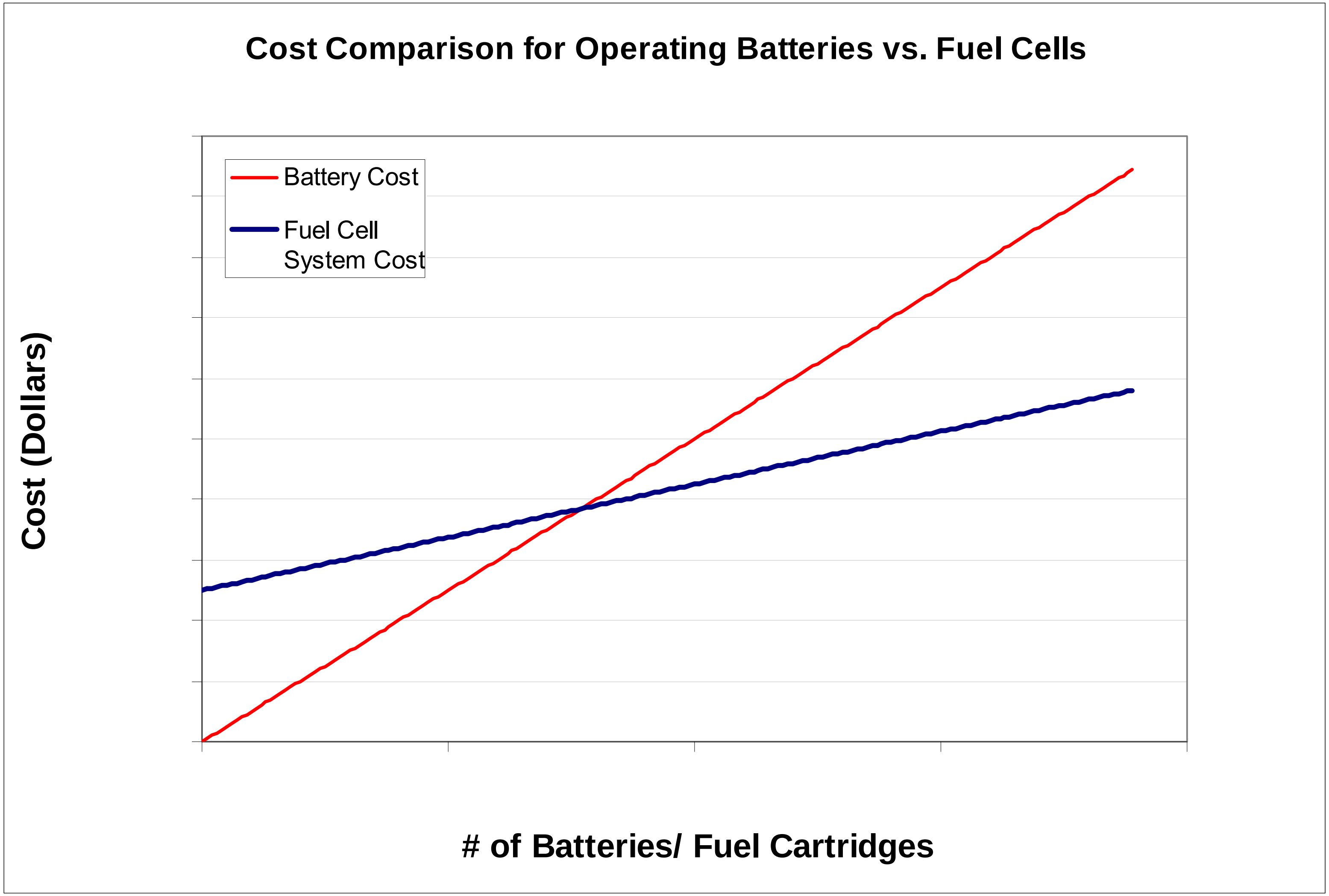
Potential Benefit – Sensor and Soldier Power



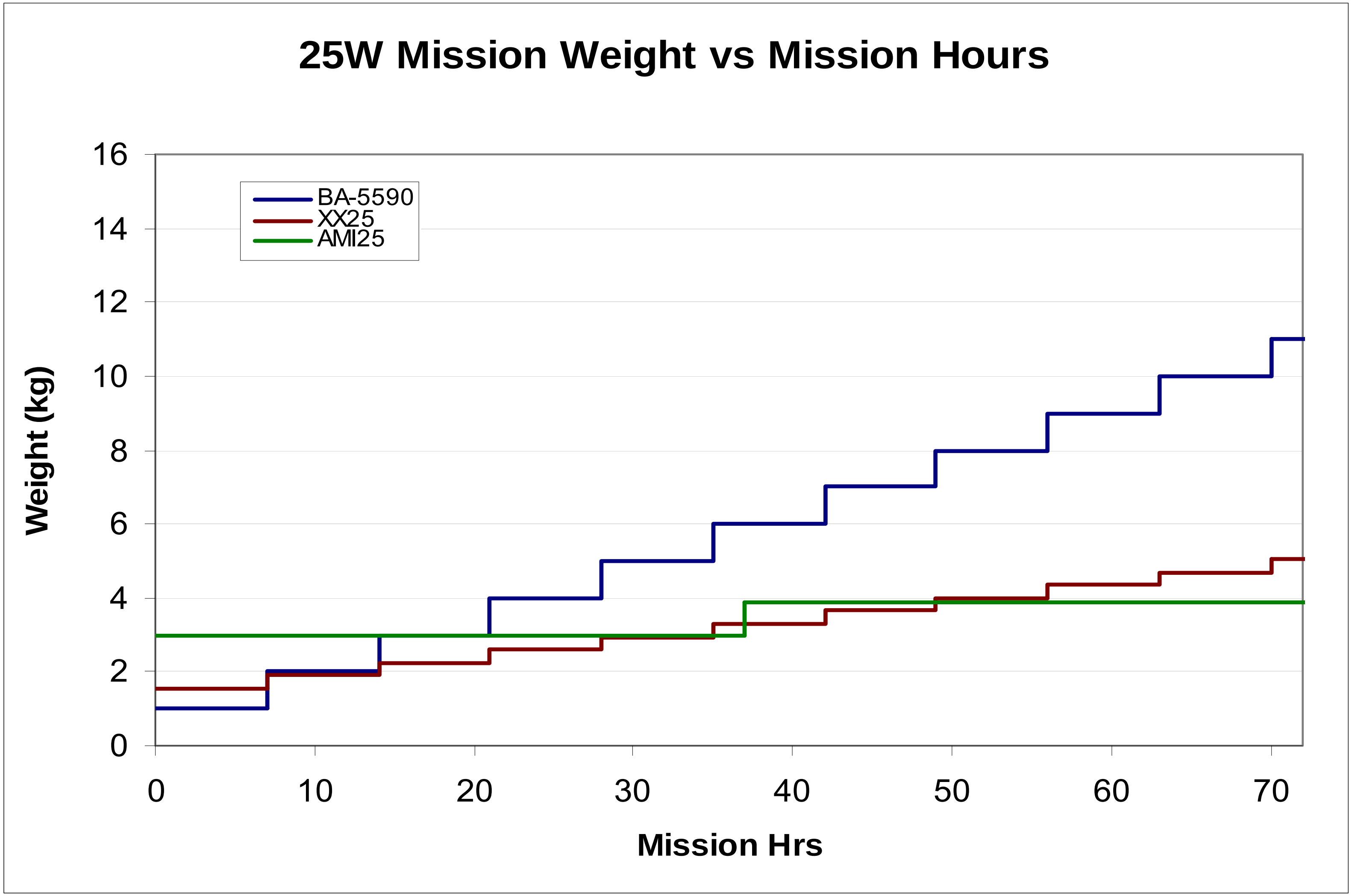


- Longer runtimes than current batteries for comparable form factors
- Logistic advantages related to handling and lifecycle costs
- Cheaper than current batteries for comparable power needs

Potential Benefit – Sensor and Soldier Power



Potential Benefit – Soldier Power



Current Programs and Recent Lab Test Results

Sensor and Soldier Power (100 mW – 55 W)

Fuel Technology	Current Efforts
Direct Methanol	SFC Smart Fuel Cell; SAMSUNG; PolyFuel
Reformed Methanol	UltraCell™ High Power Micro Fuel Cells
Chemical Hydrides	General Atomics; jadoo Power
Propane	AMI Adaptive Materials Inc.
Bio Fuel	AKERMIN

Akermin 100mW

In Development with CERDEC

Rated 100 mW continuous
Direct Methanol Fuel Cell (DMFC)
Fuel: Methanol/ Potassium Hydroxide Mix

Dimensions:	**3.63" x 2.5" x 1.5"**
Start Up Time:	**Instant (hybridized)**

System Dry Weight:	**160 g**
Fuel Weight:	**28 g (25 mL)**

100mW Mission Energy Density:
Testing In Progress

Unattended Ground Sensor

AMI 25W Alpha

In Development with CERDEC and DARPA

Rated 25W continuous
Solid Oxide Fuel Cell (SOFC)
Fuel: Commercial Propane Canisters

Dimensions:	**9.75” x 3.625” x 4.75”**
Start Up Time:	**9 min.**

System Dry Weight:	**2.1 kg**
Fuel Cartridge Weight:	**0.8-0.9 kg**

25W Mission Energy Density:

24 hr	**210 W-hours/kg**
72-hr	**460 W-hours/kg**

Orientation independent

Operated from -20 to 55 °C

Ultracell XX25

In Development with CERDEC and DARPA

Rated 25W continuous
Reformed Methanol Fuel Cell (RMFC)
Fuel: 67% Methanol / 33% Water

Dimensions:	**9.30" X 5.38" X 1.80"**
Start Up Time:	**20 min.**
System Dry Weight:	**1.2 kg**
Fuel Cartridge Weight:	**0.35 kg (250 mL)**

25W Mission Energy Density:

24 hr	**230 W-hours/kg**
72-hr	**360 W-hours/kg**

Orientation independent except upside down

Operated from -20 to 55 °C

Samsung SP-S25

In Development with CERDEC CRADA

Rated 25W continuous
Direct Methanol Fuel Cell (DMFC)
Fuel: 100% Methanol

Dimensions: **9” X 6.25” X 3.75”**
Start Up Time: **Instant (hybridized)**

System Dry Weight: **1.895 kg**
Fuel Cartridge Weight: **0.25 kg (250 mL)**

25W Mission Energy Density:
Testing in progress

Orientation independent except upside down

Fuel Cells for Man Portable Power

Potential Benefit – Man Portable

Auxiliary Power/ Battery Charging

- Bridge power gap between batteries and generators
- Greater efficiencies than TQGs and vehicle power
- Reduced noise and heat signatures
- Enables remote, portable battery charging capability where other power sources are not practical
- Low emissions

Current Programs and Recent Lab Testing Results

Man Portable Power (150 W – 500 W)

Fuel Technology	Current Efforts
Reformed Methanol	Protonex (The Next Generation of Portable Power); IdaTech
Ammonia Borane	Spectrum Brands; Rayovac
Sodium Borohydride	Ultralife Batteries; Lynntech

Man Portable Power (150W – 500 W)

Protonex™
The Next Generation of Portable Power™

IdaTech

Make (Type)	Nominal Power (W)	Dim. (in.)	System Weight (kg)*	Startup Time (min)	Fuel Cons. (g/hr @ 250W)
Protonex (RMFC)	250	10x14x20	22.8	25	360
Idatech (RMFC)	250	12x8x14	11.3	12	345

* Not including fuel weight

Recent Exercises and Demonstrations

Wearable Power Prize Challenge
September 2008

WPP Challenge Goals:

- **Capable of providing 96 hours of operation**
- **20W average power with 200W peaks**
- **Weigh 4kgs or less**
- **Attach to vest (wearable)**

Winning Companies- all received previous CERDEC support:

(1) Dupont/Smart Fuel Cell: *M-25 Fuel Cell System*
(2) Adaptive Materials Inc.
(3) Capitol Connections/Smart Fuel Cell: *Jenny 600S*

***CERDEC invested in all five of top placing companies (4 – Ultralife, 5 - Ultracell)**

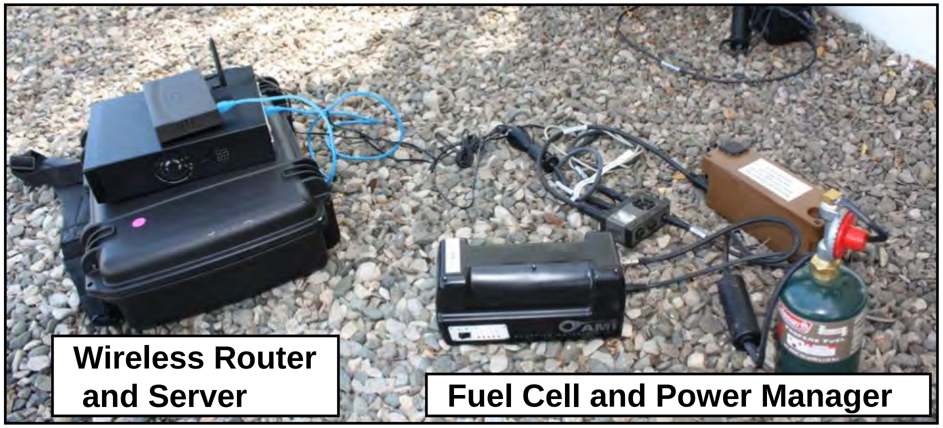
Medical Readiness Training Exercises - October 2008

Las Calderas, Dominican Republic

<u>What is it?</u>

- Two week deployment
- Underdeveloped areas
- Medical and veterinary services
- Power grid not always reliable

Medical Readiness Training Exercises - October 2008



25 Watt AMI System

Power Manager

Three fuel cell systems and power manager provided power for MUGR Mobile Recognition Terminal (MRT), laptop computers & local wireless network.

25 Watt Ultracell System

Universal CLA Adaptor

Two fuel cell systems and CLA adapter provided power for laptop computers for validating and keeping medical records.

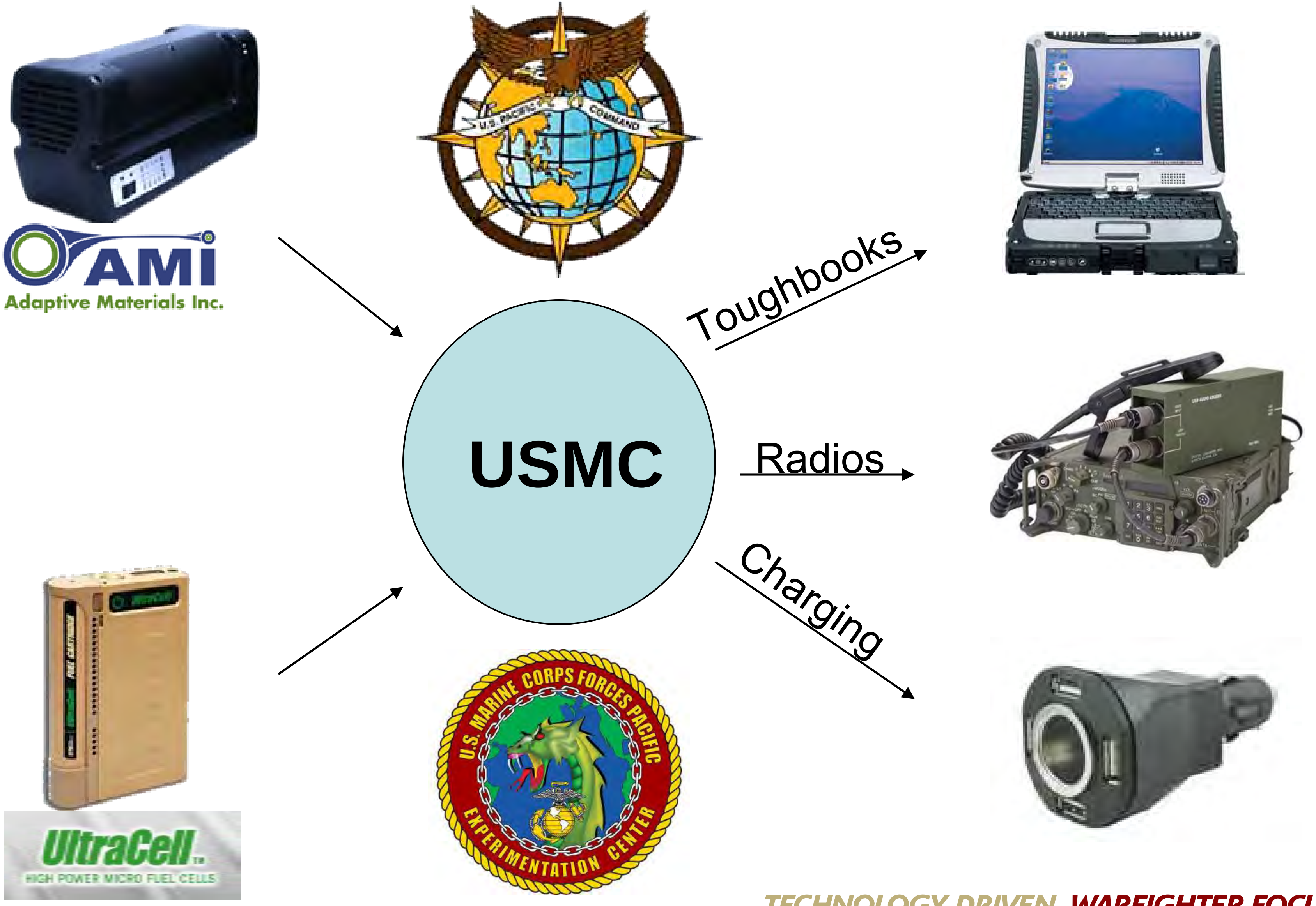
Cobra Gold
February 2009

Sukhothai, Thailand

What is it?

Training exercise designed to provide training in a real world environment and work on logistics, operations, and interoperability with ally countries in southeast Asia.

Cobra Gold
February 2009



Cobra Gold February 2009

Environmental Conditions

Temp: 25° to 35°C
Humidity: 60% to 80%
Environment: Dusty

Successes

- Marines liked the portability, lightweight power sources.
- Reduced battery change-outs
- Reduced vehicle idle time

Shortcomings

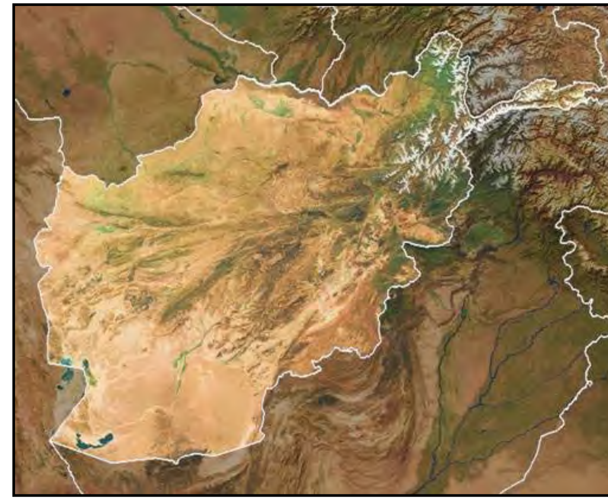
- Some issues with reliability
- Heat and awkward connectors

Rapid Fielding Initiative Afghanistan - Current

CERDEC

RDECOM FAST

ARL



- Need for lightweight, continuous, reliable power
- Five XX25s delivered to Afghanistan by CERDEC/ARL, November 2008
- XX25s are currently being used by different units in need of lightweight, long runtime power sources

Conclusions

- **Fuel Cells have shown great potential for military applications**
- **Many current systems have increased reliability and ruggedness**
- **No one technology has shown it will be the sole solution for the military**
- **Test and evaluation of fuel cell power systems plays a vital role in assessing the state of technology**

Michael Dominick, Mechanical Engineer
US Army CERDEC, Army Power Division, Fuel Cell Development Team

Phone: (410) 278-8950, DSN: 298-8950

E-mail: michael.dominick1@us.army.mil

Thank You!

Questions?

Joint Defense Manufacturing Technology Panel (JDMTP) Power Sources Technical Working Group (TWG) Fuel Cell Roadmap

Frank Sokolowski
DCMA Industrial Analysis Center

Joint Service Power Expo
May 5, 2009

Disclaimer/Warning !!!!

- **The views expressed herein do not necessarily represent the views of management, the Department of Defense (DoD), or Defense Contract Management Agency (DCMA). They are the views, reflections and comments of the presenter only.**

Outline

- Why Roadmap?
- Background
- Goals of the Roadmap
- The Process/Data Sources
- Roadmap Content
- Questions/Contact Information

Why Roadmap?

Identify the path forward

Meet future platform needs

Allocate Resources

Support the Warfighter

Right stuff, right time

Why Roadmap? (cont'd)

Scope:

- Batteries and Fuel Cells

Purpose:

- Identify ***current*** state of technology
- Project ***future*** needs of the military
- Identify and bridge ***gaps*** between the two
- Facilitate the availability of affordable and reliable military power and energy devices essential to the Warfighter

Why Roadmap? (cont'd)

Purpose: (cont'd)

- Identify the technology needs of DoD power source systems:
  - Near term (1-3 years) Batteries/Fuel Cells
  - Mid term (4-7 years) Batteries/Fuel Cells
  - Long term (8-12 years) Batteries
- Roadmap establishes a needed foundation for further planning of potential R&D projects

Background

- Requested by the Manufacturing Technology (ManTech) Office at OSD
- Identify the Services' Science & Technology (S&T) elements
- Needed efforts to move technology to production
  - Complimentary to Services' S&T Road Maps prepared by OSD Energy and Power Technologies Initiative (EPTI)

Goals of the Roadmap

- Strategic/high level overview of military power sources technology development
- Tool for comparing current and future military power source capabilities versus WarFighter requirements
- Indentify a path for resolving shortfalls

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Goals of the Roadmap (cont'd)

- Provide a tool for guiding future resource allocation decisions (especially within the ManTech community) – Span the Valley of Death
- A byproduct of other strategic initiatives
- Bridge from S&T to production

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The Process

Govt SMEs

Review Data/Reports

Initial Draft

Review by Govt SMEs

Second Draft

Review by Industry
NDIA Site

Final Govt
Review

We are
here!

Foundational
Document
1 July 2009

Data Sources

- Government Subject Matter Experts
- Service S&T Roadmaps
- EPTI Goals Objectives Technical Challenges and Approaches "GOTChAs" Charts
- Peer Reviews
- Handbooks & Web Sources
- Industry Input

Roadmap Content

- **Fuel Cell Roadmap covers 3 ranges:**
  - Soldier-carried power and sensors & Man-portable power (1W-1kW)
  - Mobile Power (1kW-100kW)
  - Stationary Systems (>100kW)

Roadmap Content (cont'd)

- **The Roadmap addresses various Fuel Cell types as well as Reformers:**
  - Direct Methanol Fuel Cells (DMFC)
  - Reformed Methanol Fuel Cells (RMFC)
  - Chemical Hydrides
  - Proton Exchange Membrane (PEM)
  - Solid Oxide Fuel Cells (SOFC)
  - Molten Carbonate Fuel Cells (MCFC)

Roadmap Content (cont'd)

- **Technology Overview**
- **Current State -** Demonstrated capability of the technology as of today. Assessment Code (AC) is based on ability of technology to meet ***today's*** WarFighter requirements
  - Advantages
  - Disadvantages

Roadmap Content (cont'd)

- **Future State (Six years out)** - Two future states are considered, one with no additional funding and one with all required funding provided. AC based on the ability to meet the projected ***<u>future</u>*** needs of the WarFighter
  - GOTChA Charts
  - Parameter Matrices

Roadmap Content (cont'd)

Assessment Codes:

Green	Meets or exceeds desired capability
Yellow	Comes close to or has potential to meet desired capability
Red	Does not come close to or can not meet desired capability
Pink	Unproven ability to meet requirement
Orange	Significant investment & research required to meet desired capability

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Roadmap Content (cont'd)

- **Projected Applications of Army, Air Force, Navy and USMC**
  - Soldier Power, sensors, Battery Chargers, Unmanned Aerial Vehicles (UAV), Unmanned Ground Vehicles (UGV), Unmanned Underwater Vehicles (UUV), Auxiliary Power Units (APU), Forklifts, Tent Cities, Ground Support Equipment, Troop Buses, Tactical Operation Centers

Roadmap Content (cont'd)

Parameter Matrices Example

Item No	Strategic Thread	Parameter	Requirement	Current Status	Invest?	6 Year 2014
1	A	Commercial Applications	Desired		Y	
					N	
2	D	Temperature Performance - High	Perform to +55° C	+45° C	Y	+55° C
					N	+45° C
3	D	Temperature Performance - Low	Perform to -20° C	-20° C	Y	-20° C
					N	-20° C
4	C,D	TRL	TRL 9	TRL 6	Y	TRL 9
					N	TRL 6

DCMA Defense Contract Management Agency

Roadmap Content (cont'd)

Technology Maturity Horizon Example				
Technology	**Now**	**Near**	**Mid**	**Far**
Type 1	< 100W →			
Type 2	< 100W →			
Type 3	100W - 500W →			
Type 4	100W - 500W →			
Type 5	< 500W →			
Type 6	>100W →			
Type 7	500W - 1kW →			
Type 8	500W - 1kW →			
Type 9	1W - 1kW →			

Green – Meets or exceeds desired capability
Yellow – Comes close to or has potential to meet desired capability
Red – Does not come close to or can not meet desired capability

Roadmap Content (cont'd)

- **Roadmaps**
  - Funding Requirements
- **Conclusions**
- **Recommendations**
- **Definitions**
- **Appendices**

Roadmap Content (cont'd)

Funding Roadmaps Example

ID	Strategic Thread	Action/Metric	Priority	$Cost M	$Source
1	Performance Improvement	Increase High Temperature Performance from +50° C to +55° C	1	$4.00	ManTech
2	Performance Improvement	Increase Power Density from 25W/kg to 100W/kg	2	$2.00	ManTech

Timeline →

2009	2010	2011
TRL 4	→	TRL8
MRL3	→	MRL8

Acronym List

- **AC** - Assessment Code
- **EPTI** - Energy and Power Technologies Initiative
- **GOTChA** - Goals Objectives Technical Challenges and Approaches
- **JDMTP** - Joint Defense Manufacturing Technology Panel
- **OSD** - Office of the Secretary of Defense
- **SME** - Subject Matter Expert
- **S&T** - Science and Technology
- **TWG** - Technical Working Group

Contact Information

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Questions?

Questions and Comments?

Solid State Power Control in Smart Power Management & Distribution

William M. Thorp
Senior Electrical Engineer, Data Device Corporation

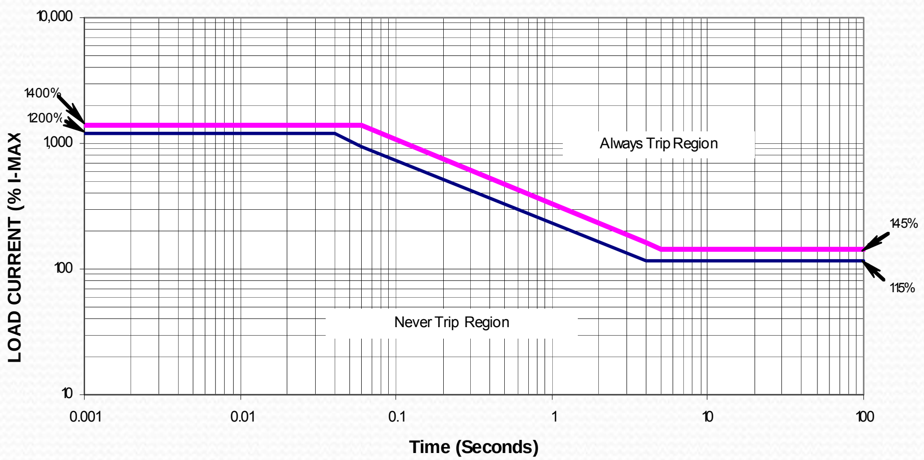
Introduction of SSPC on Military Vehicles

- Challenge: Reliability Impact of Thermal Mechanical Breakers and Relays
  - Wear-out Mechanism
  - Fused or Oxidized Contacts
  - Uncontrolled Turn-on and Turn-off Impacting the Load
- Solution: Solid-State Power Controllers

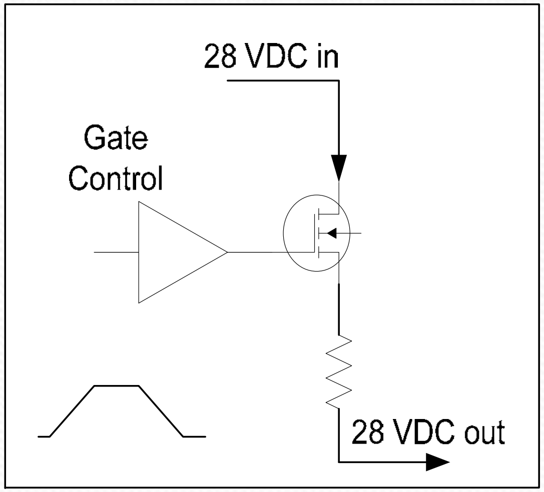
SSPC Basic Functionality

- Provides the Same Protection of Harnesses and Loads as Thermal Breakers, but with a Solid-State Circuit
- Control Turn-On to Drive Large Capacitive Loads
- Control Turn-Off to Prevent Spikes on Inductive Loads
- Minimize EMI

I^2T Curve



Controlled Gate



Ground Vehicle History

- M1A2 Abrams Tank
  - SSPC Inserted in 1988
  - >200K Nodes Installed
- M2A3 Bradley Fighting Vehicle
  - SSPC Inserted in 2004
  - >200K Nodes Installed
- SSPC Planned for…
  - M88A2 Hercules Tank Recovery Vehicle
  - Paladin/FAASV M109 Self-Propelled Canon
  - MULE
  - JLTV
  - M-ATV

Power Distribution Challenges

- New Challenges:
  - Military Vehicles Require More Power, but have Limited Generation and Storage Capability Due to Weight and Size Constraints
  - Power Systems are Inflexible, Making it Difficult to Configure Vehicles for Varying Missions
- Solution: Smart Solid State Power Controllers
  - Network Control
  - Autonomous Monitoring
  - Programmability

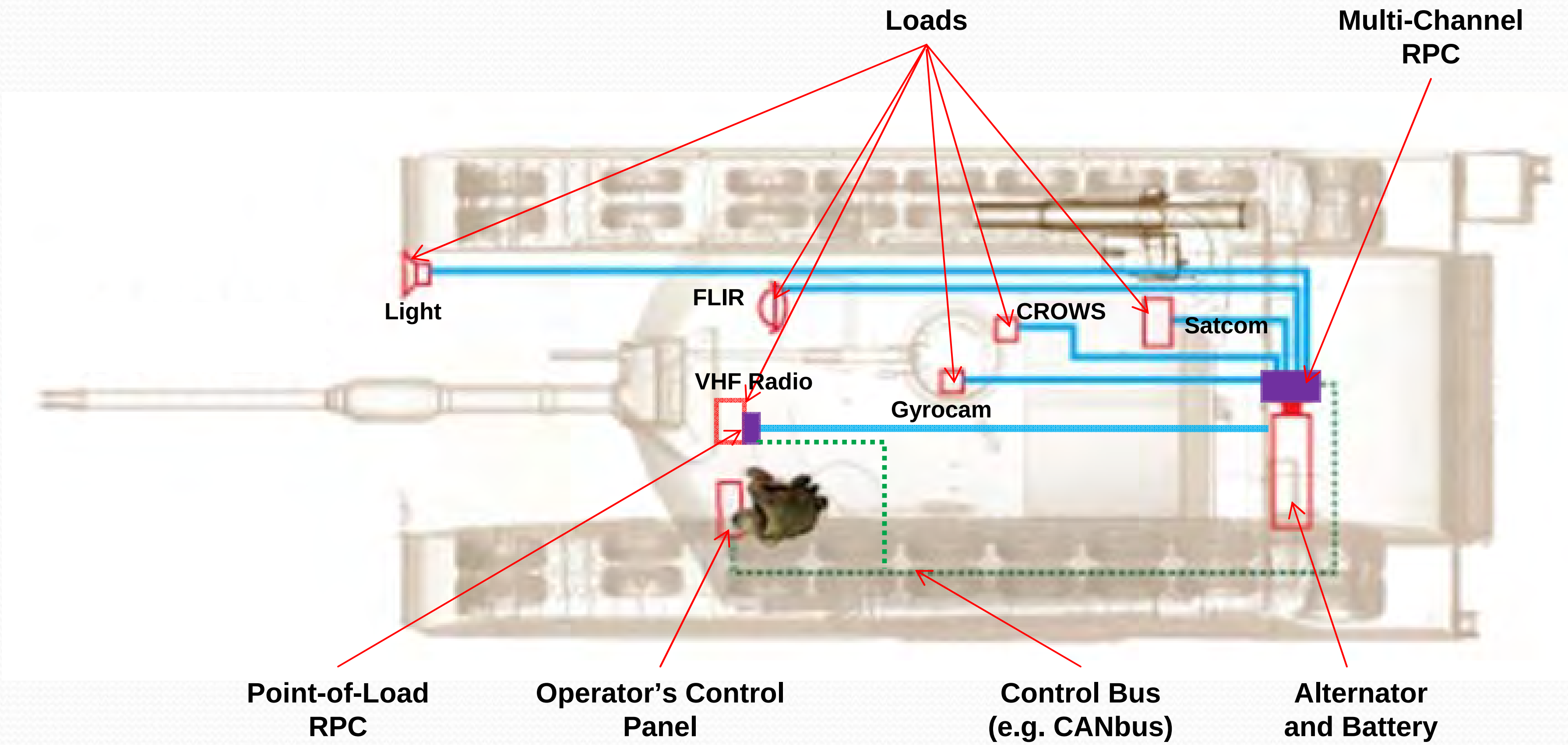
Power Control Architectures

- High Density Load Centers
  - One or More Power Distribution Units Handling Multiple Vehicle Loads
  - Implemented Using Multi-Channel SSPC

- Point of Load
  - SSPC Modules Located Near Loads

- Design Considerations
  - Cost
  - Space
  - Load Mix
  - Flexibility

Power Distribution Example



Smart SSPC Capabilities

- Network Control (i.e., CAN SAE J1939, Ethernet)
  - State: On/Off
  - Status: Enabled/Tripped
  - Set Current Rating
  - Battle Override
- Enables…
  - Crew Offloading, Operating Mode Selection

Smart SSPC Capabilities (Cont.)

- Network Monitoring of Load Health/Status
  - Get Output Channel Voltage and Current
  - Get SSPC Board or Load Temperature
  - Voltage, Current and Temperature Alarms
- Enables…
  - Real-Time Power Management
    - E.g., Load Shedding
    - Situational Load Profiles
  - Diagnostics
  - Prognostics

Smart SSPC Capabilities (Cont.)

- Adaptability Features
  - Wide Channel Trip Programming Range
  - Channel Paralleling
  - TARDEC Power Management API
- Enables…
  - Reduced Development Time and Cost
  - Reduced Part Number Count (i.e.,Common Modules)

SSPC Design Challenges

- EMI
- Thermal Management and Dissipation
- Ruggedization and Reliability
- Robustness
  - In-rush Current
  - Transient Suppression
  - Connectors
  - Immune to Sympathetic Tripping

Technology Trends

- Diagnostics/Condition-Based Maintenance
  - Arc Fault Detection
  - Fault Location
  - Data Logging
- Increased Power Densities
  - Higher Current Density SSPC's
  - Move to 610Vdc Primary Power Distribution
  - Silicon Carbide FETs

Questions

L3 communications

Integrated Starter Generator

"More than a 24V Vehicle Power Supply"

L-3 Combat Propulsion Systems

Muskegon, MI 49442

Presented by

Donald Underwood – VP, Engineering

Talking Points

- Power & Energy – Critical Combat Enablers
- ISG System Architecture
- Performance Capabilities
- Retrospective

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Over-Arching Technology Requirements

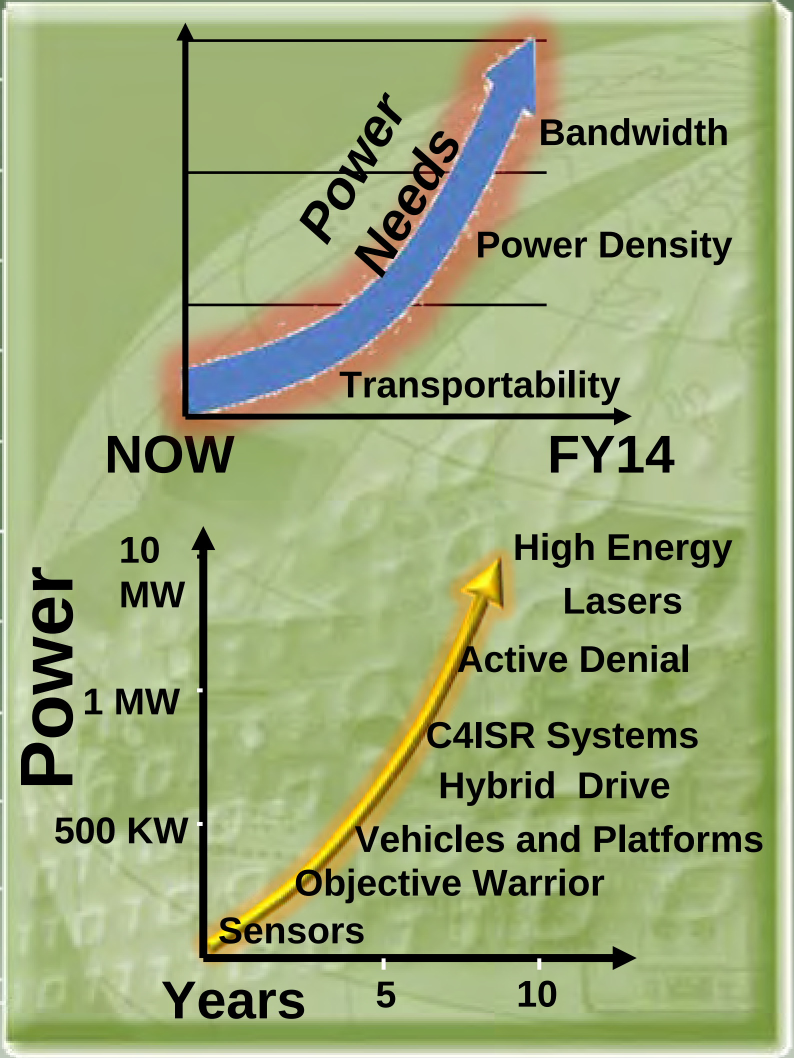
- Build Lighter and Smaller (Weight, Volume)
- Build to Last (RAM)
- Build User-Friendly (Interfaces, displays, and automation to manage operator workload)
- Reduce/Manage Required Network Bandwidth
- Build Affordably (Production Cost Reduction)

Terms of Reference

- High Energy Systems (High Value) will dominate the "Future Battlespace"
- Tactical Vehicle designs impose severe limitations on volume and weight
- Fuel Economy is Combat Power … a key performance parameter
  - Energy Density is the primary figure of merit for mobility solutions
  - Long term commitment to manufactured liquid hydrocarbon fuels from domestically abundant feedstocks (Bio-diesel, methanol, ethanol)
  - Hydrogen presently unsuitable for tactical mobility fuel but is feasible for hotel power
- Network Centric Operations and increasing bandwidth are driving electrical power requirements exponentially
- U.S. Defense has committed to hybrid-electric architecture for FCS and future Tactical Wheeled Vehicles (e.g. JLTV)

Power and Energy are Critical Transformation Enablers

The Power Issue



- **Total System Energy Management:** is a critical resource for future economies
  - *Stability/instability of World regions*
  - *Energy "independence" should be based on diversity*
- **Scaleable Options:** Concepts must include methods for supporting and facilitating natural resources and alternative energy sources
  - *Highest Possible Packing Density and Utility to maximize system's use*
  - *S&T funding is supporting fuels/synfuels/bio-diesel research*

"Power"… Critical Resource on Tomorrow's Battlefield

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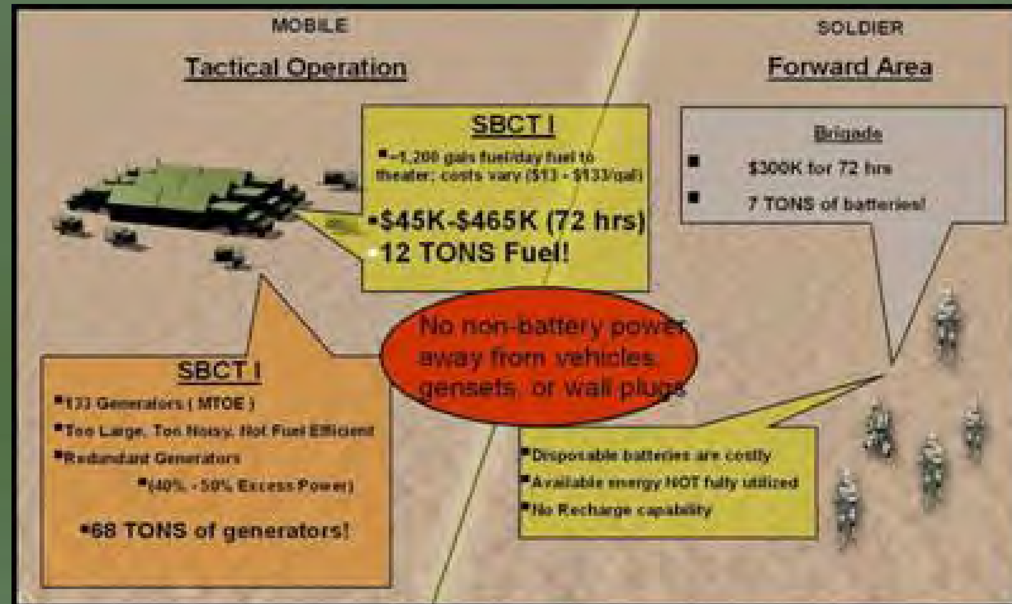
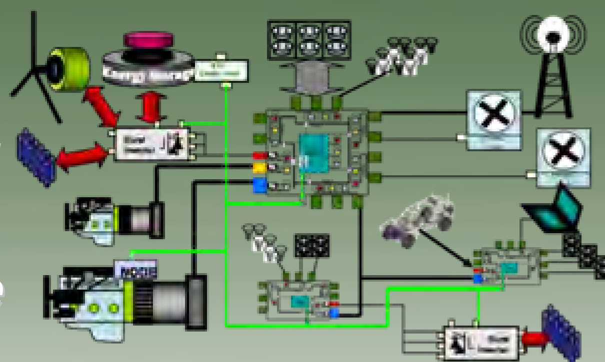
Adv Mobile Electric Tactical Power Sources

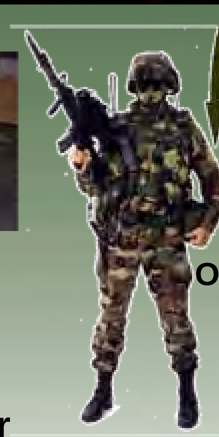
- ***Addresses Power Generation Mission Capabilities Gaps (5-75kW) to support Future Force and dismounted warfighter***
- ***Development of high power density (>1kW/kg) systems (generators and fuel cells)***
- ***Development of Hybrid Intelligent Power Mgmt architecture using node control switchgear***





Hybrid Smart Grid

30 kW Modern Tactical Quiet Generator



OPOC-FL 1.5kW

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Proven Exportable Power Systems: TRL 6-7

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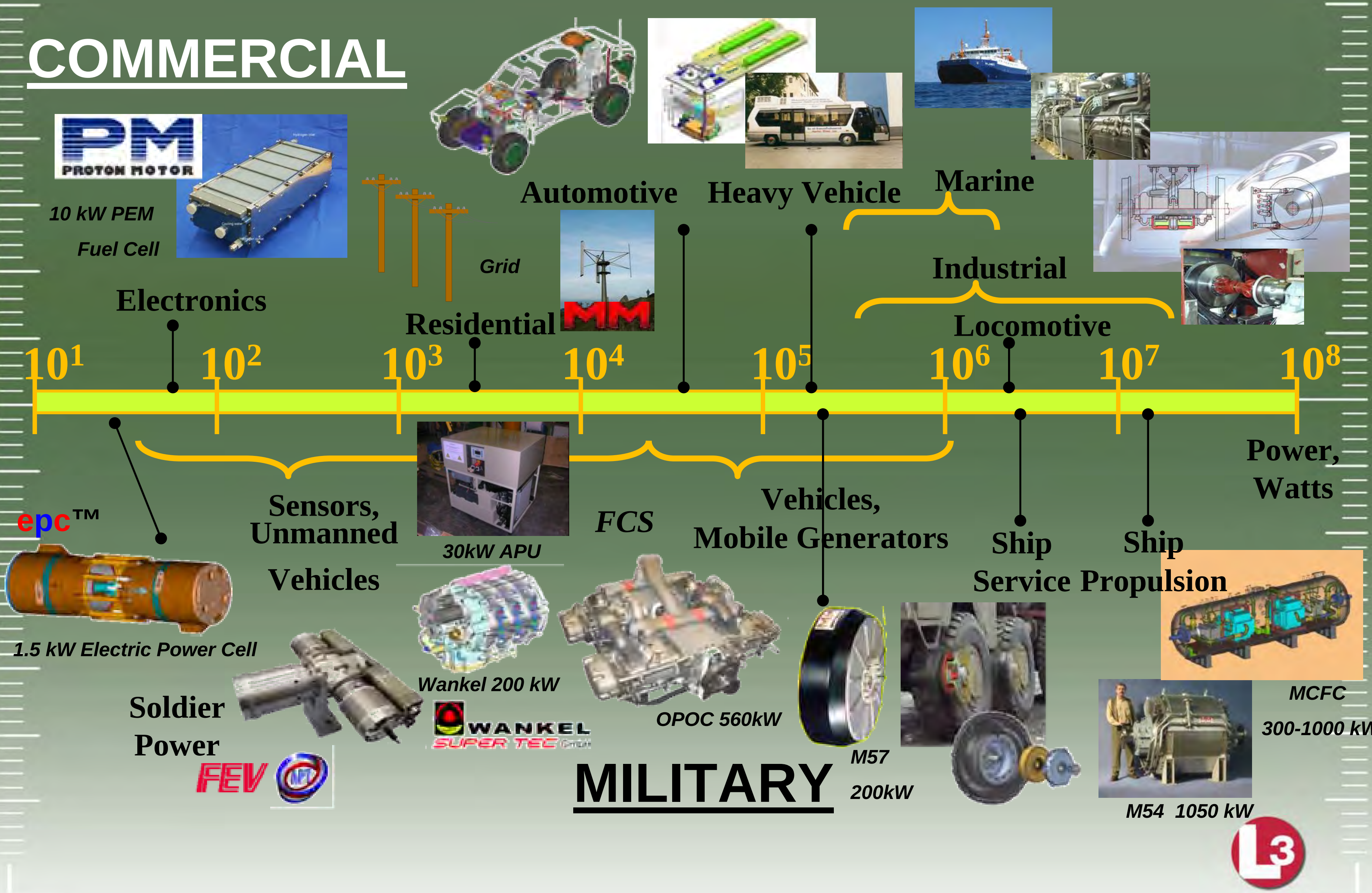
L-3 Commitment to Hybrid Architectures



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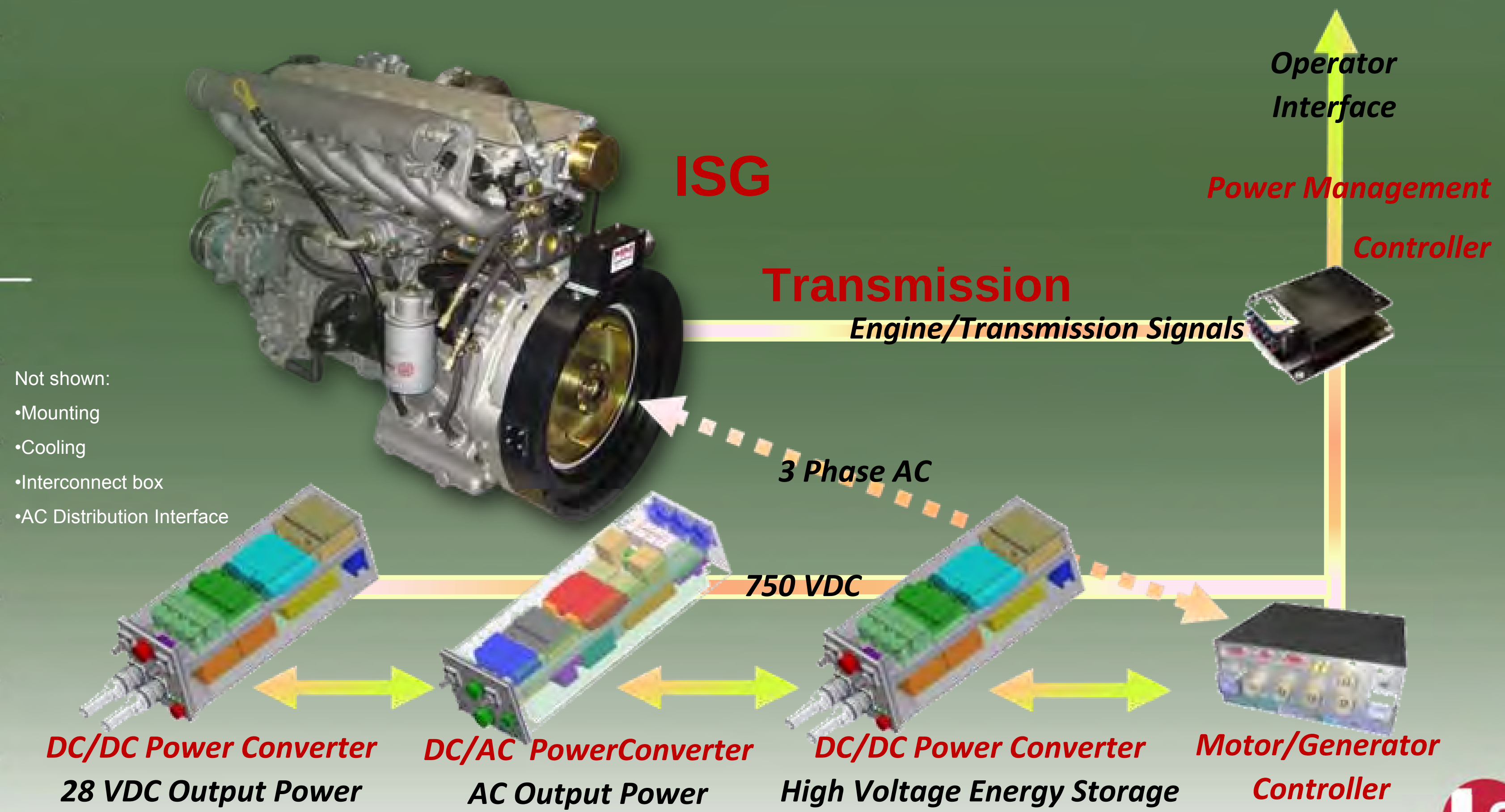
ISG System Architecture

- Design based on military application prototypes
- Modular capability with incremental power 20-110kW



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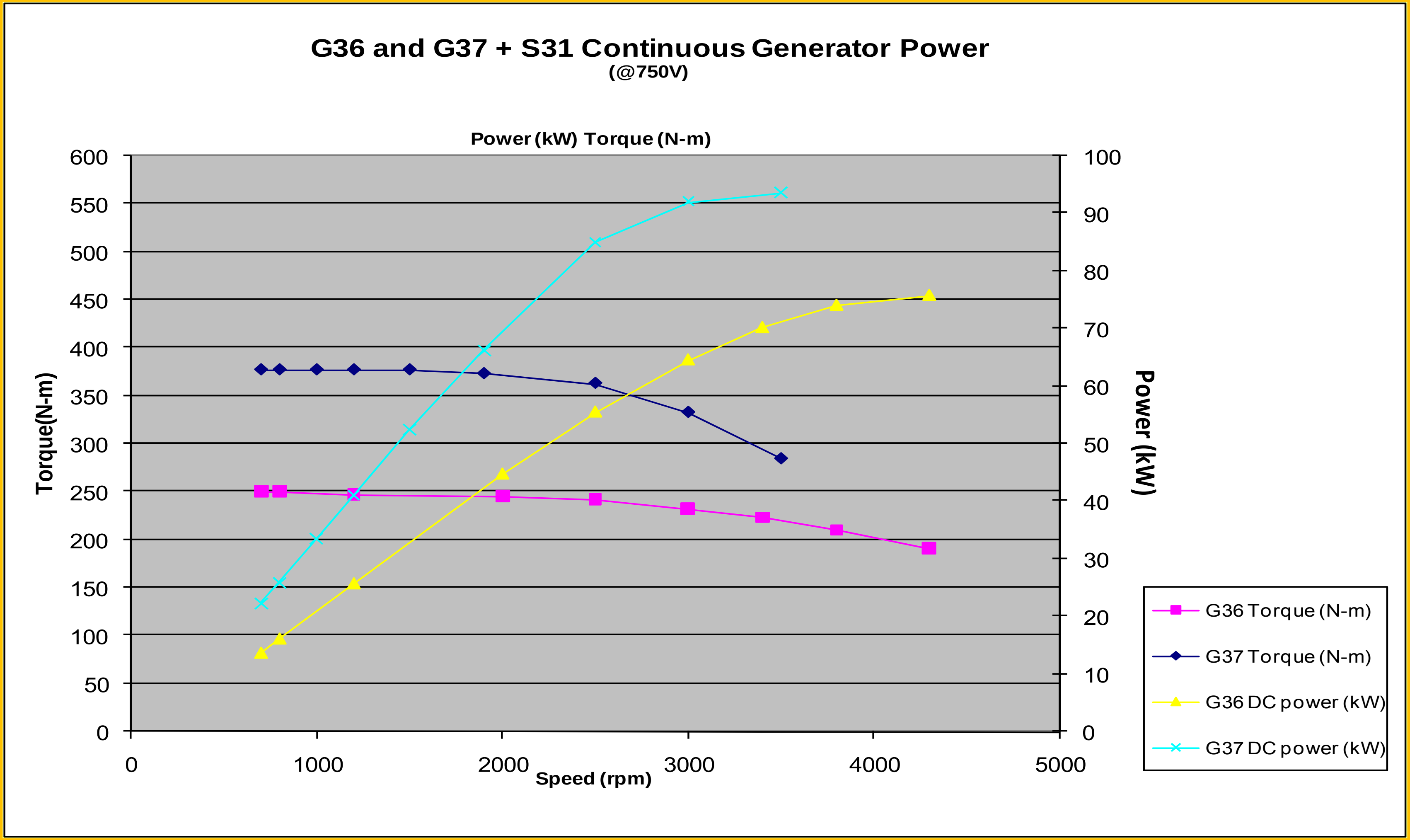
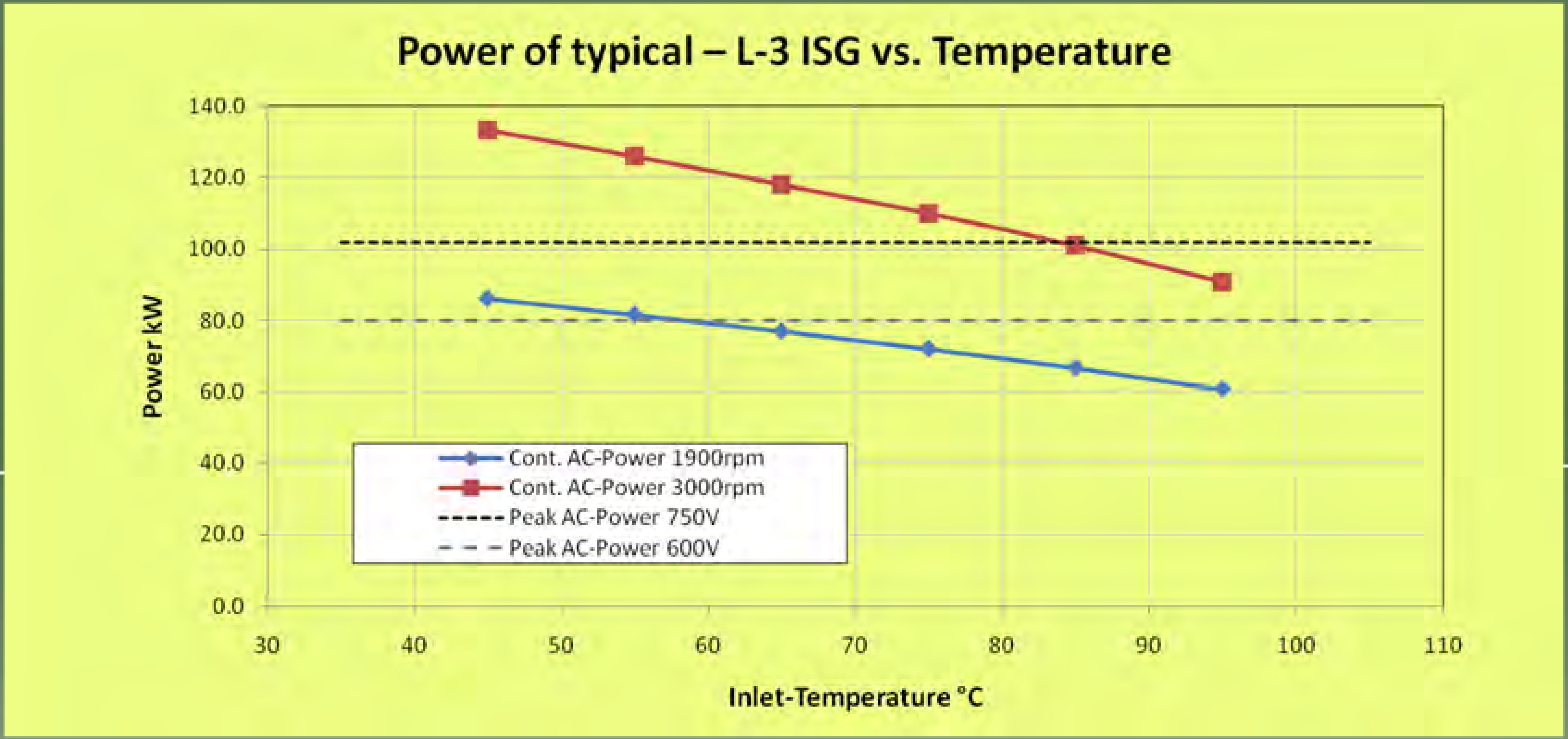
Nominal ISG Performance Capabilities



ISG AC Output vs. Temperature



- AC-Power = Power at 3-Phase between Generator and PE
- Cont = Continuous = Thermal Limit
- Peak = Possible Power due to DC-Voltage, BEMF and Inductance of Coils

How to use:

1)Choose rpm + chose Inlet temp -> get possible cont. Power

2) Choose DC-Voltage -> get possible Peak Power

3) Power that can be used = Minimum of 1) and 2)

- DC-Voltage-dependency indicates that lower temp does not always mean higher power.

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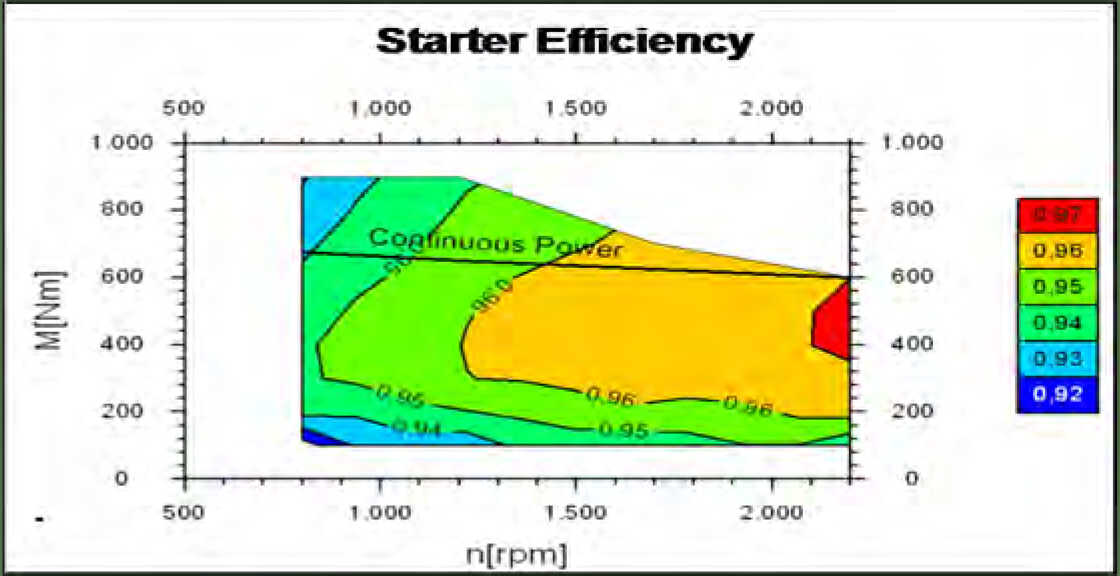
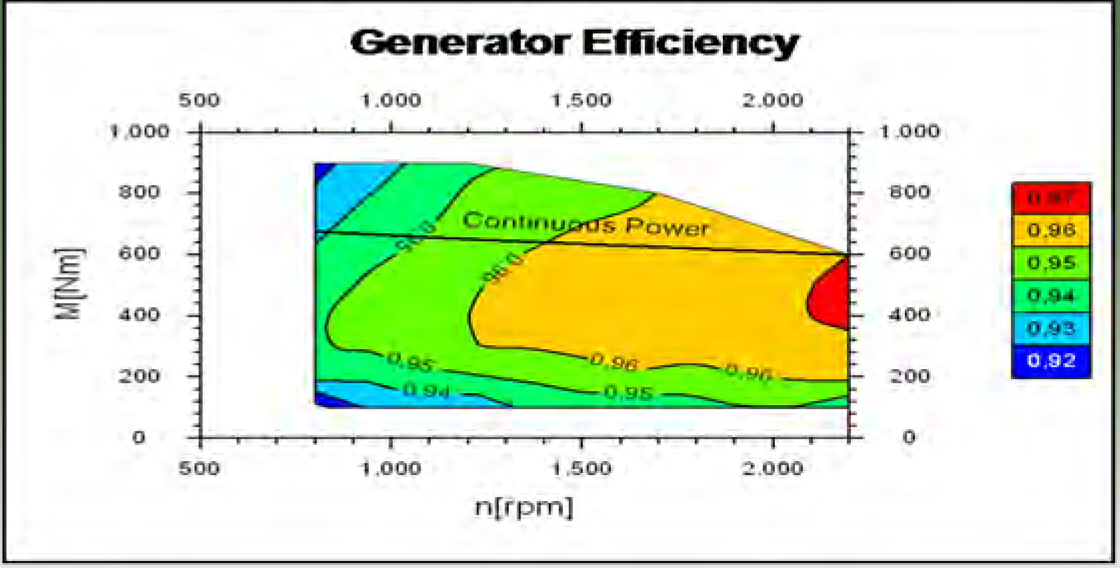
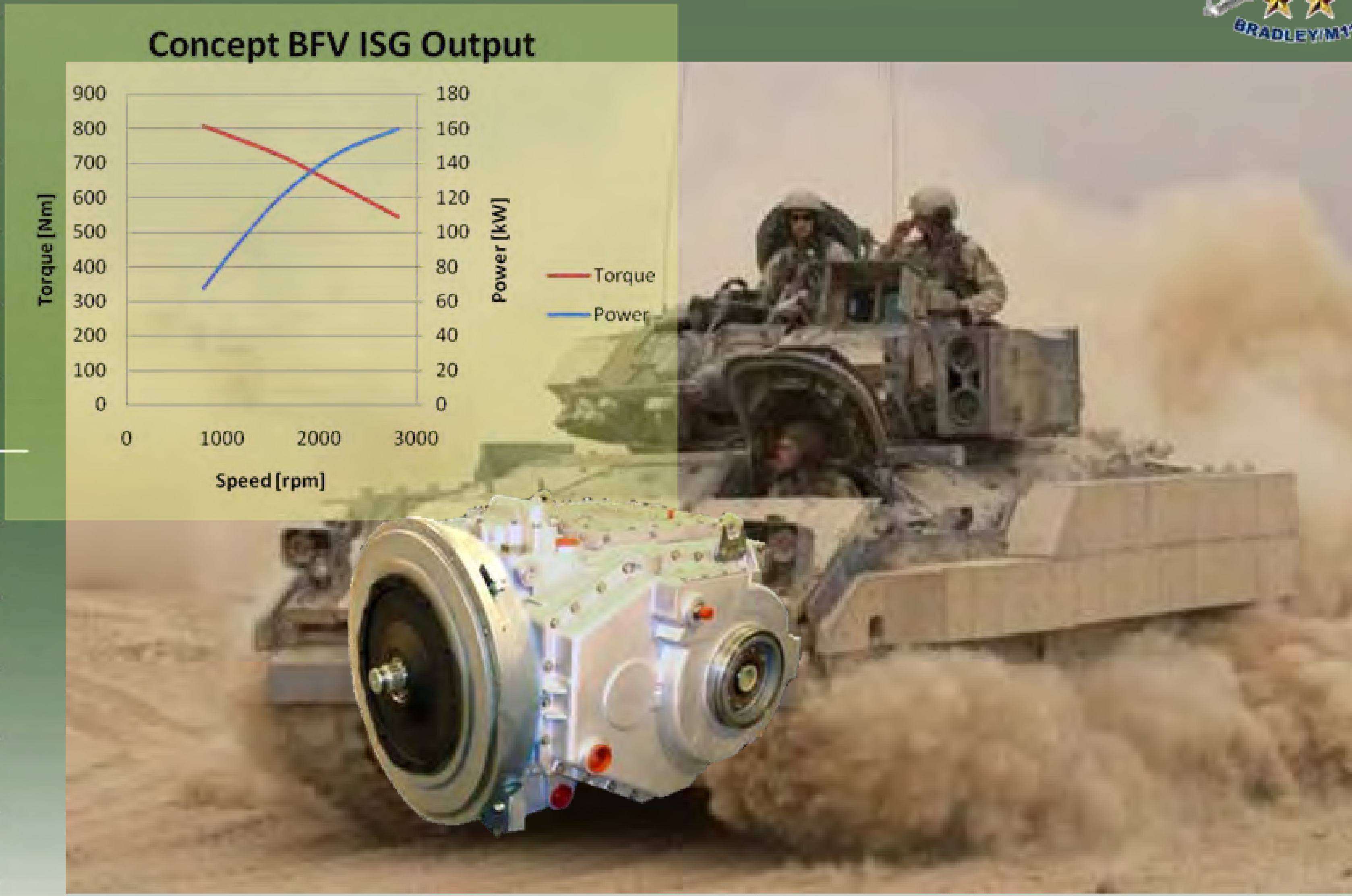
G37 - ISG Motor /Starter Efficiency





HMPT 600/675/800 with ISG



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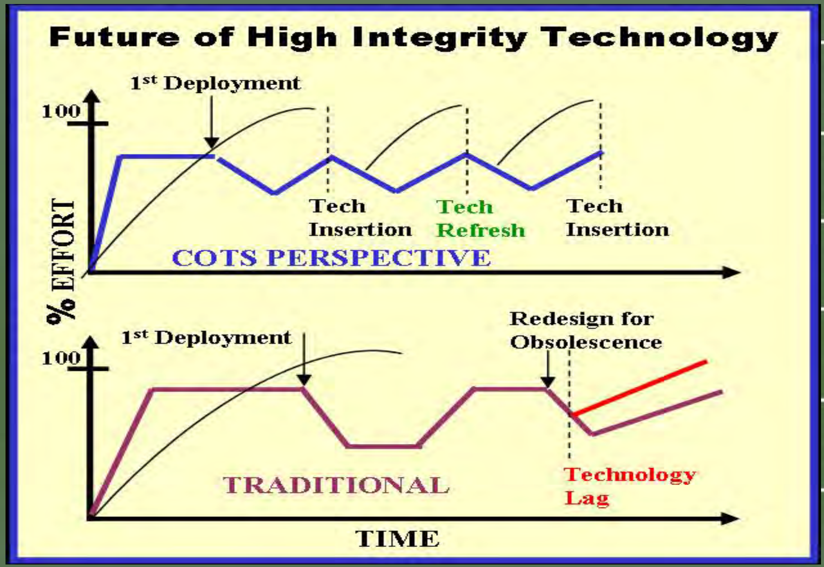
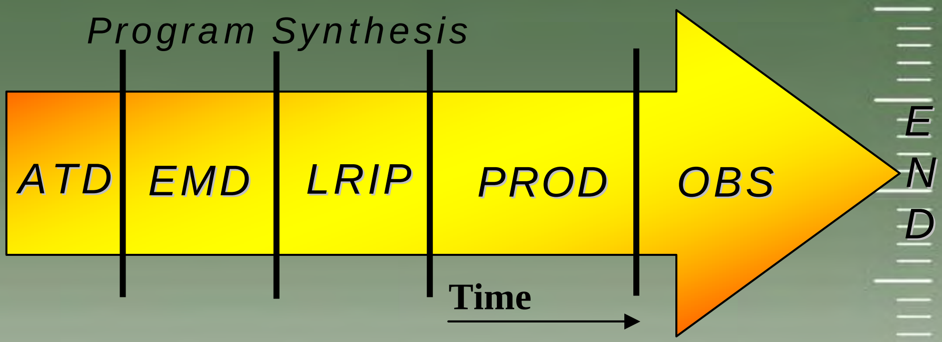
Open Systems Technology

- Leverages Hybrid and energy management validated legacy
  - Combat Vehicle Concepts & Iterations
  - Wheel-hub drive product application
  - High energy / Power Density
- Seamless Horizontal Technology Insertion into current and future platforms
- Dual use COTS / NDI components maximizes affordability





HEV modular power control design provides continuous upgrade/modernization during the life of the system

Retrospective

- Evolutionary acquisition focused on spiral development
  - New technology that gives conventional systems more capability
  - New technology that provides unconventional capabilities
- Multi-dimensional options
- Logistics transformation enabler
  - Builds, generates and sustains combat power
  - Pathway to energy “independence”

- L-3 CPS is meeting emergent challenges with innovative applications of leading technology and extensive expertise in engineering and analysis
- The Presence of Hybrid Powered Vehicles and Energy Generation Systems permits the utilization of broad ranging concepts for energy management that will revolutionize the makeup of future economies and infrastructures
- Energy Management Architectures and Power Distribution Products are modular and scalable to provide maximum system flexibility
- Spin-Out technologies (FCS/JLTV) applications provides current and future force systems growth margins to meet emerging requirements

Development of SOFCs for Liquid Fuels

May 5, 2009

N. Fernandes, D. Schmidt,

N. Bessette

Outline

1. Introduction to Acumentrics
2. Acumentrics' SOFC Technology
3. Development of SOFC for Military Use
4. Reliability
   - Mechanical strength- Shock and Vibration
   - Thermal Shock
   - Liquid Fuels
5. Future Work

Acumentrics Corporation

- *~ 80 Employees*
- *Manufacturing since 1994*
- *Based in Westwood, Mass.*
- *~40,000 sq. ft facility*
- *Profitable for the past 30 months*
- *Critical disciplines in-house*

Electrical Engineering
Mechanical Engineering
Chemical Engineering
Thermal Modeling
Ceramics Processing
Manufacturing
Sales & Marketing
Automation
Finance

Acumentrics
Trusted Power Innovations

Acumentrics *Battery based UPS*




Uninterruptible Power Supplies for Harsh Environments

Industrial-UPS®
Commercial

Rugged-UPS®
Military


Features:

- Sealed electronics
- Able to withstand vibration
- Unity power factor input
- Wide input 80VAC - 265VAC
- Isolated 120 / 240VAC output
- Hot swap battery case
- Parallelable to 20 kWatts

Why Solid Oxide Fuel Cells?

- PEM
  - Polymer MEA, H^+ charge carrier
  - Low temperature
    - Light weight assembly

    But
    - Acutely susceptible to poisons (CO and Sulfur), thus heavy fuel processor
    - Expensive Pt catalyst because of slow kinetics
- SOFC
  - Ceramic MEA, O^{2-} charge carrier
  - High temperature
    - Heavy ceramics and metals

    But
    - Inexpensive catalysts (e.g. Ni) due to fast kinetics
    - CO is a FUEL, not a poison
    - Bottoming cycle is possible, *high efficiency*

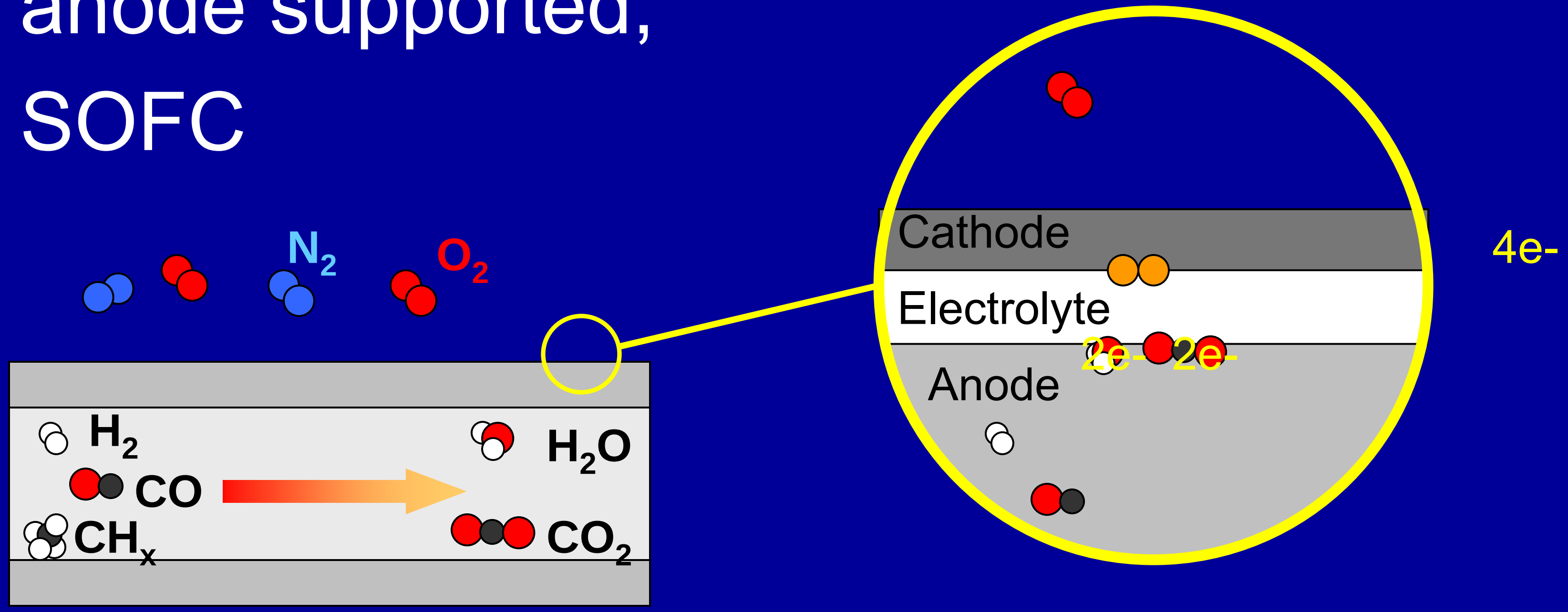
High temperature favors reforming kinetics and thermodynamics, SYNERGY

Rugged Tubular SOFC

Tubular,

anode supported,

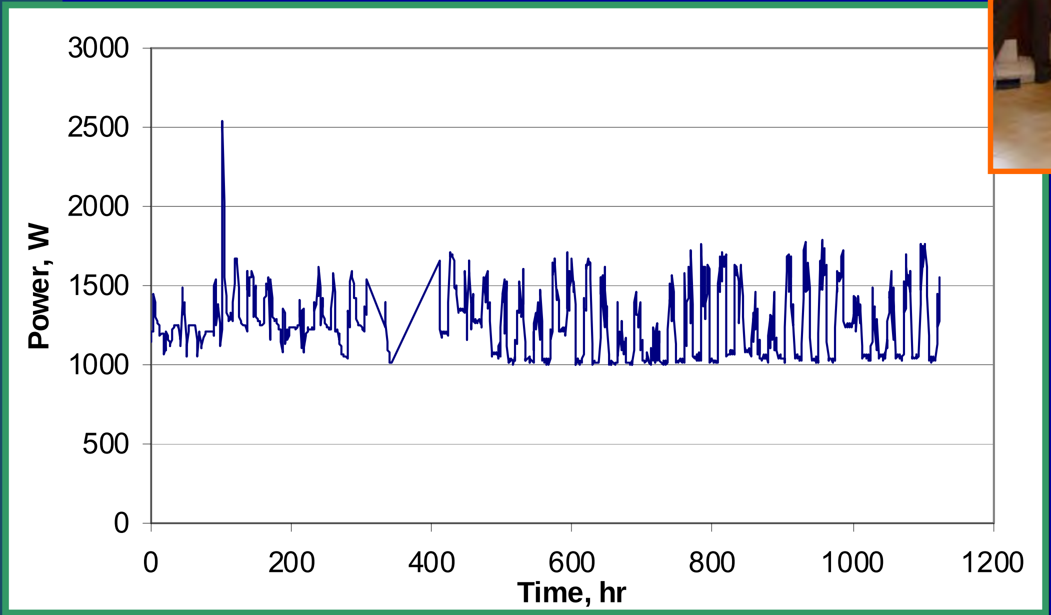
SOFC



Exit Glacier

Operation for another summer at Exit Glacier Visitor's Center

Shutdown at end of season



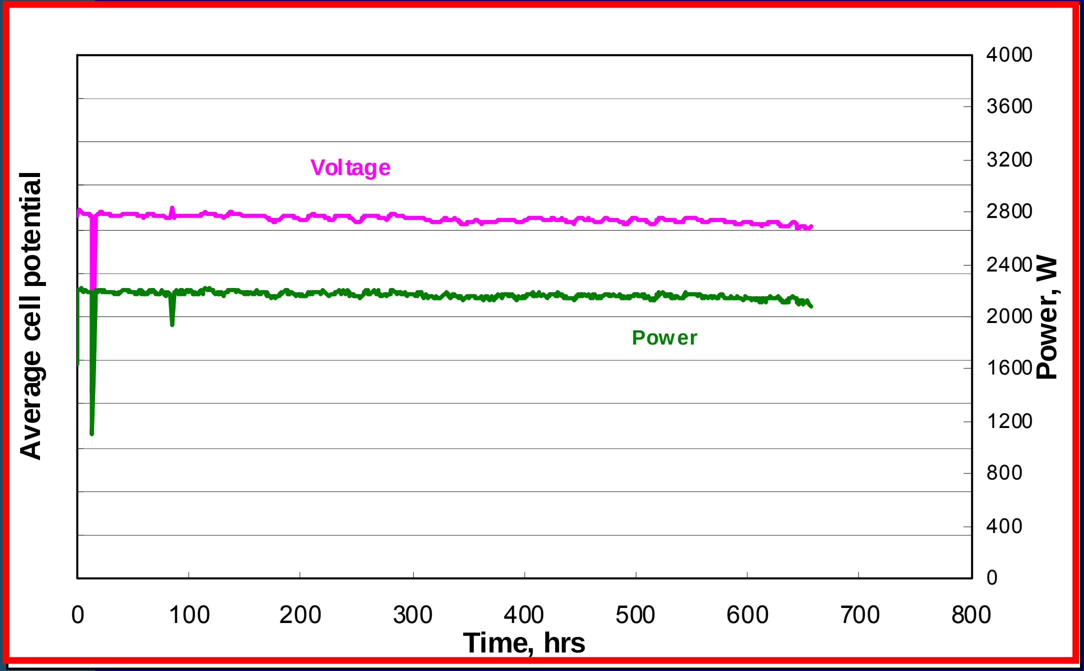
Fuel: Propane

Products: hot water for radiator heating and electrical power

Acumentrics
Trusted Power Innovations

Cuyahoga State Park

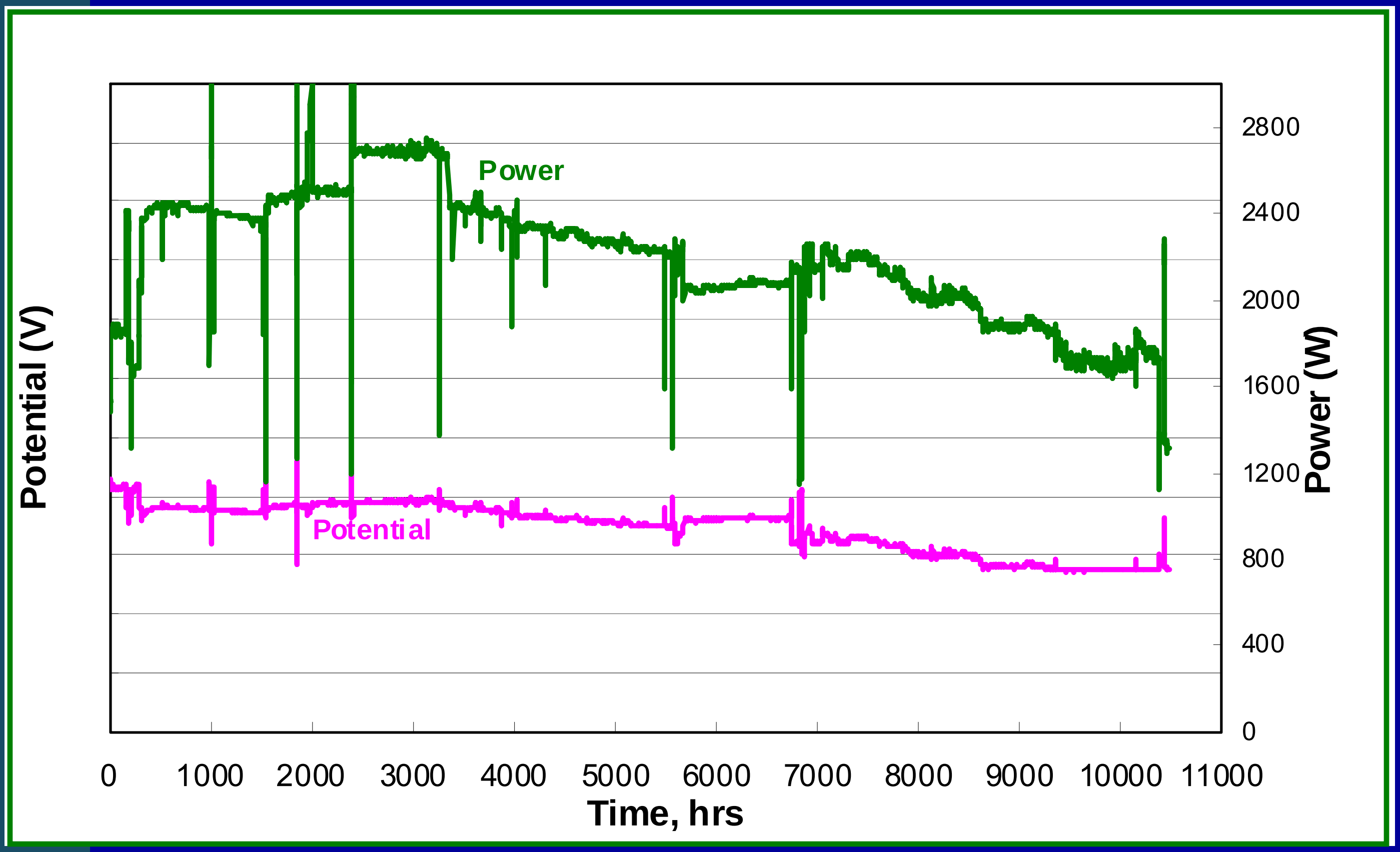
Location: Outside, grid tied



Fuel: Natural gas

Products: electrical power

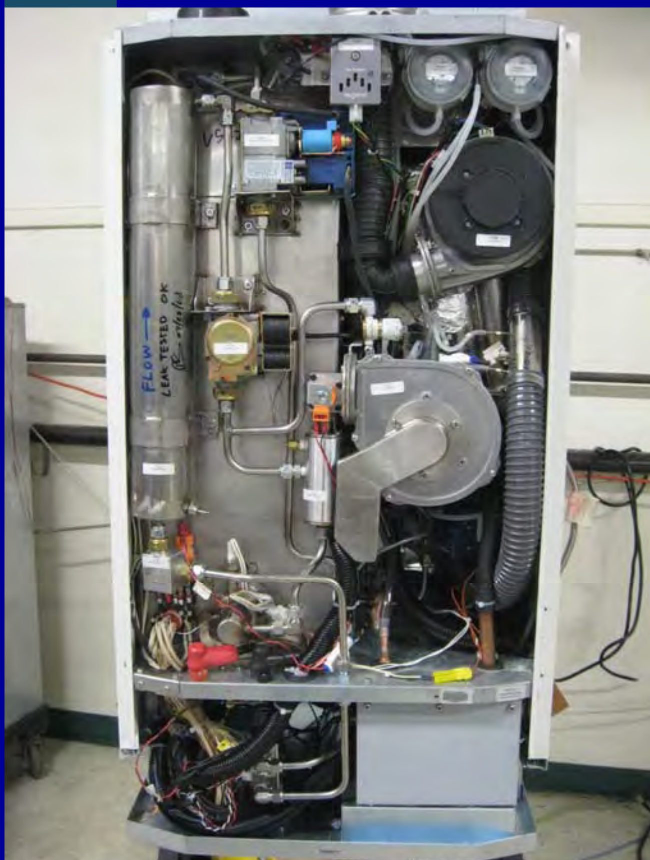
SECA Phase I Generator



- Total run time 10,500hr
- Major ESTOP event at 3200hrs
- 18 Thermal cycles
- Shipped twice (part of SECA Phase I testing at NETL)
- 2004 cell technology

Acumentrics
Trusted Power Innovations

Micro CHP



3 have been built to date

Has started CE certification

Plan to undergo testing with the MTS consortium in the next month

1kWel AC out, 20kWth eff(all)=85%,

SOFC for Military Applications

High Performance

- High power density, small and light
- Silent
- Rapid start-up
- Efficient, water neutral

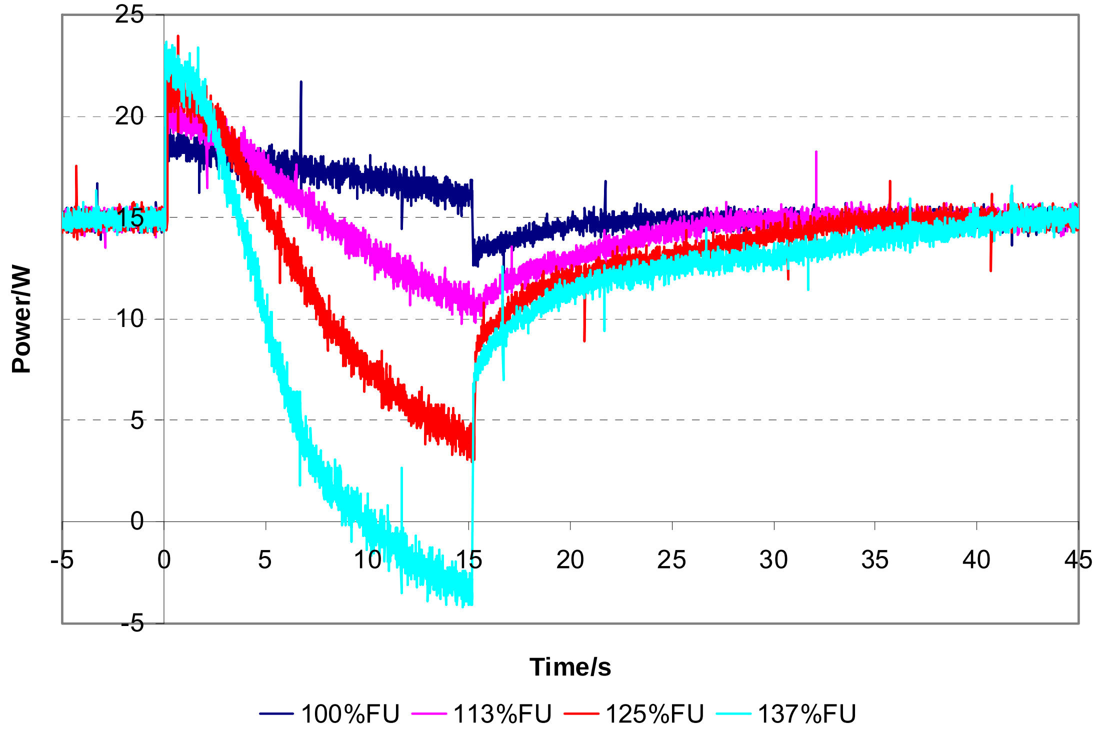
➢ Reliable

- Mechanical, shock and vibration
- Thermal, shock and thermal cycling
- Electrical, load cycling
- Chemical, poison (sulfur) and fouling (carbon) resistance

SOFC for Military Applications

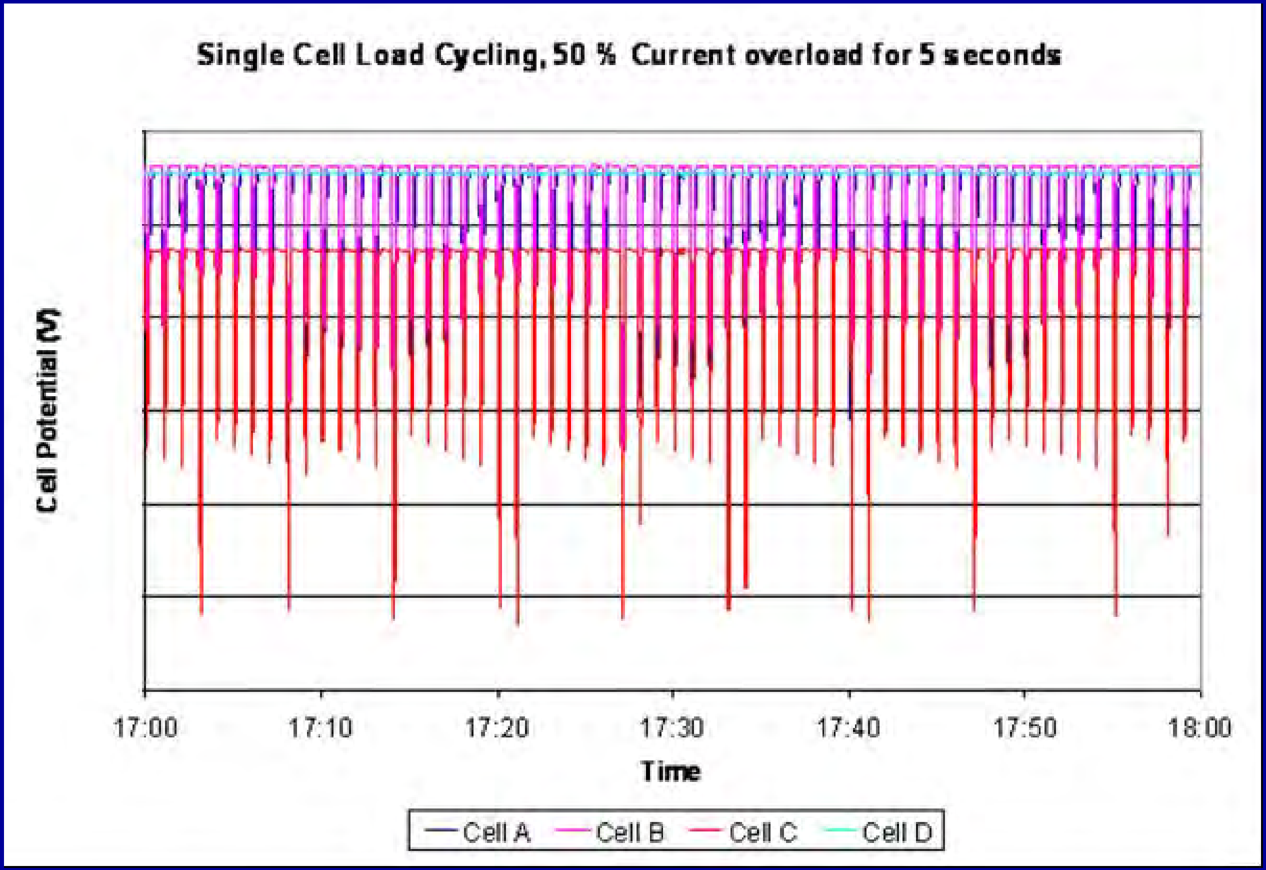
The fuel cell stack and BOP assembled onto the frame of a transit case

Electrical Load Cycling



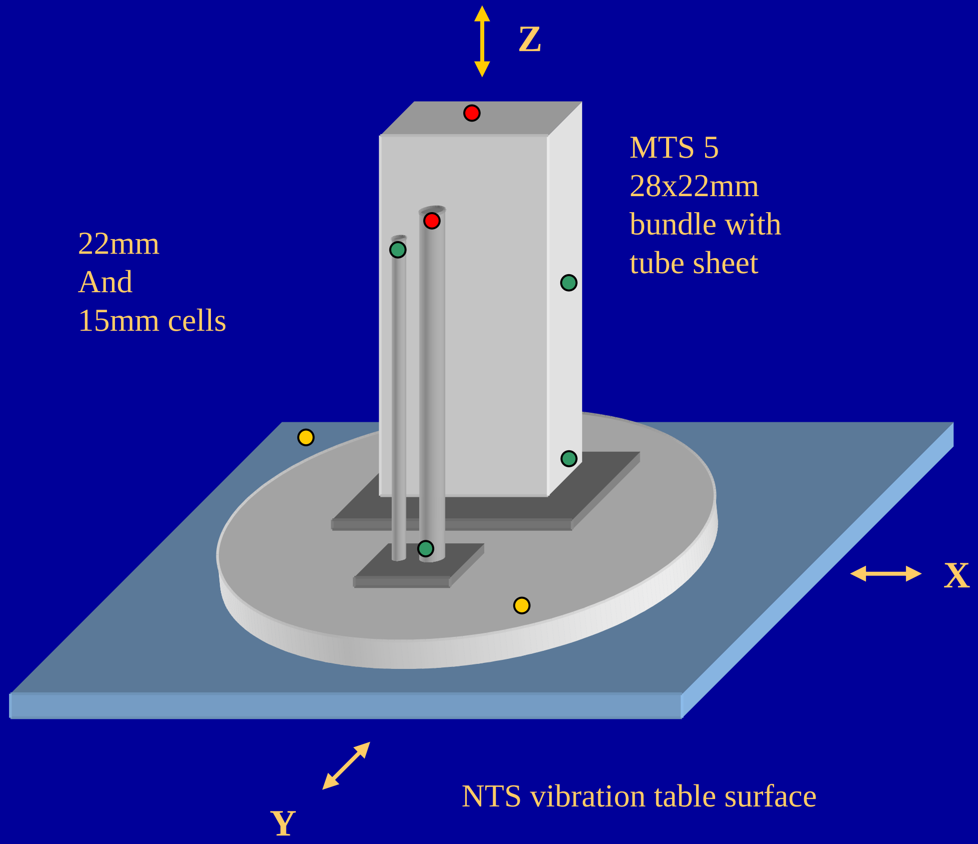
Cell voltage recovery after operation at >100% Fuel Utilization

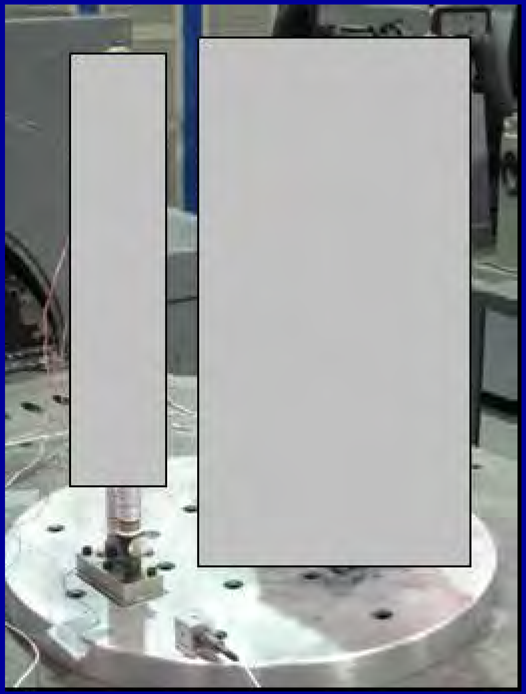
1000x Load Cycling



Mechanical Testing

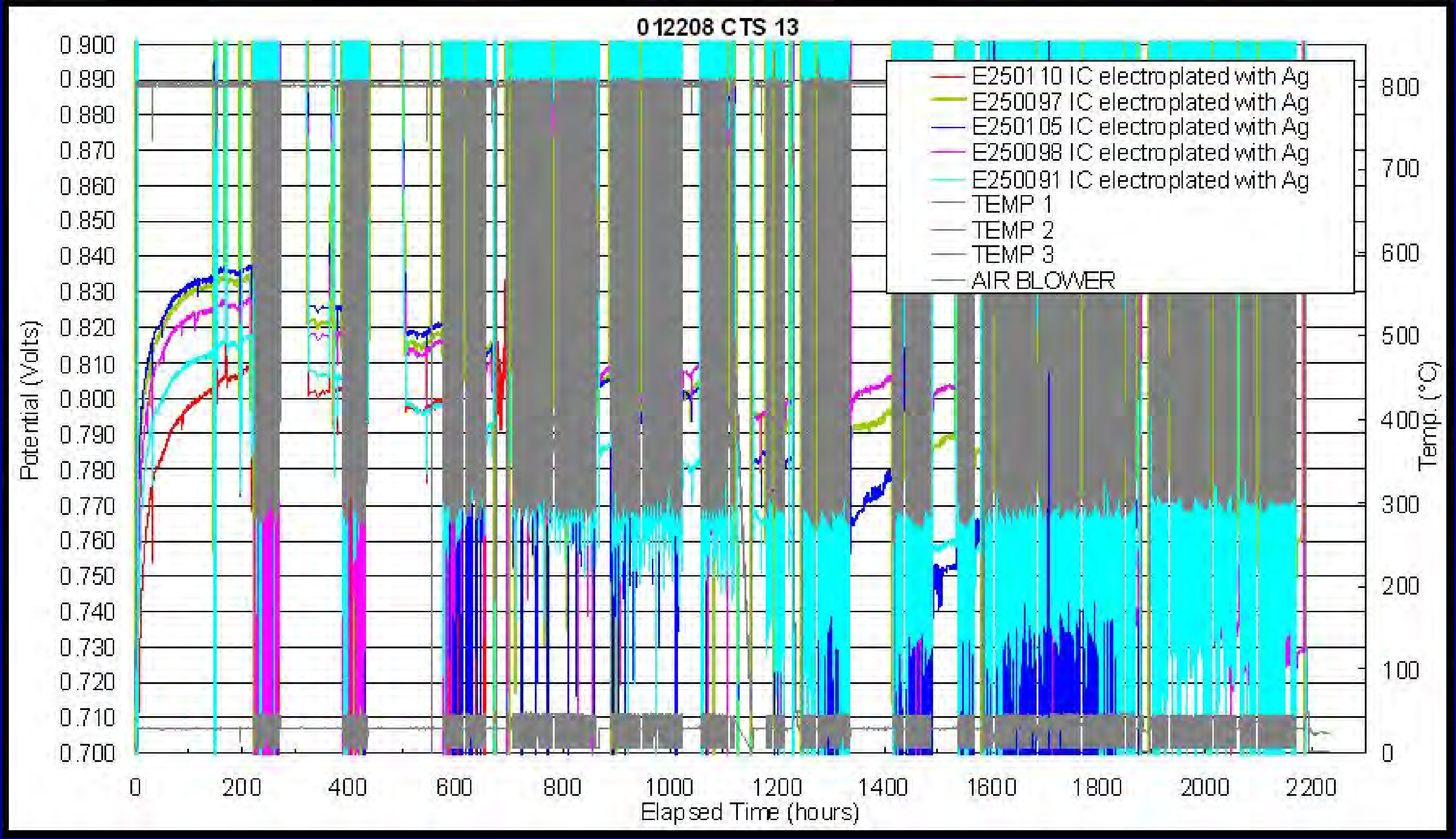
MIL-STD-810F 2 Wheel trailer 30 min vibration test



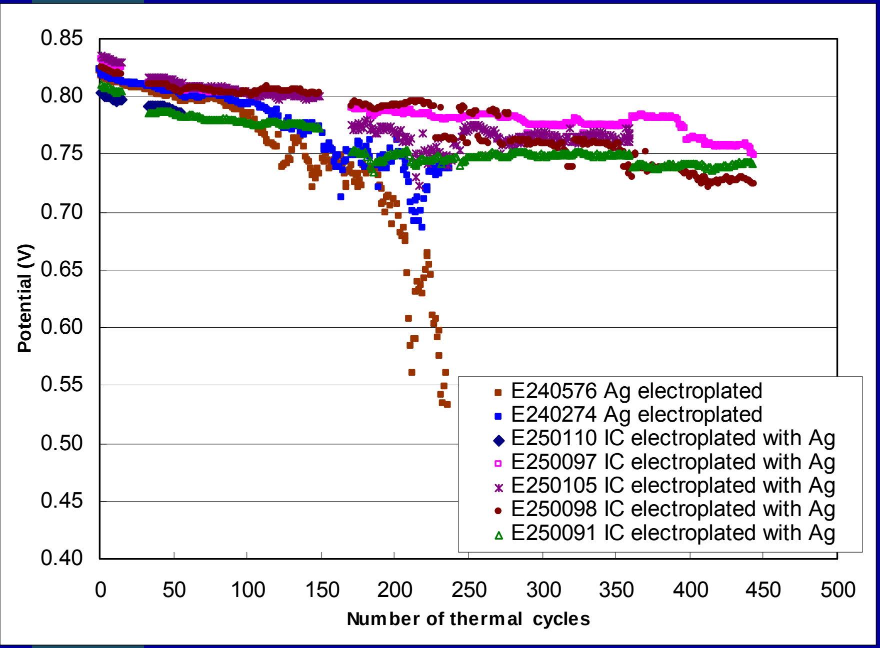


- Single axis accelerometer
- Triple axis accelerometer
- Single axis control accelerometer

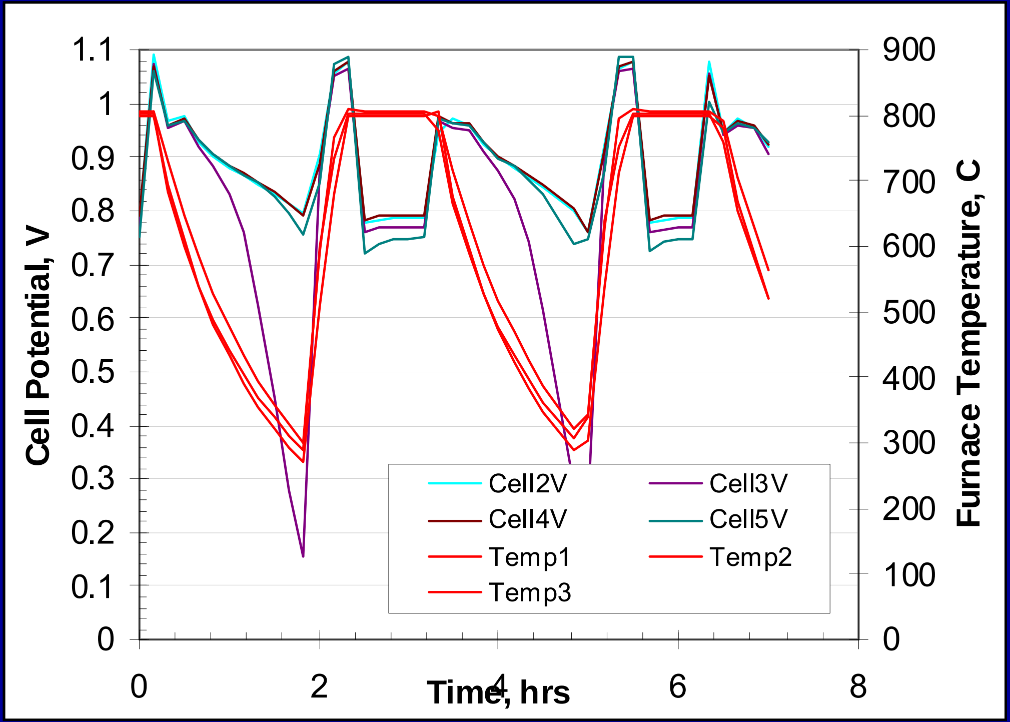
Electrical Testing- Thermal cycling



Electrical Testing- Thermal cycling



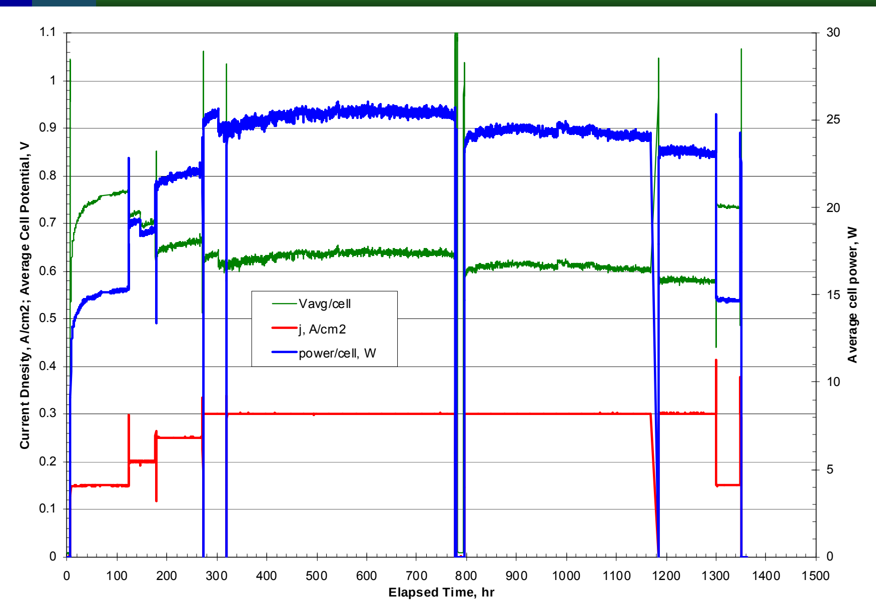
Loaded Cell performance graphs show a Loss rate of about 1%/100TC
~4000hr run time/1500hrs at power

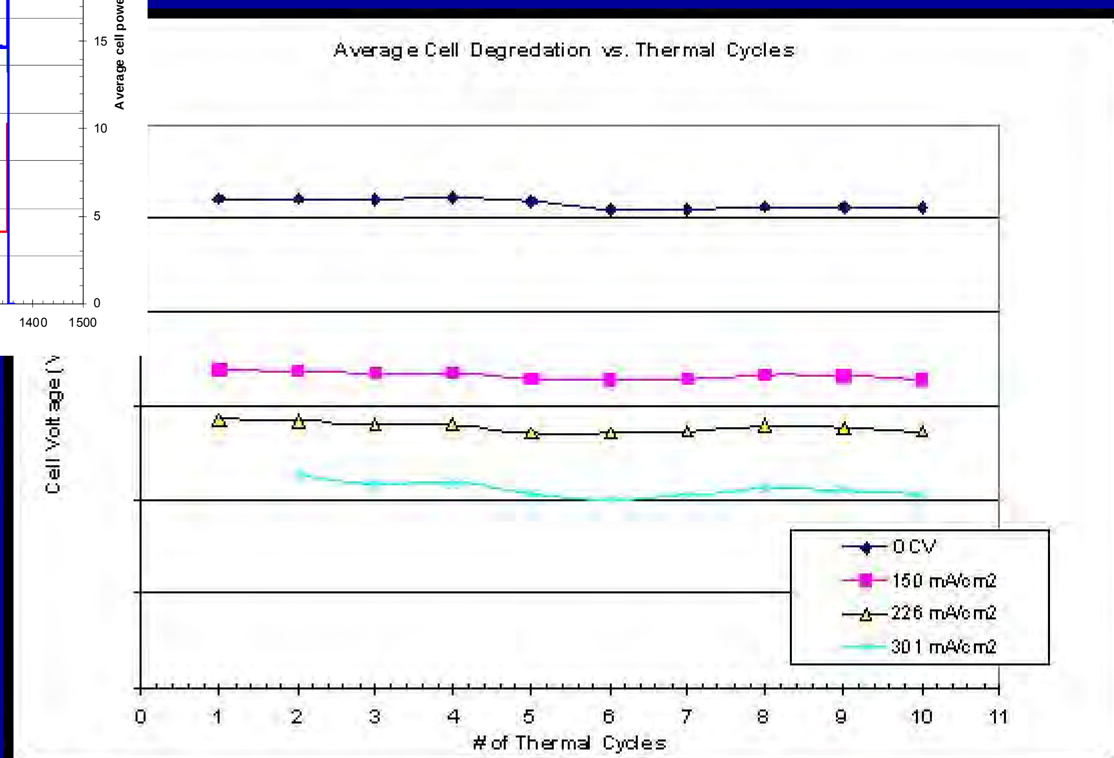


1. Unload cell and go to OCP- 5min
2. Go to Purge gas-Lower Temp to 300C
3. Back to 800C-start H_2, wait 10min
4. Load 30 minutes and record data
5. Loop

Acumentrics
Trusted Power Innovations

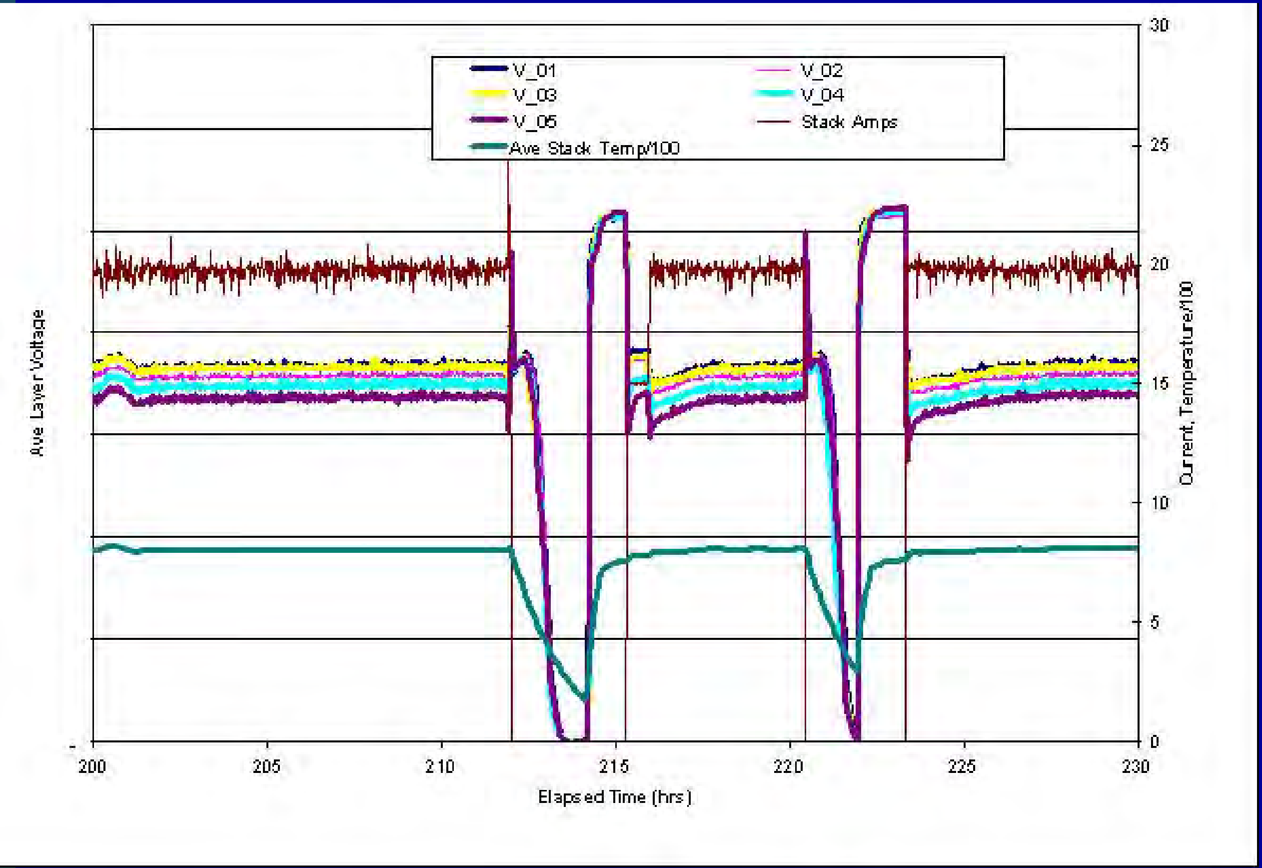
Thermal Cycles on Stacks





Hours Run	Time	Notes
0	**7/29/08 10:21**	**Start / Cycle 1**
0.59	7/29/08 10:57	light reactor
0.99	7/29/2008 11:21	CPOX
3.17	7/29/08 13:32	Pre-Reactor inlet sa
4.48	7/29/08 14:50	OCV
5.71	7/29/08 16:04	150
5.85	7/29/2008 16:12	226
5.95	7/29/08 16:18	shutdown, stack vo

Micro CHP Thermal Cycling



Schedule:

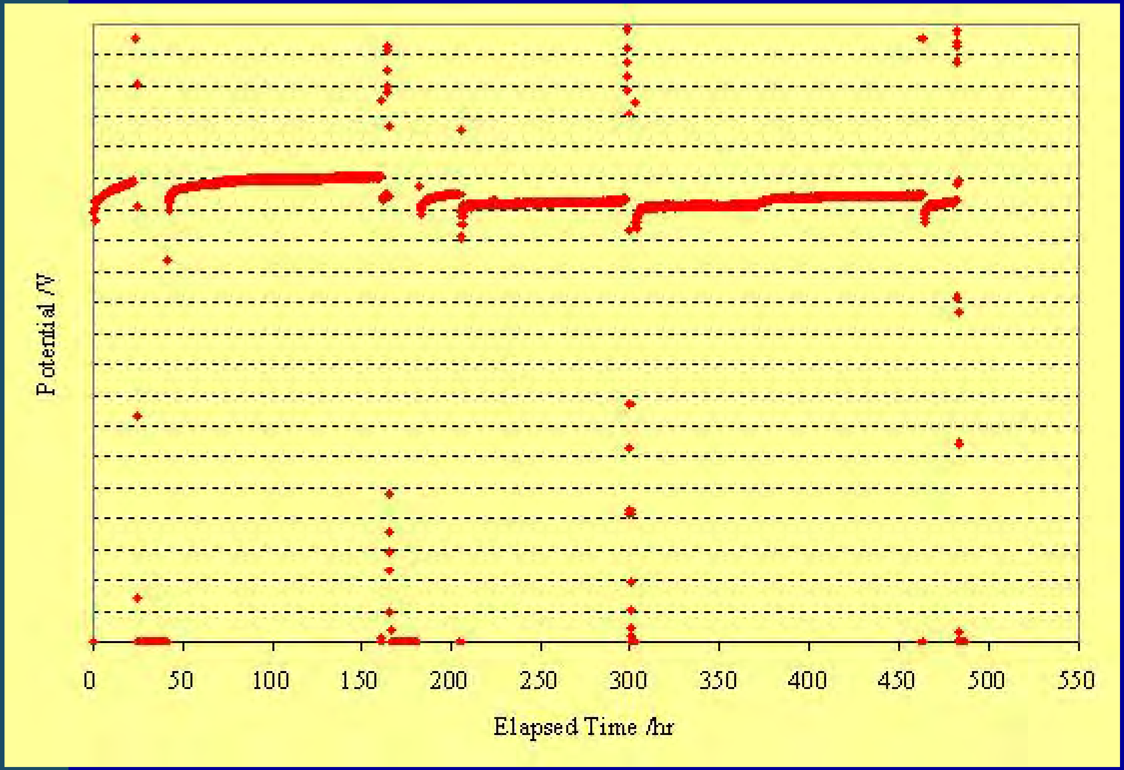
- About an hour down to ~200C
- Less than 30 min back to power
- Run
- Redo

20 thermal cycles

Purgeless cycles

Excellent recovery

Thermal Gradients



1/3 cell sitting *OUTSIDE* furnace

6 Thermal Cycles

459 load hours

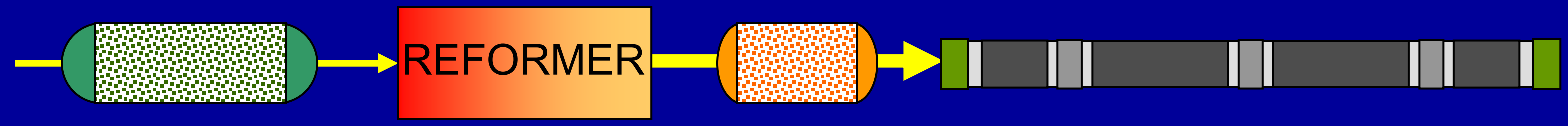
Fuel Flexibility

High energy density fuels

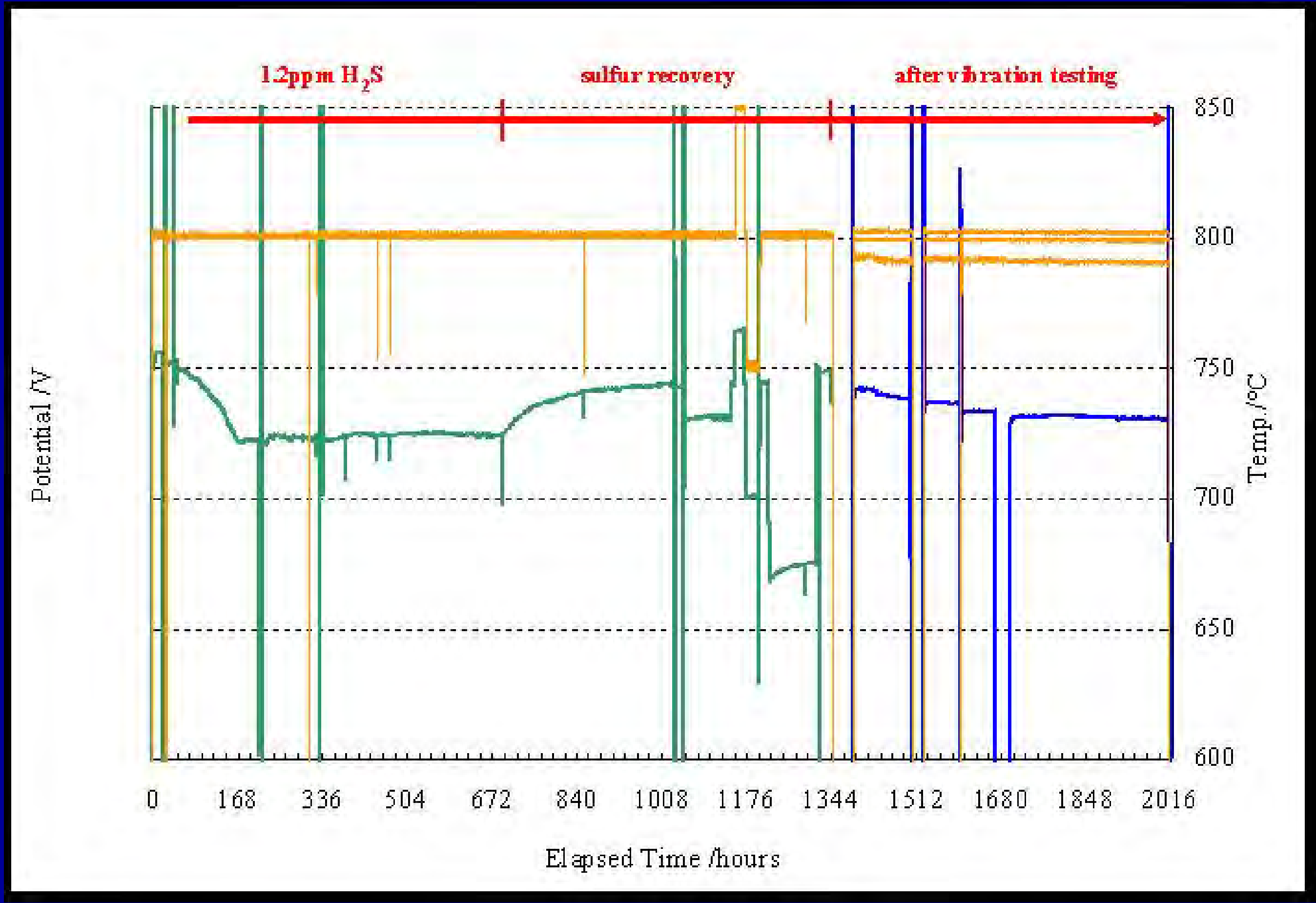
- JP-8 MIL-T-83133
  - Aromatics 15-20%
  - Olefins 1-2%
  - Saturates 78-83%
  - Sulfur 10-1000ppm
- Synthetic JP-8
  - Saturates 100%
  - Sulfur < 0.1ppm
- LPG
  - Sulfur up to 180 ppm

Sulfur Poisoning

- Sulfur present in large quantities in military fuels (possibly up to 1wt%)
- Common fuel cell catalysts susceptible to sulfur poisoning (need <10ppm)
- Solutions:



Sulfur Testing on Single Cells

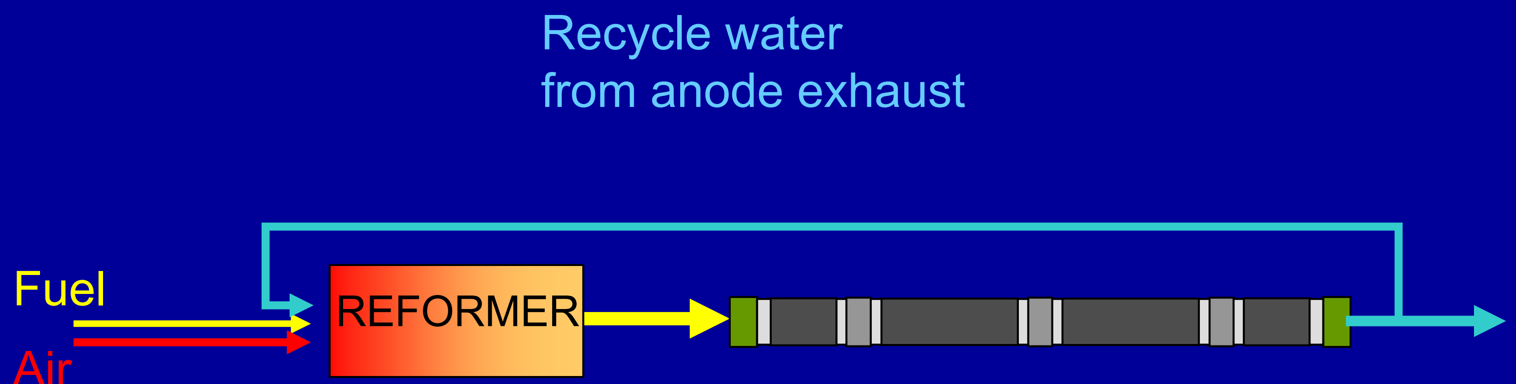


JP8 Reforming

- Reforming Modes
  - Steam reforming (H_2O, CH_x)
    - High efficiencies, requires significant water (high S/C), heat transfer difficulties, larger reactors, upstream liquid phase desulfurization
  - Partial oxidation (O_2,CH_x)
    - Less efficient, but small reactors and fast dynamics, down stream gas phase desulfurization
  - Autothermal reforming (O_2, H_2O, CH_x)
    - Best (and worst) of both worlds?
- Reforming Techniques
  - Catalytic, Plasma, Thermal

Water Neutrality

- Water at the military front is expensive!
  - e.g. 1 gal JP8 requires ~2 gal water at S/C=2
- Solution: Fuel cells produce water



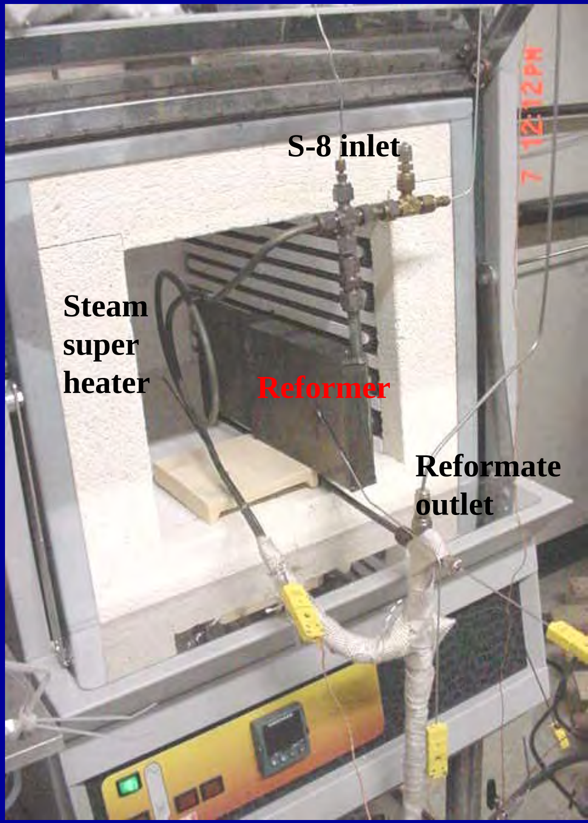
Catalytic Reforming at Acumentrics

Breadboard testing of reformers

- Steam Reforming
  - >1000hr testing on S-8 (zero sulfur) S/C=4
  - 300W stack test
- Partial Oxidation
  - JP-8 (~280ppmS) CPOX reformer at steady state
  - 24 hr test on 1kW stack
- ATR
  - ATR reformer
  - 1000hr testing on JP8 (~10 ppmS) on a 1kW stack
  - 2 days of transient testing, load following and cycling

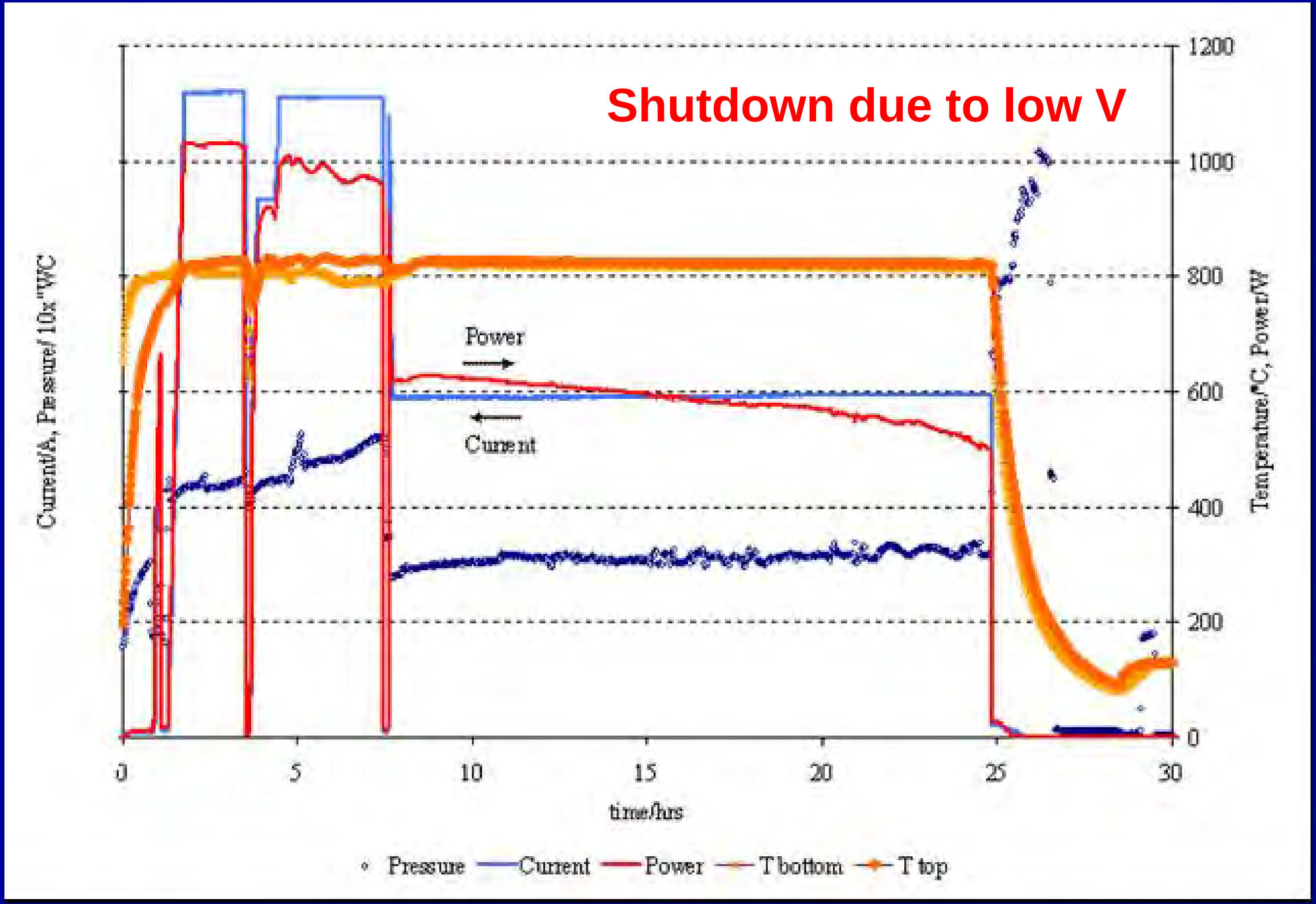
Steam Reforming of Synthetic JP8

- 48 gal of Synthetic JP8 reformed over 1550 hours.
  Total cell testing time on reformate was 1330 hours.
- Longest continuous cell testing (300W bundle) were 624 and 427 hr periods; stops due water and diesel pump failures.
- Longest continuous reformer operation was 1171 hours.
- Testing done mostly at S/C=4, also down to 3.5
- Total reformer testing to date approximately 2500hrs as scheduled.

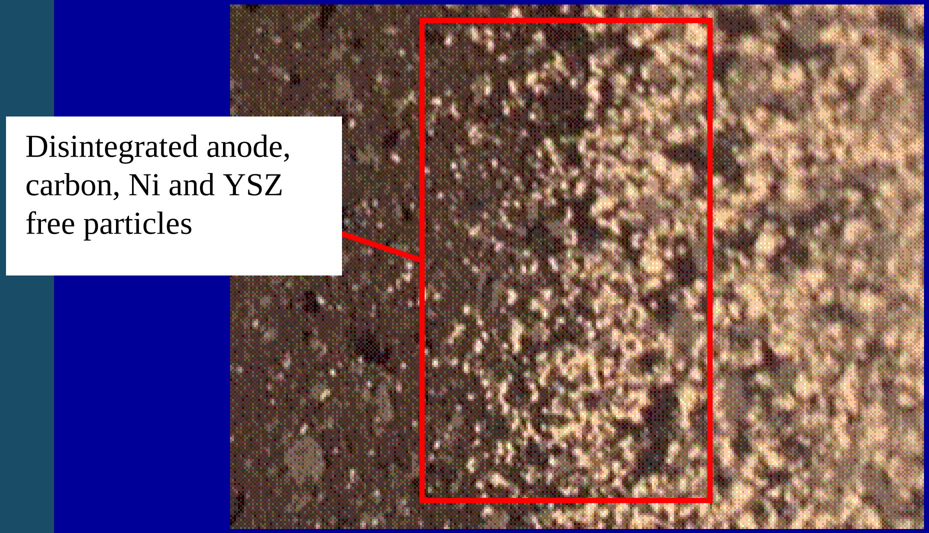


1 kW JP-8 CPOX

JP8, 280 ppmW S, O/C=1.03

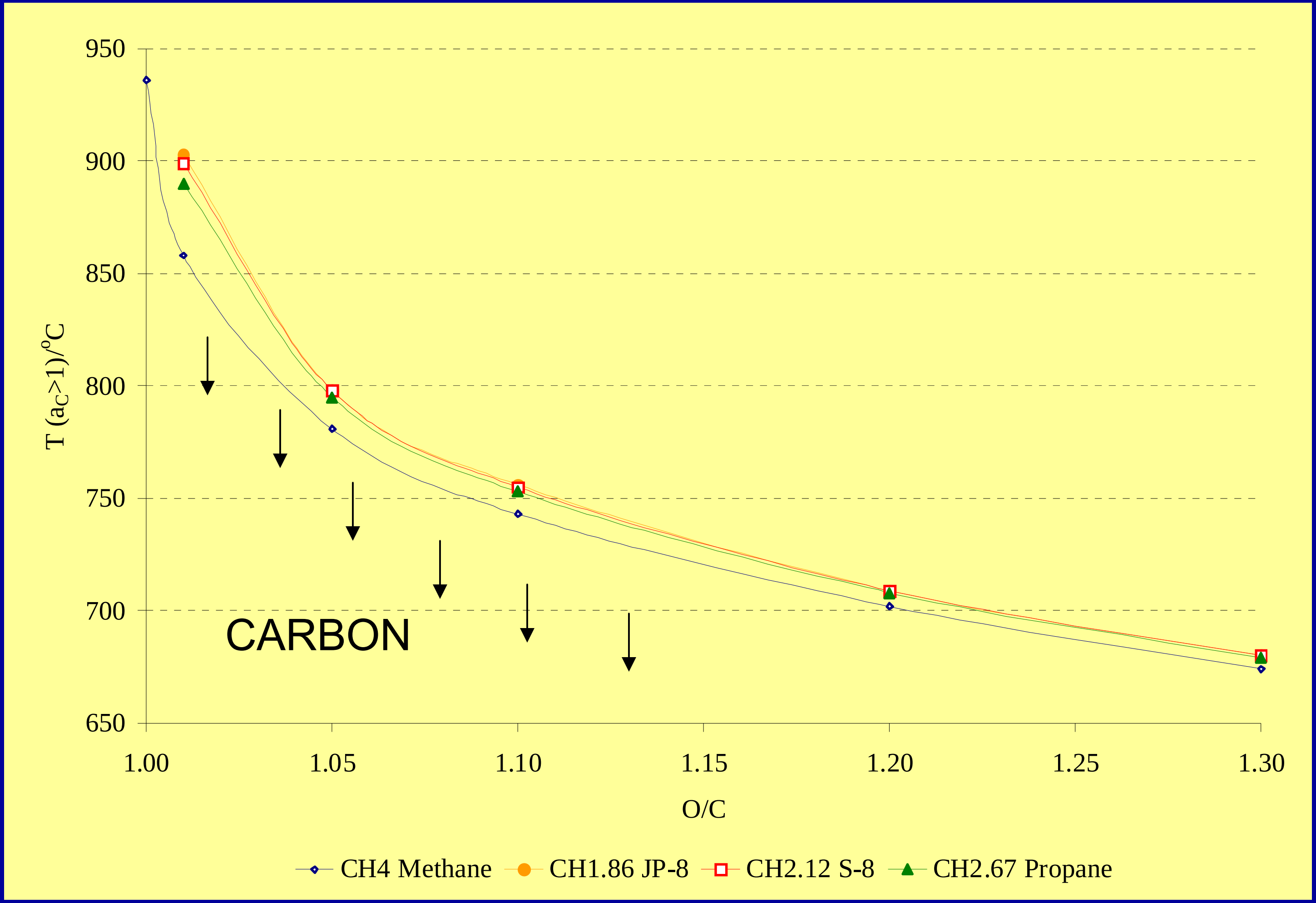


JP-8 CPOX 24 hr test



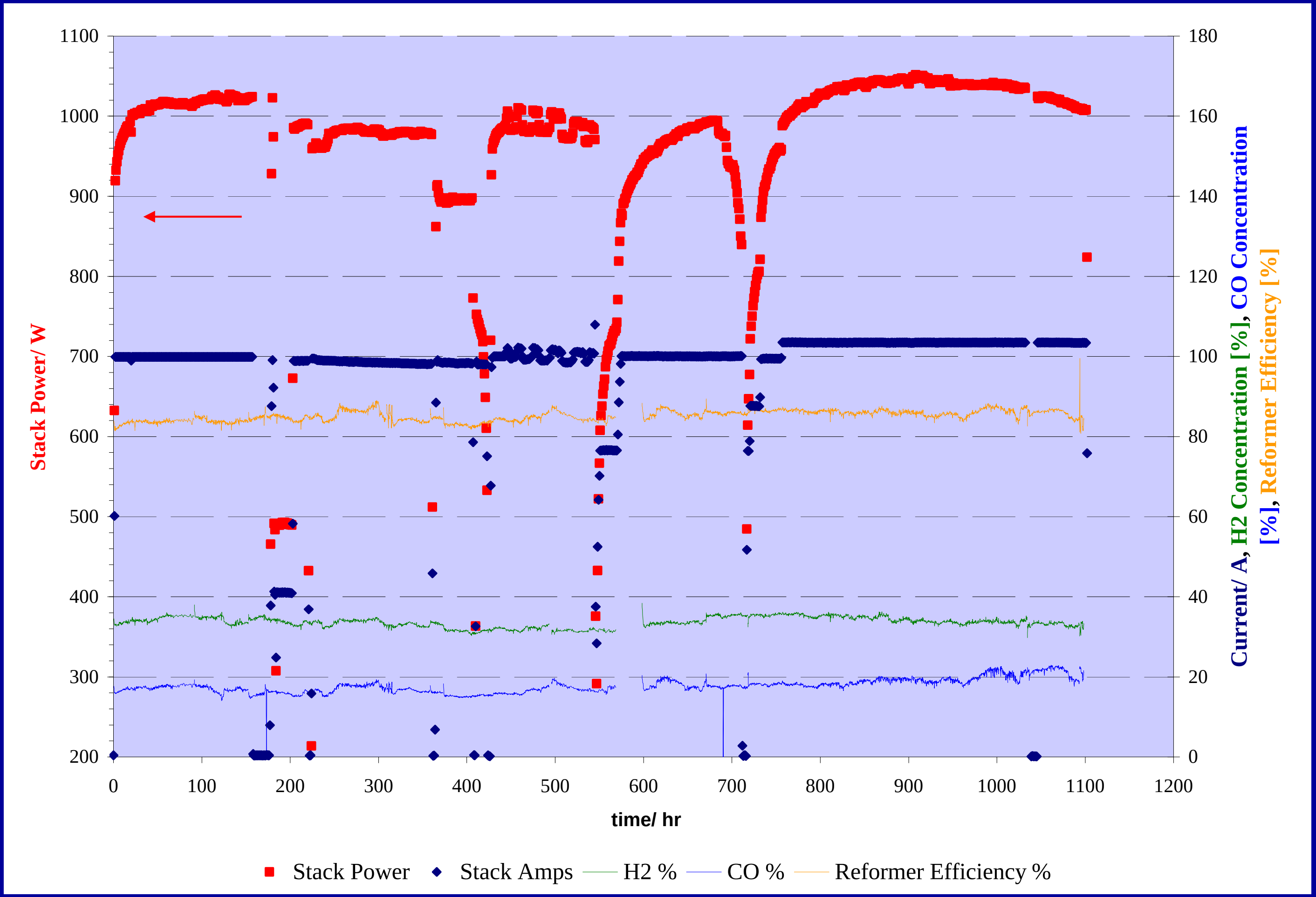
Carbon deposition throughout hot manifolds and cells (O/C~1). Temperature boundary for carbon deposition is ~800°C (*thermodynamic*)

CPOX Caveat

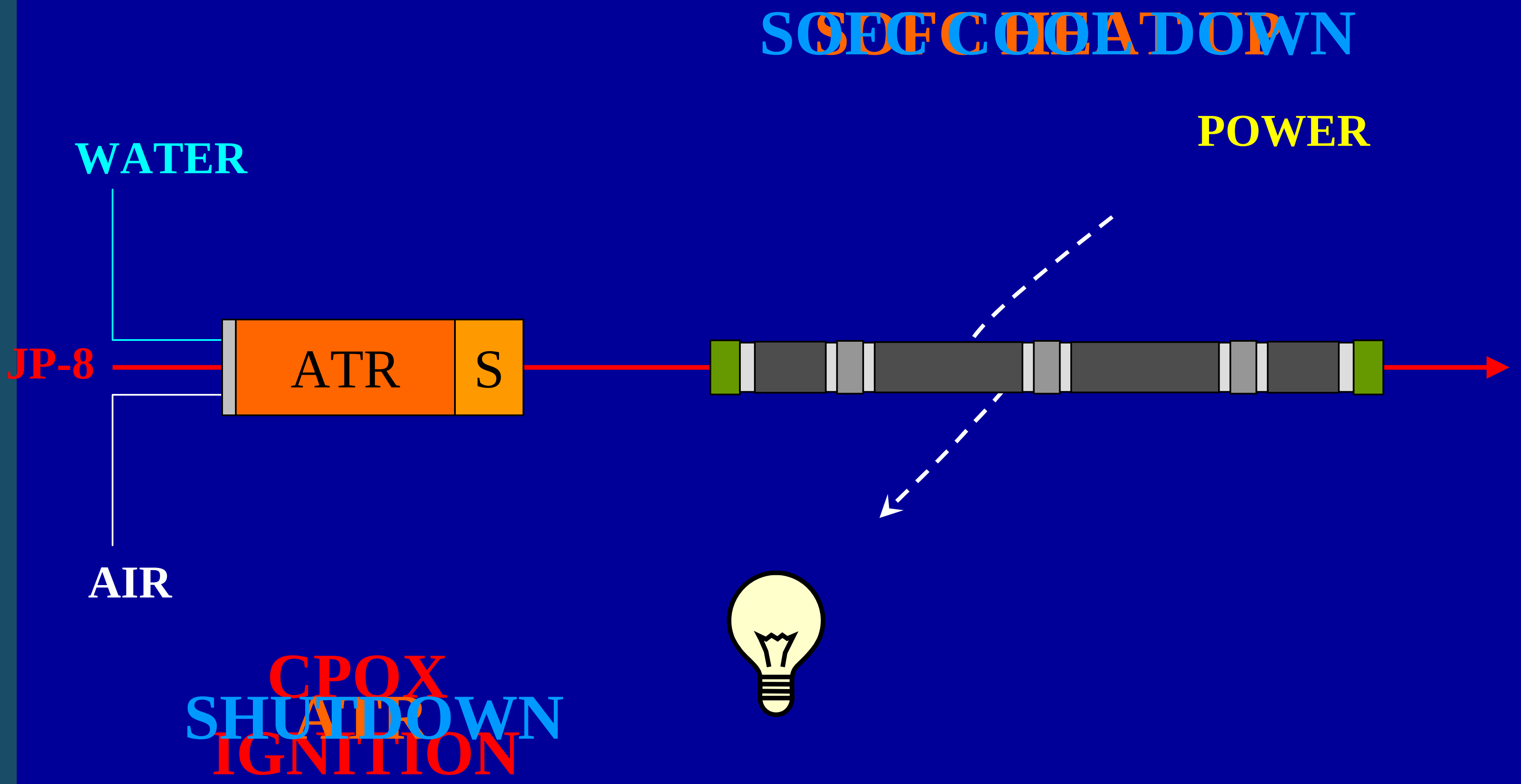


950
900
850
800
750
700
650
T (a_C>1)/°C
CARBON
1.00
1.05
1.10
1.15
1.20
1.25
1.30
O/C
CH4 Methane
CH1.86 JP-8
CH2.12 S-8
CH2.67 Propane

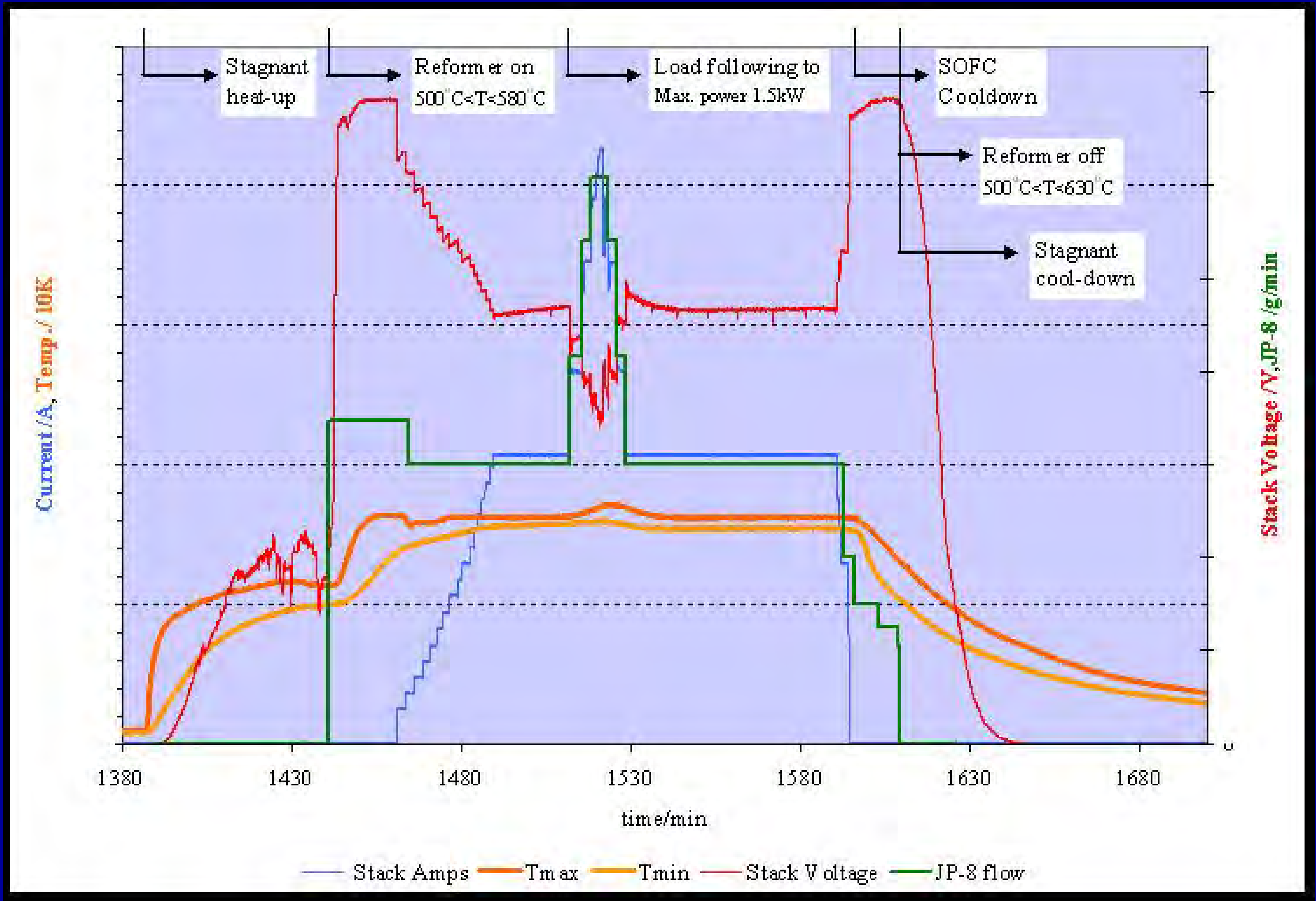
1000 hr ATR test on JP-8



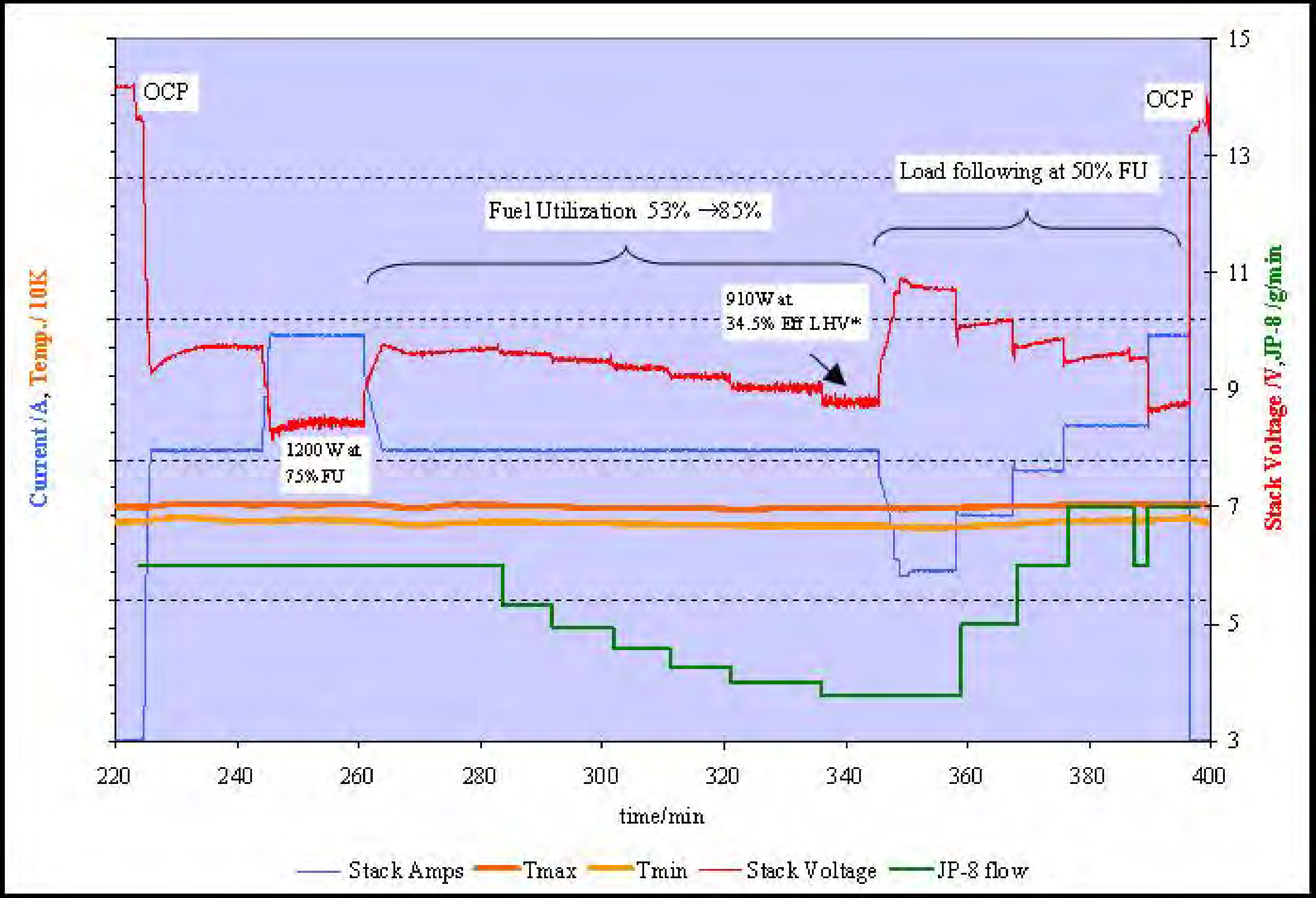
Direct JP-8 Start-up/Shutdown



Direct JP-8 Startup



Transient Testing



Going Forward

- Integration of SOFC stack with ATR reformer
  - SOFC controls ATR, enabling transient testing (fast start-up, load following, thermal cycling)
  - Incremental integration to full water neutrality
- Continued testing of reformers

Thanks to

- Reginald Tyler of EERE
- Don Hoffman, John Kuseian, John Heinzel of ONR
- MTS/Consortium members
- Acumentrics Team

QUALLION

>450wh/kg Li/CFx Technology with Low Temperature Capability at -70°C

Hisashi Tsukamoto, PhD, CEO/CTO Quallion LLC

Powering Life.

QUALLION

Key Business Metrics:

- Diversified across medical, military, vehicle and aerospace markets, 104 employees. More than 60,000 cells produced annually
- Quallion is fiscally sound with cash reserves and profitable. Quallion is not reliant on the external credit markets for expanding production
- Unique knowledge of Li ion chemistry as technology is rooted in Material science
- Active large Li ion battery programs include: USG Title III, Aircraft Retrofit, NASA Orion program (new space shuttle), Blackhawk Helicopter Retrofit, APUs for HMMWV, UAVs, Launcher Vehicle Batteries, Satellite Systems, USAF X-51 Scramjet

- In-house battery electronics design capability
- 5year/$40M United States Military contract to establish 30 year supply of materials and cells for satellite and military applications
- Strong Li ion battery IP Position with over 60 chemistry, cell and battery patents issued and numerous patents pending
- Operations contained within 52,000 sq ft production facility in Los Angeles, CA, with an option to expand to 200,000 sq ft of contiguous manufacturing space
- Certifications include ISO 9001:2000, AS9100B, and ISO 13485:2003

Powering Life.

QUALLION

Company Milestones

1998 – Company established in Southern California, USA

2001 – Developed 7 new cell designs (4 implantable grade); shipped 30,000 production units; plant reached 6,000 unit per month volume

2002 – Entered Aerospace/Defense market with OGA and CECOM Contracts Initiated Development of Primary Chemistries

2003 – Registered under ISO 9001 &13485; Zero-Volt™ technology patented (recertified in December 2004)

2004 – Zero-Volt™ technology patented

2005 – SaFE-LYTE™ technology patented

2006 – Title III Award; Registered AS9100

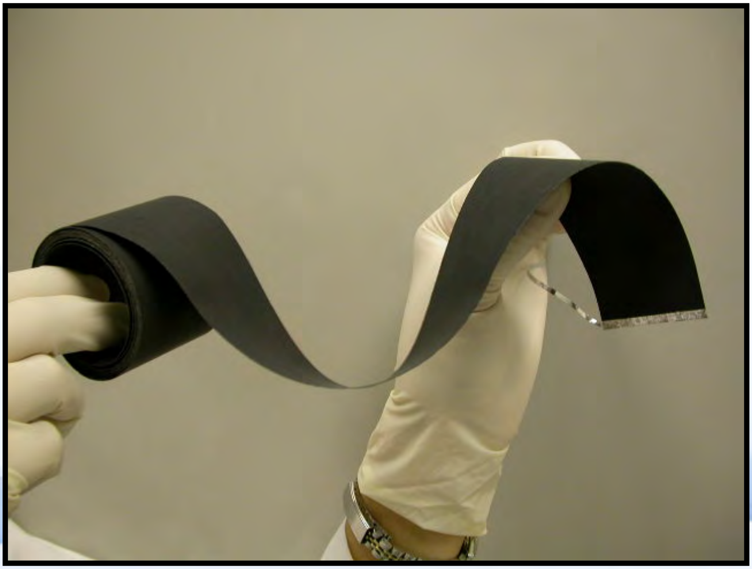
2007 – Frost & Sullivan Award for Lithium Ion Power Sources

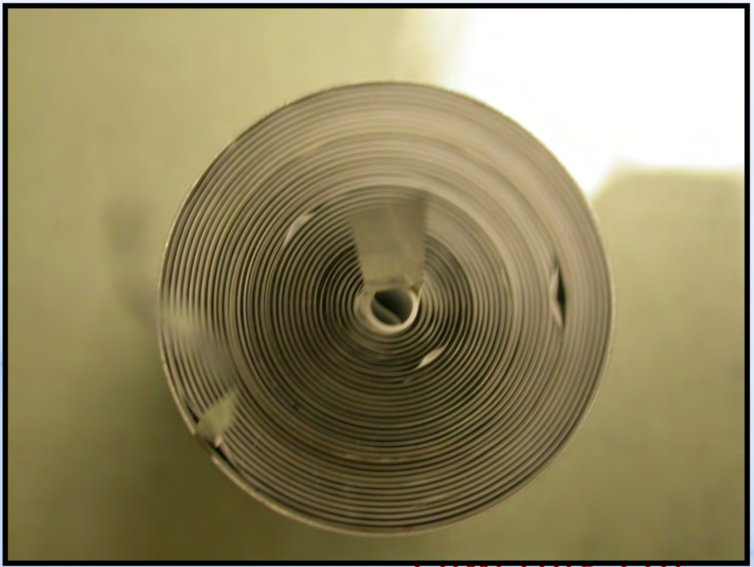
2008 – Boeing Technology Supplier Award

Powering Life.

Y2004: Proof of Concept >500wh/kg Li/CFx Cell (D-size, Aluminum Can)

- Thin film coating to create flexible electrodes that can be easily wound into a jellyroll.
- The high surface wound jellyroll design enables high power discharge of the cells.





__ISSUE__

Safety was concerned because of large exothermic reaction during high rate and high temperature discharge

QUALLION

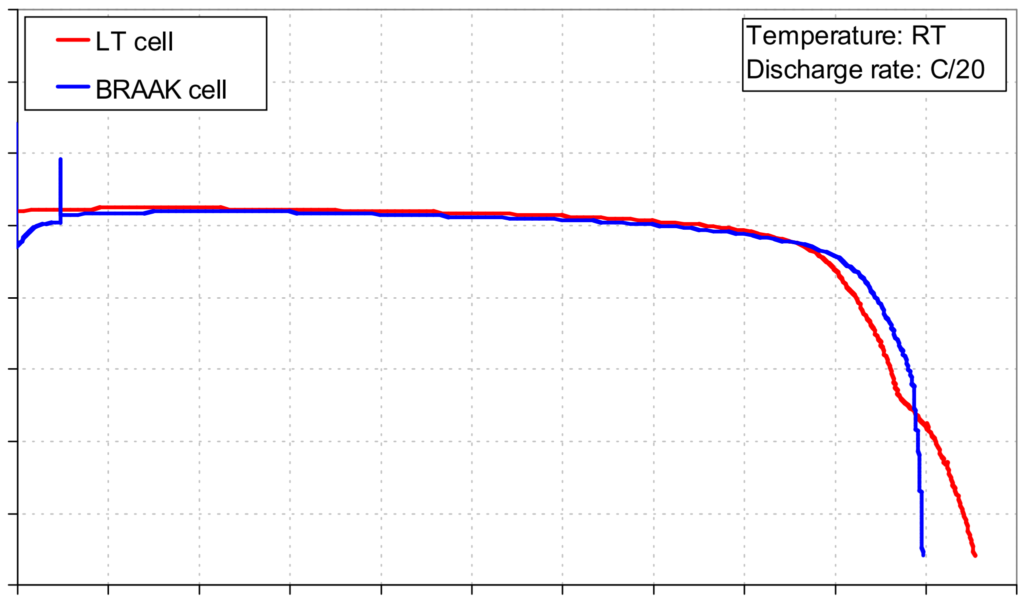
Y2007: Small Cell Approach with Advanced Safety and Low Temperature Capability

	Base line cell	Prototype (C-HE)	Base line cell	Prototype (AAK-LT)
	C-size		AA-size	
Chemistry	Li/CFx			
Nominal Volatge (V)	3			
Nominal Capacity (mAh)	5000	6500	2500	
Dimension (dimameter x height)	D26mm, H50.5mm		D14.5mm, H50.5mm	
Weight (g)	42	42	16	16
Energy density (Wh/kg)	357	464	468	468
Typical operating rate (C-rate)	<C/20		<C/5	
Typical operationg temperature (.C)	-40C to +85C			-70C to +85C

- Quallion is developing the Half-5590 pack with Li/CFx AA-size cells. The pack has 15Ah, 12V with 2.3lb.

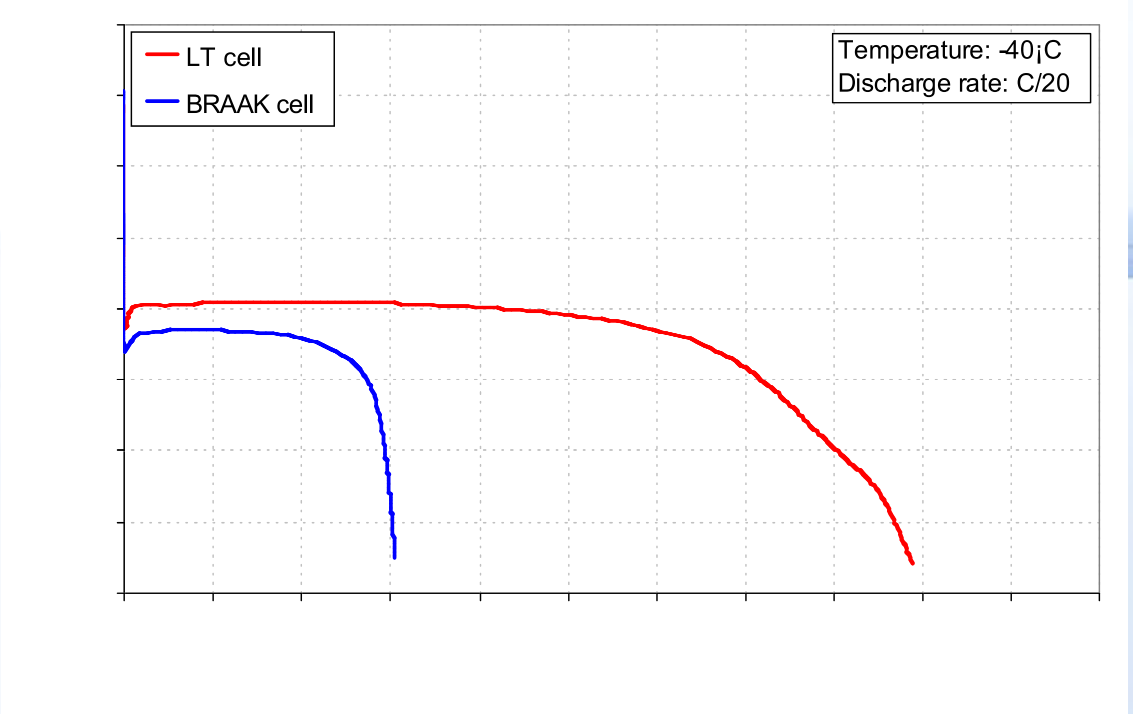
Comparison of SOA Li/CFx AA cell and Quallion low temperature AA cell (NASA application)

Room temperature discharge characteristic



Comparison of SOA Li/CFx AA cell and Quallion low temperature AA cell

-40 C temperature discharge characteristic

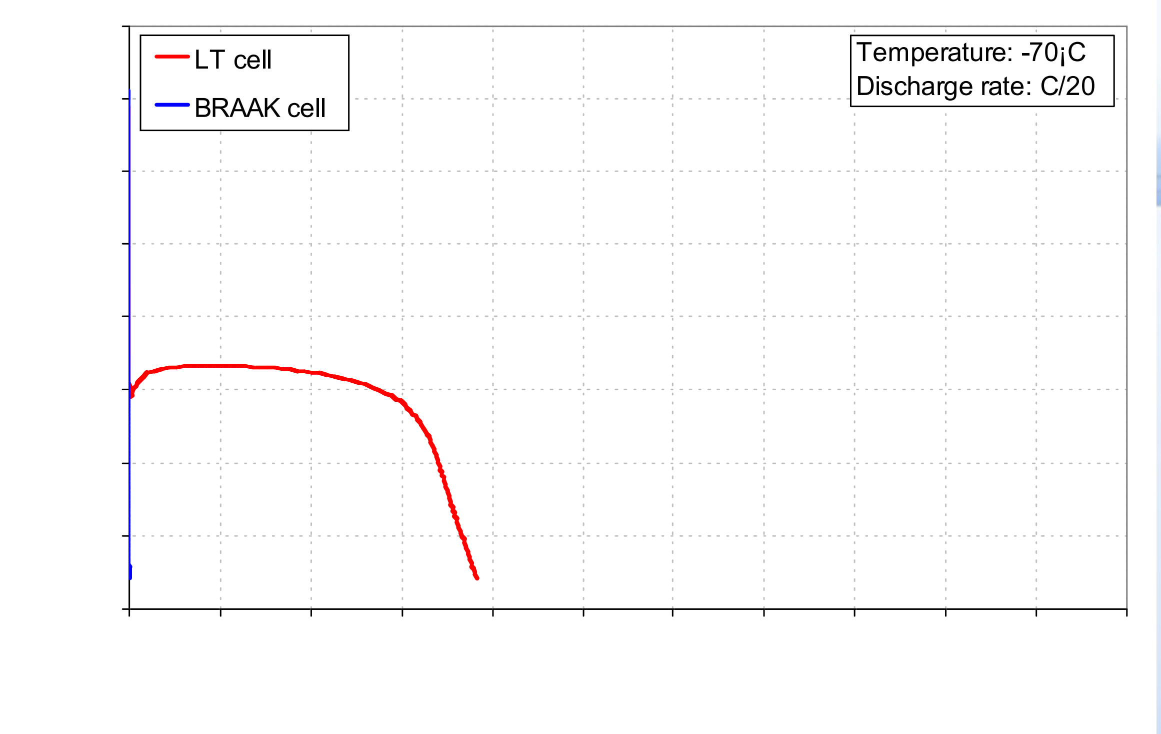


QUALLION

Powering Life.

Comparison of SOA Li/CFx AA cell and Quallion low temperature AA cell for NASA application

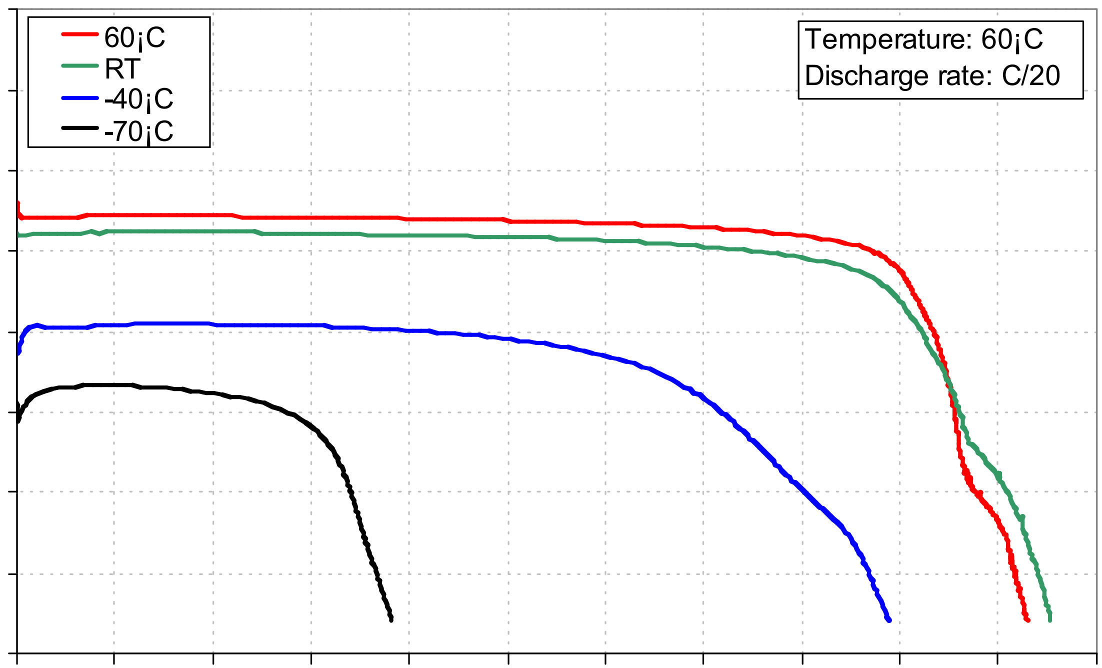
-70C temperature discharge characteristic



Powering Life.

Quallion low temperature LI/CFx AA cell performance

-NASA application-



SINCGARS to JTRS Radio Transition

JTRS Program: Produce a family of interoperable, affordable software defined radios to provide, secure, wireless, networking capabilities for Joint services.

LEGACY SYSTEMS

- SINCGARS (over 250,000 units produced)
- ASIP
- Falcon
- MBITR
- ATCS

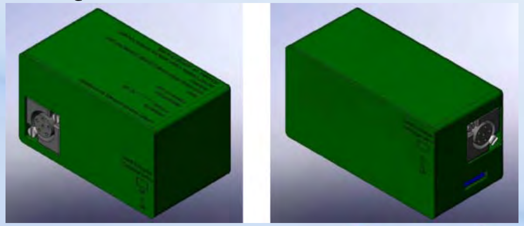
- HMS (Handheld & Manpack Systems)
- GMR (Ground Mobile Radios)
- AMF (Airborne Maritime)

Li/SO2 BA-5590

95% market saturation against primary and rechargeable solutions

Reduced envelope, lighter weight with same mission profile

Qualion Li/CFx Half-5590



Quallion Half BA pack with unique wide temperature Li/CFx chemistry

- Small cell approach (AA-size)
- -40 to 71ºC Operational
  - *Quallion Medical Li/CFx cell is capable 150 degree C Autoclave*
- 85ºC Storage Capable
- C/20 to C/3 Discharge Capability
- The Half BA pack with **15Ah, 12V and 2.3lb**

QUALLION

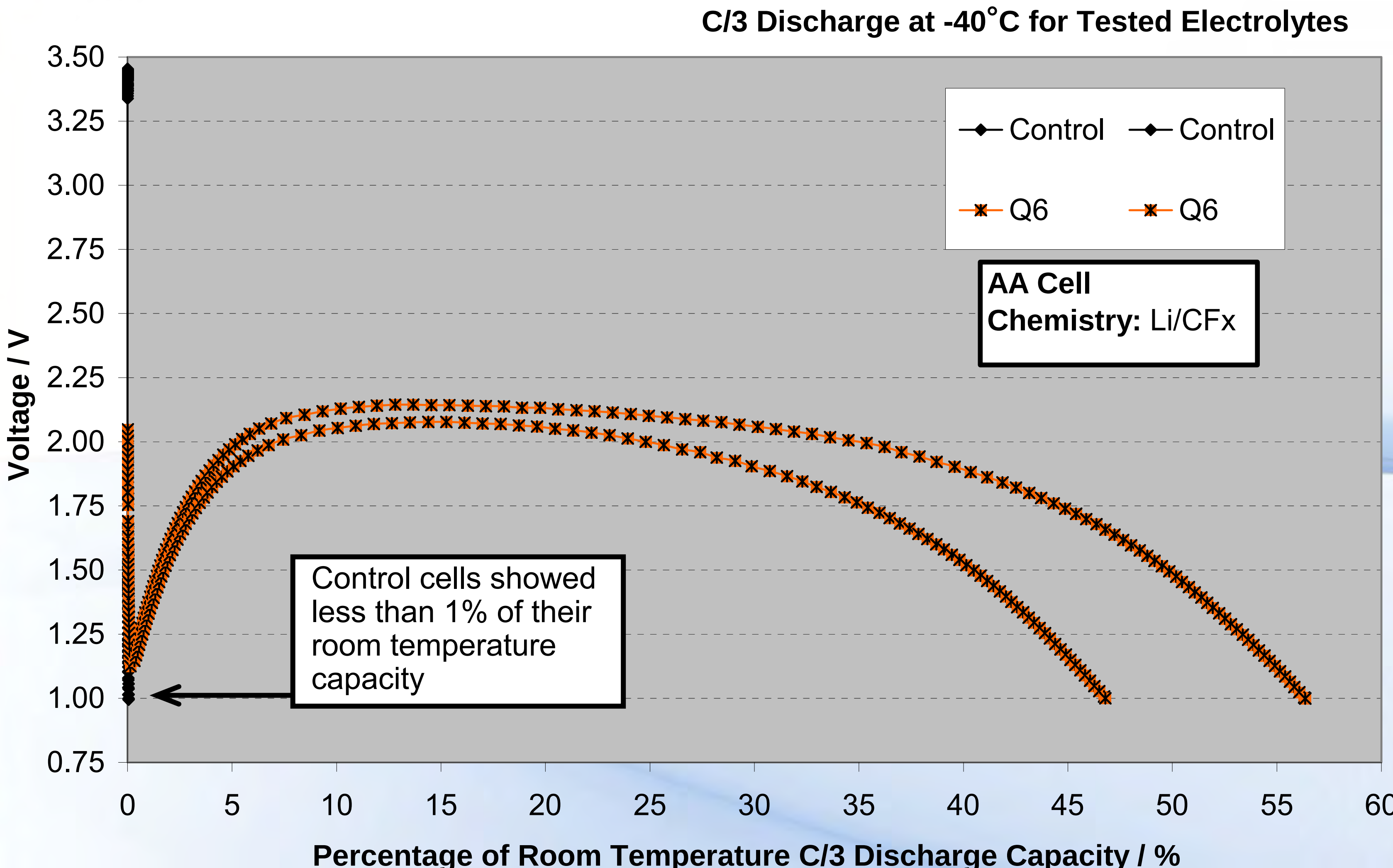
Cell Design
Qualion Wide Temperature Primary Battery with ***966 Wh/L*** Capability

Cell type	**Li/CFx AA**
Nominal Voltage	**3V**
Nominal Capacity	**2.5Ah**
Standard Discharge Current	**2.5mA**
Weight	**16g**
Electrolyte	**Quallion Low Temperature electrolyte**

NOTE: D (D34.2 xH61.5mm) size Li/CFx cell with 15Ah has ***798 Wh/L*** energy density. The 2.5Ah AA (D14x H50.5mm) size Li/CFx has 20% larger energy density than 15Ah D size Li/CFx.

Powering Life.

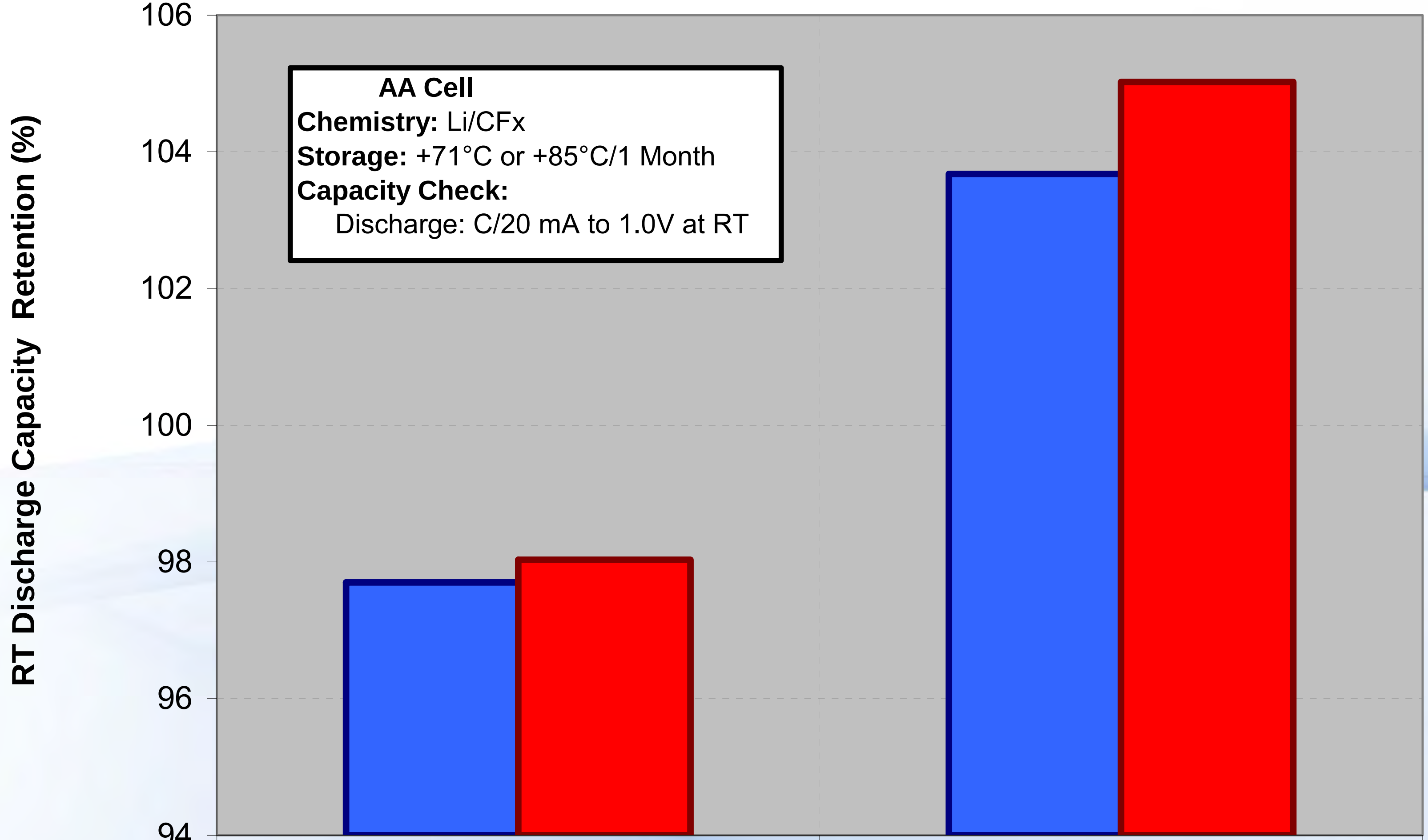
C/3 Discharge Curves at -40°C



Discharge : C/20A to 1.0 V at -40°C

Powering Life.

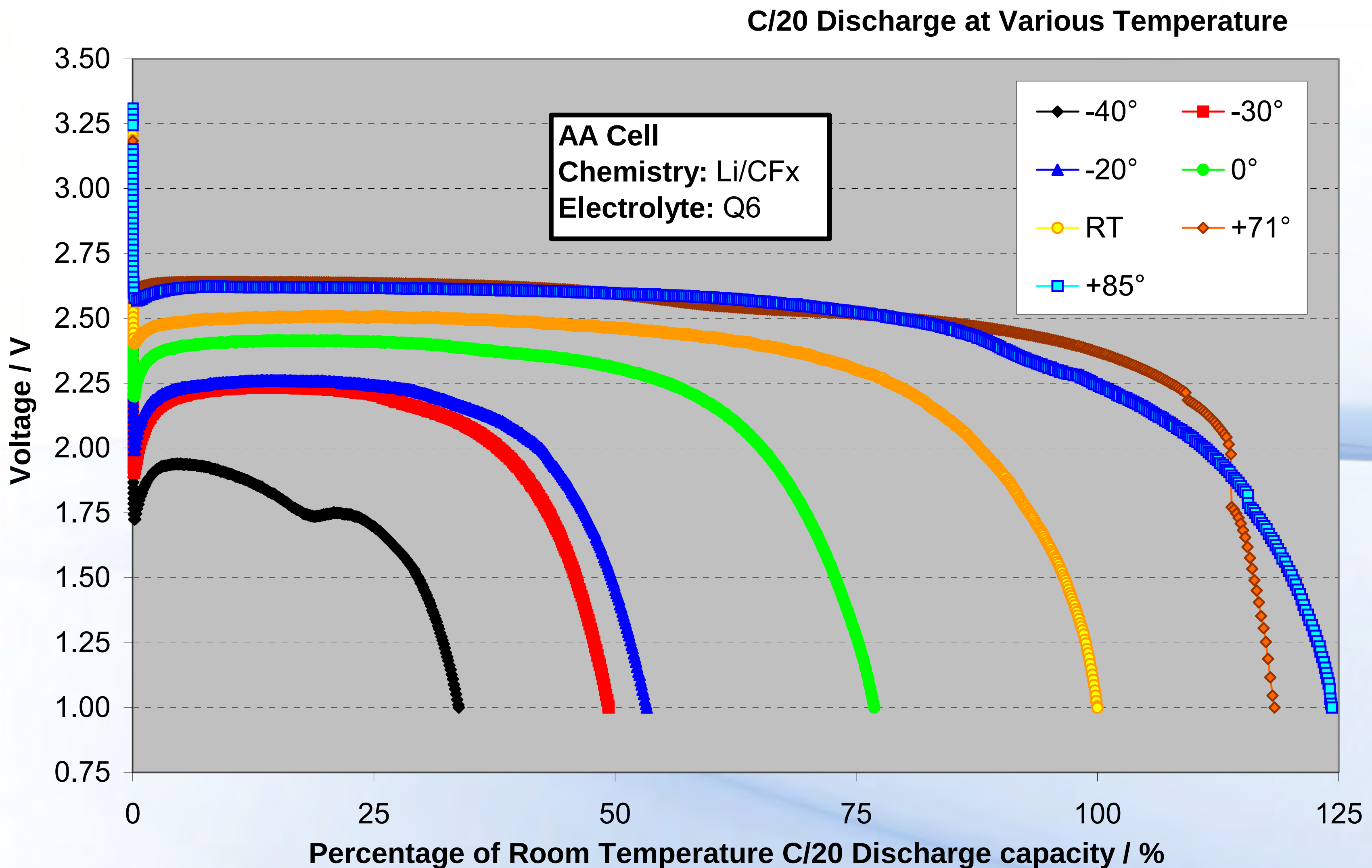
Capacity Retention After 1 Month +71° or +85°C Temperature Storage



	CTL-1	Q6
85°C % Retention	98	104
71°C % Retention	98	105

Powering Life.

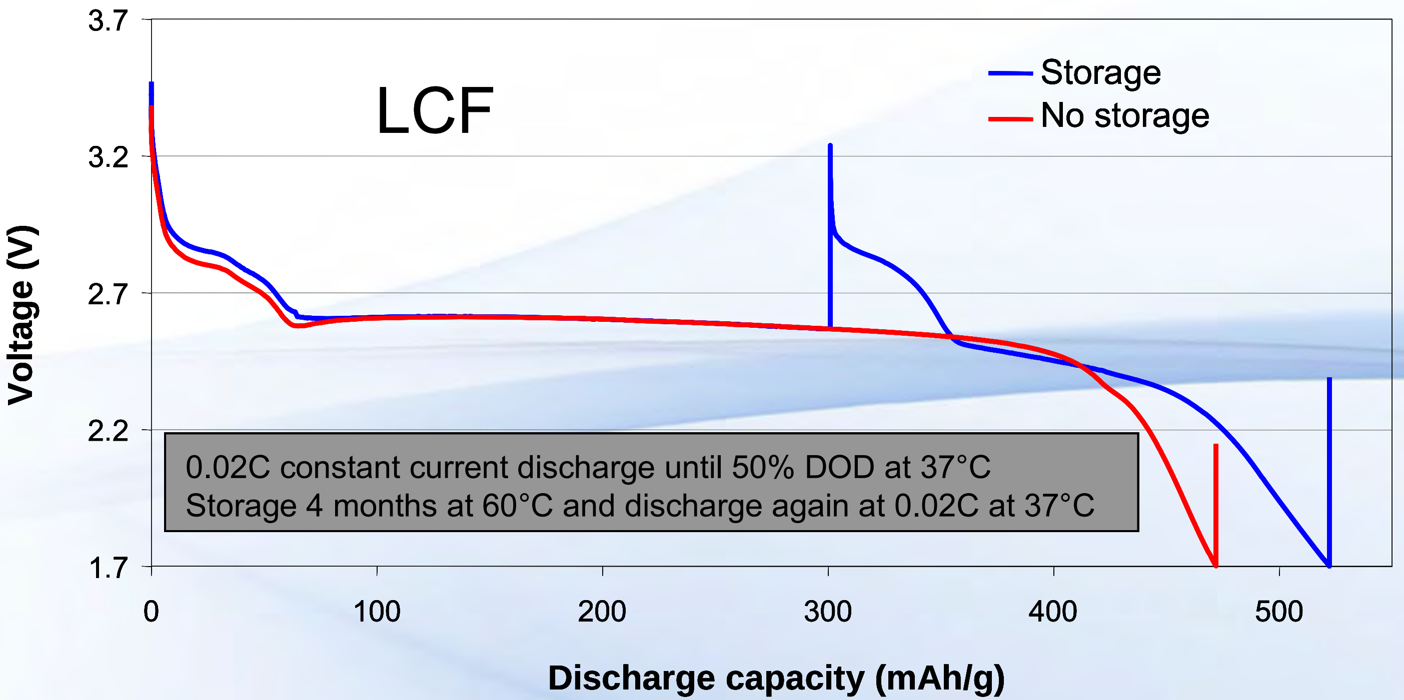
C/20 Discharge Rate Data of Q6-AA Cell



Discharge : C/20A to 1.0 V at -40°, -30°, -20°, 0°, RT, +71°, & +85°C

Powering Life.

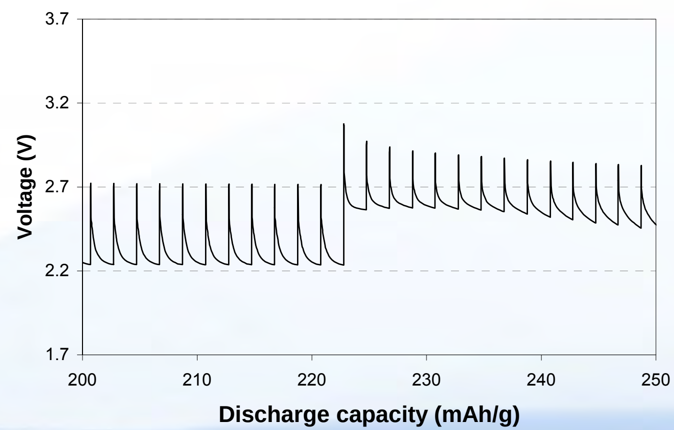
LCF Technology: Discharge Curve after 4 months Storage

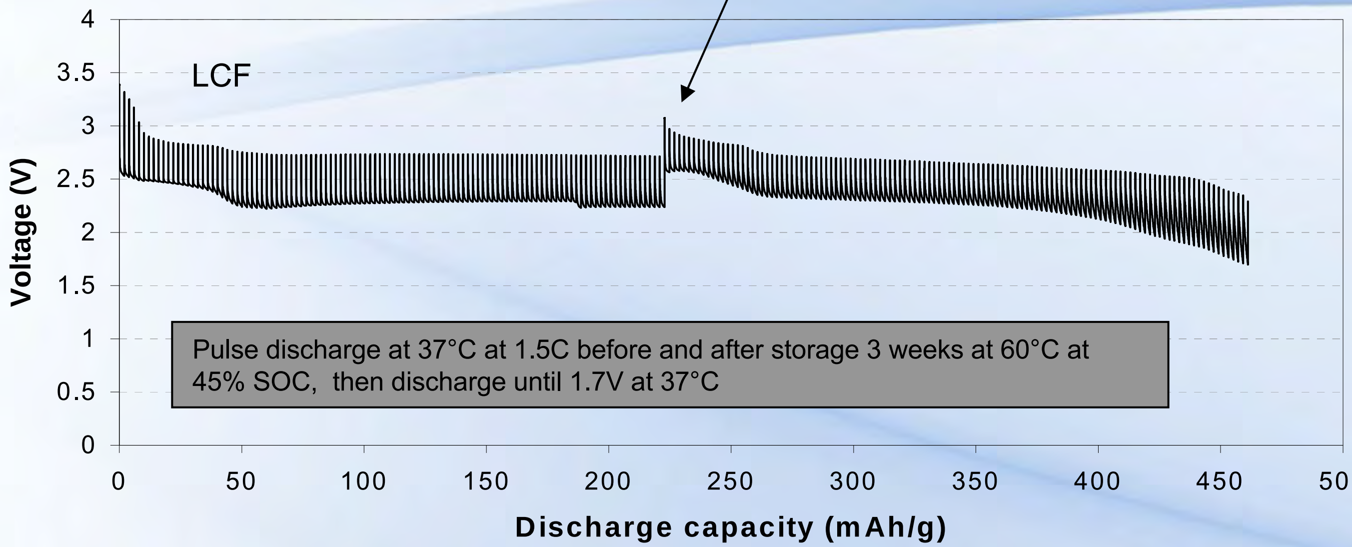


Note: After storage, the cell again showed LVO discharge curve at initial discharge period.
This proved that LVO was charged during storage by CFx which has higher OCV.
Stored cell and Non-stored cell showed comparable discharge capacity.
This indicates that LVO did not accelerate self discharge of the cell.

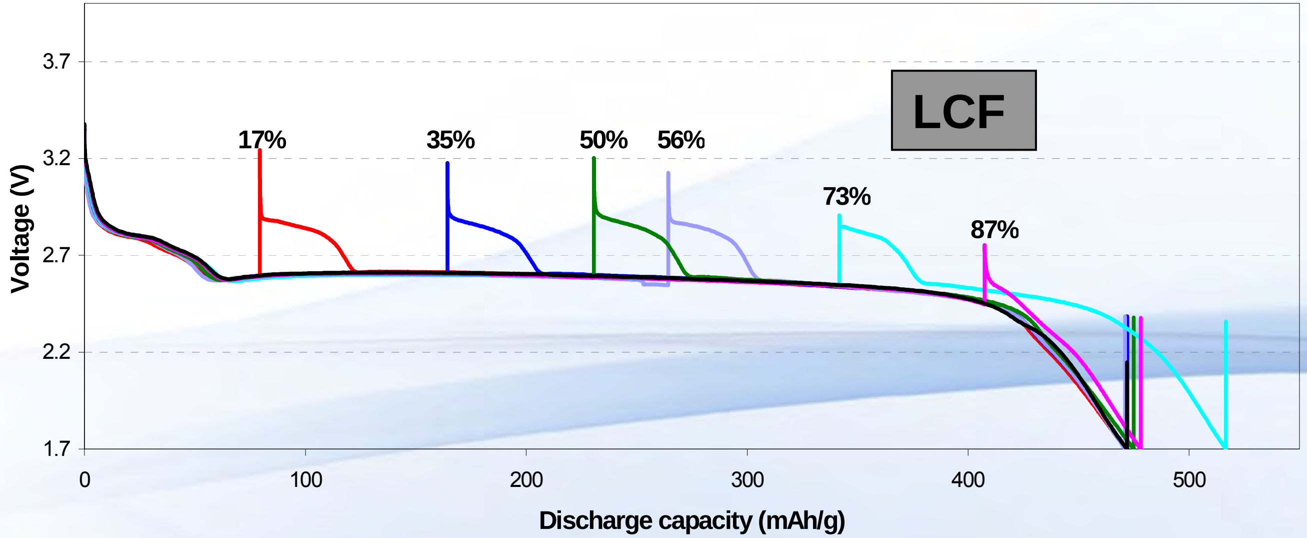
Powering Life.

LCF Technology: No voltage Delay after 60 degree C, 3 weeks at SOC 45% Storage





LCF: Discharge Curve after Storage at Various DOD



0.02C Constant current discharge with 3 weeks storage at different DOD then until 1.7V, 37°C

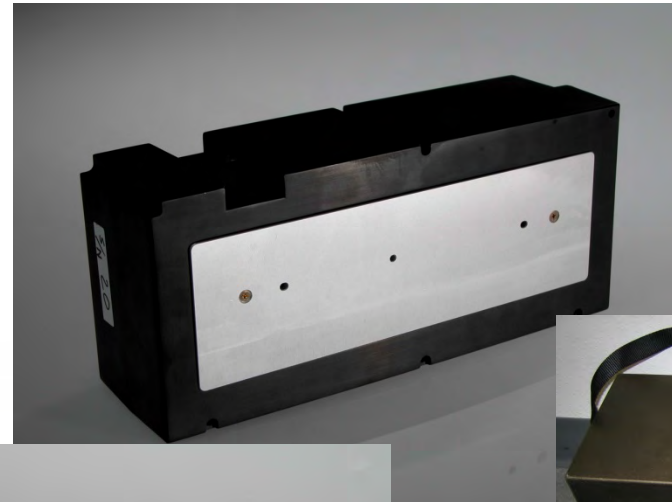
QUALLION

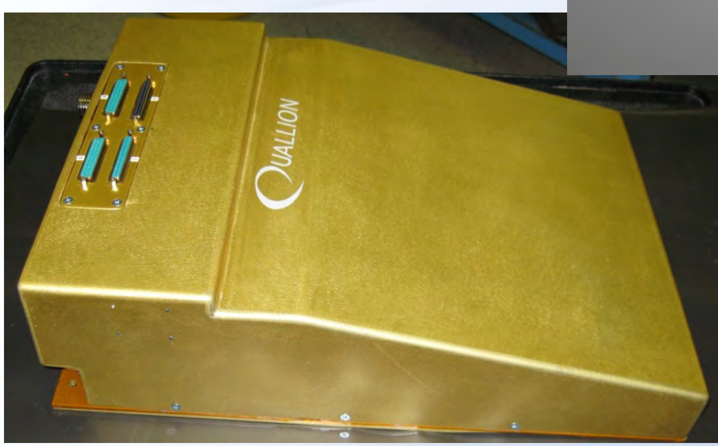
Qualliion Li/CFx Summary

- Improved Low temperature performance of Li/CFx cells through low temperature electrolyte formulation
- Removed voltage delay issue by Quallion unique LCF technology
- The half BA pack with **15Ah, 12V and 2.3lb**

Powering Life.

QUALLION





Powering Life.

Joint Service Power Expo 2009

Battery Management
and Sustainment System

PulseTech Products Corporation

Presented by:

PulseTech Products Corporation

Mark Abelson

800-580-7554, ext. 167

817-307-5603 (cell)

mabelson@pulsetech.net

www.pulsetech.net

Battery Failure in 24 Volt Systems

- Most 24V systems are made up of multiple batteries in series or series parallel
- Failure occurs for a variety of reasons
  - Received “new” in an undercharged condition
  - Never fully recharged
  - Key off loads
  - Parasitic drains
  - Environmental
  - Battery set imbalance
    - 12 Volt Taps
    - Dissimilar Chemistries

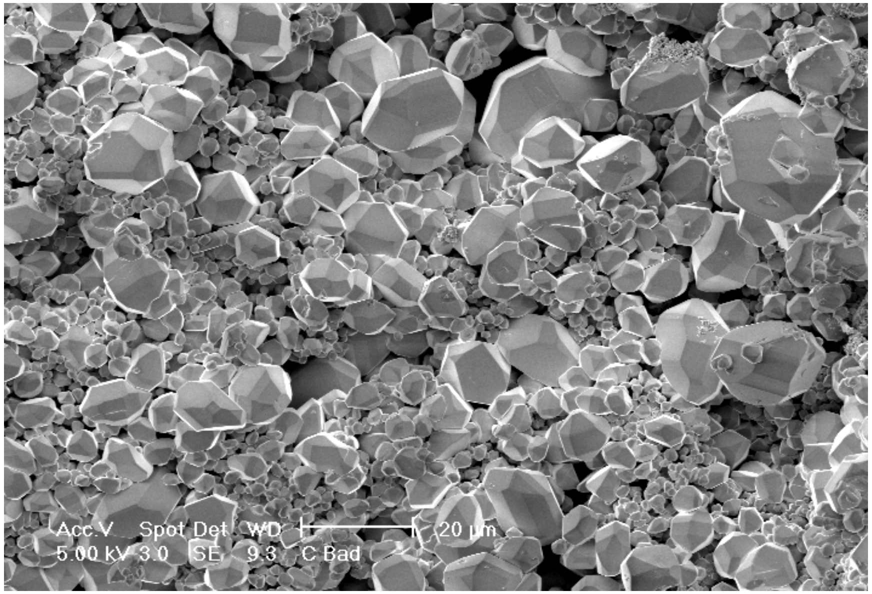
PulseTech Products Corporation

Impact on Battery Performance

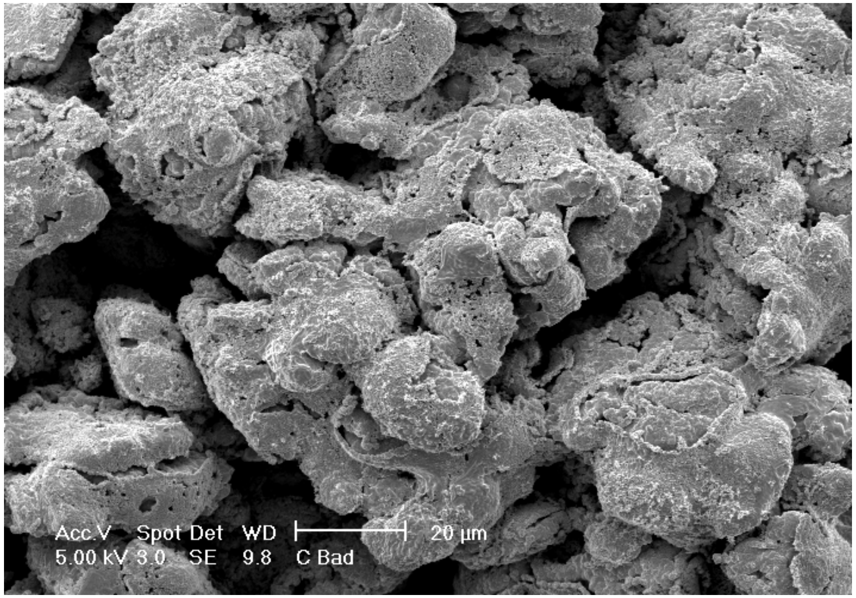
- Lead Sulfate Build up---Enlarged Crystals
- All L/A batteries create PbSO4
  - AGM – slower formation
  - Flooded Cell- faster formation
  - Heat accelerates self discharge/crystal formation

Common Causes of Battery Failure

Ohio State University
5-yr. old fully charged batteries



Cathode crystalline structures remaining after charging **without** pulsing



Cathode after charging **with** pulsing

Impact on Battery Performance

- Overall capacity is reduced
- Starting issues begin to increase
  - Heat
  - Cold
- Shorter “silent watch” times
- Insulating layer of crystals

Premature battery replacement

Operational & Financial Impact of Battery Failure

- Equipment Not Mission Capable
- Shrinking O&M budget spent on batteries
- Man-hours wasted on replacing batteries
- HAZMAT requirements
- RBE whole fleet battery replacement

Overcoming Battery Problems

- Goals
  - Minimize handling batteries
  - Keep them in the vehicles
- Training at every level
- Testing
- Preventive Maintenance
- Corrective Maintenance

490 PT and MBT-1
Part Nos. 741x490 and 741x800
(NSNs: 6130-01-510-9594 and 6130-01-463-8499)

PM Goal

KEEP BATTERIES IN VEHICLES

- Pro HDs

- Solar Chargers

Corrective Shop Maintenance

- When batteries are too far gone to be recharged/recovered in the vehicle

  Caused by:
  - Imbalanced set
  - Short run times
  - Too many add-on loads
  - Low output alternator
  - Mixed chemistries
  - Sitting too long without Solar Maintenance Charging (RBE)
  - How long is too long?

PulseTech Products Corporation

Corrective Shop Maintenance

<u>HD Pallet Charger</u>
Part No. 746x820
NSN: 6130-01-532-7711

<u>Redi-Pulse Pro HD</u>
Part No. 746x800
NSN: 6130-01-500-3401

<u>Pulse Charger/World Version</u>
Part No. 746x725
NSN: 6130-01-477-4703

<u>490PT</u>
Part No. 741x490
NSN: 6130-01-510-9594

<u>Redi-Pulse Pro-12</u>
Part No. 746x912
NSN: 6130-01-535-2718

<u>Battery Service Equipment Set (BSES)</u>

- **1 – HD Pallet Charger**
- **1 – Redi-Pulse Pro-HD 12/24V Charger**
- **1 – Redi-Pulse Pro-12**
- **10 – MBT-1 Battery Testers**
- **1 – 490PT Battery Analyzer**

"Initially we didn't think it was going to be anything other than additional charging stations, but immediately we found that we could recover twice as many batteries using the technology incorporated into the BATTCAVE Chargers." DOL – Fort Lewis

Conclusion

- **Many battery failures are preventable**
- AGM (Hawker, Optima) can have over 6 yr service life
- Flooded Cell (6T's, 2/4HN, Grp 31's) can have over 3 yr service life

Stop by PulseTech Products
Booth 417
for more information!

Joint Service Power Expo

POWER FOR VEHICLE AND BATTERY OPERATED WEAPON SYSTEMS

Michael Bissonnette

Team Lead / L-3 Communications Support

Expeditionary Power Systems, Marine Corps Systems Command

6 May 2009

Purpose

- **Review the Tactical Communications Modernization (TCM) program and impact on the Marine Corps tactical radio inventory**

- **Review current (PM EPS) capabilities and future programs to support the power demands (under 2 kW) of this rapidly changing and increasing operational capability**

Talking Points

- What is TCM?
- Radio Power Adapters
- DC to AC inverter requirements
- Battery chargers (COMM-ELEC)
- Renewable energy for small tactical units
- TCM impact on Tactical Vehicles

Tactical Communications Modernization Program

- **Several events led to a rapid expansion of the Marine Corps' tactical radio inventory**

  - Enhanced Company Operation (ECO) concept

  - Planned force increase (202K) / OIF Reset

  - Supplemental funding for radio procurement and fielding over a four year period

Enhanced Company Operations (ECO)

- **Field C2 systems that support greater distribution of units**
- **Expand networks for communicating Commanders intent**
- **Enable “fire teams” to collect and pass (real time) battlefield intelligence**

Tactical Communications Modernization Program

- **Phase 1 - Modernize & Reset the Force (2006 – 2009)**

  - Replace all legacy HF systems with PRC-150

  - Replace all legacy UHF systems with PRC-117

  - Field radios to support ECO requirements

  - Begin fielding of SVA/DVA vehicle radio mounts

- **Phase 2 - Modernize & Reset the Force (2008 – 2010)**

  - Replacement of vehicular SINCGARS systems with amplified, multi-band radio capabilities

  - Fielding of onboard radio systems to vehicle platforms that traditionally had no communications capability

Tactical Communications Modernization Program Phase 1

- **ECO requirements + 202K increase + funding =**

	PRE-OIF	TCM AAO
PRC-117	0	9,817
PRC-150	?	4,957
PRC-152	0	8,387*
PRC-153	0	49,360

* Note: Does not include 13,653 DVA's and 15,068 SVA's

Tactical Communications Modernization Program Phase 1

Dual Vehicle Adapter (DVA)

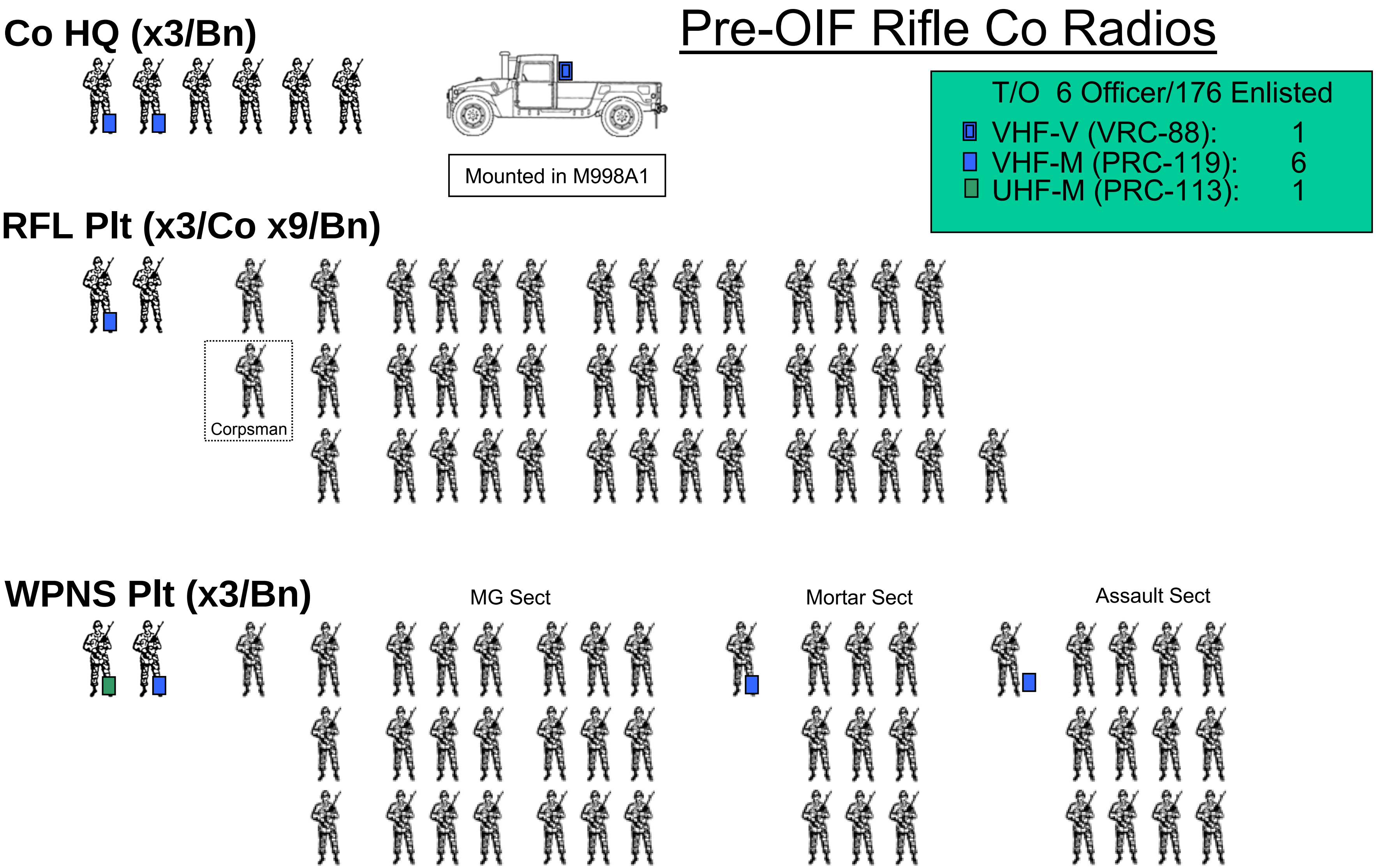
AN/PRC-153 IISR

AN/PRC-152

AN/PRC-117F

AN/PRC-150

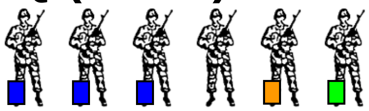
Tactical Communications Modernization Program

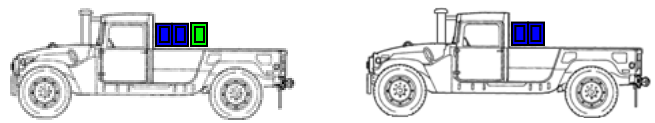


Tactical Communications Modernization Program

TCM

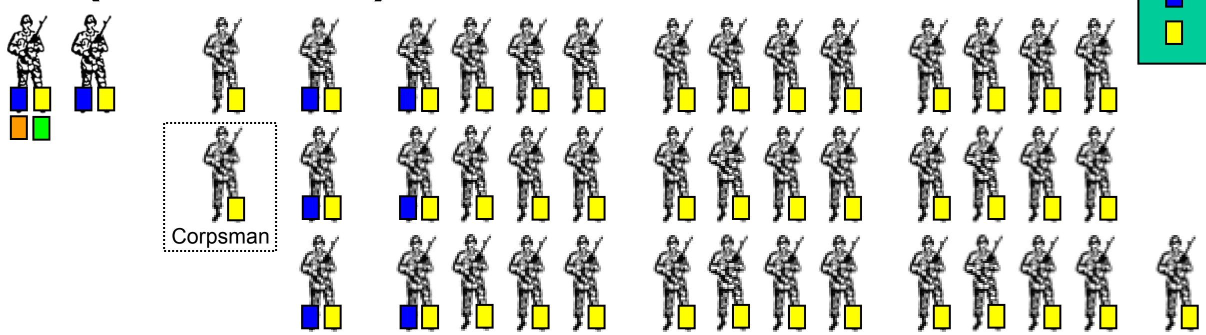
Co HQ (x3/Bn)





Mounted in M1123A2s

RFL Plt (x3/Co x9/Bn)



T/O 6 Officer/176 Enlisted

MBR-V (VRC-103):	1
MBR-M (PRC-117):	6
HFMR (PRC-150):	5
DVA (VRC-110):	2
THHR (PRC-148/152):	35
IISR (PRC-153):	176

*Corpsman IISR counted in H&S

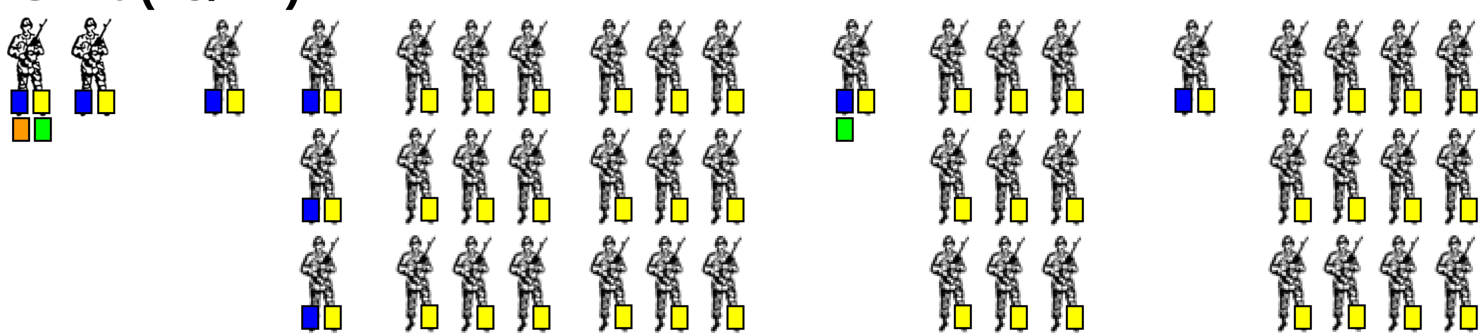
"98" RFL Companies not counting MARCENT

WPNS Plt (x3/Bn)

MG Sect

Mortar Sect

Assault Sect



Tactical Communications Modernization Program

- **Challenges**

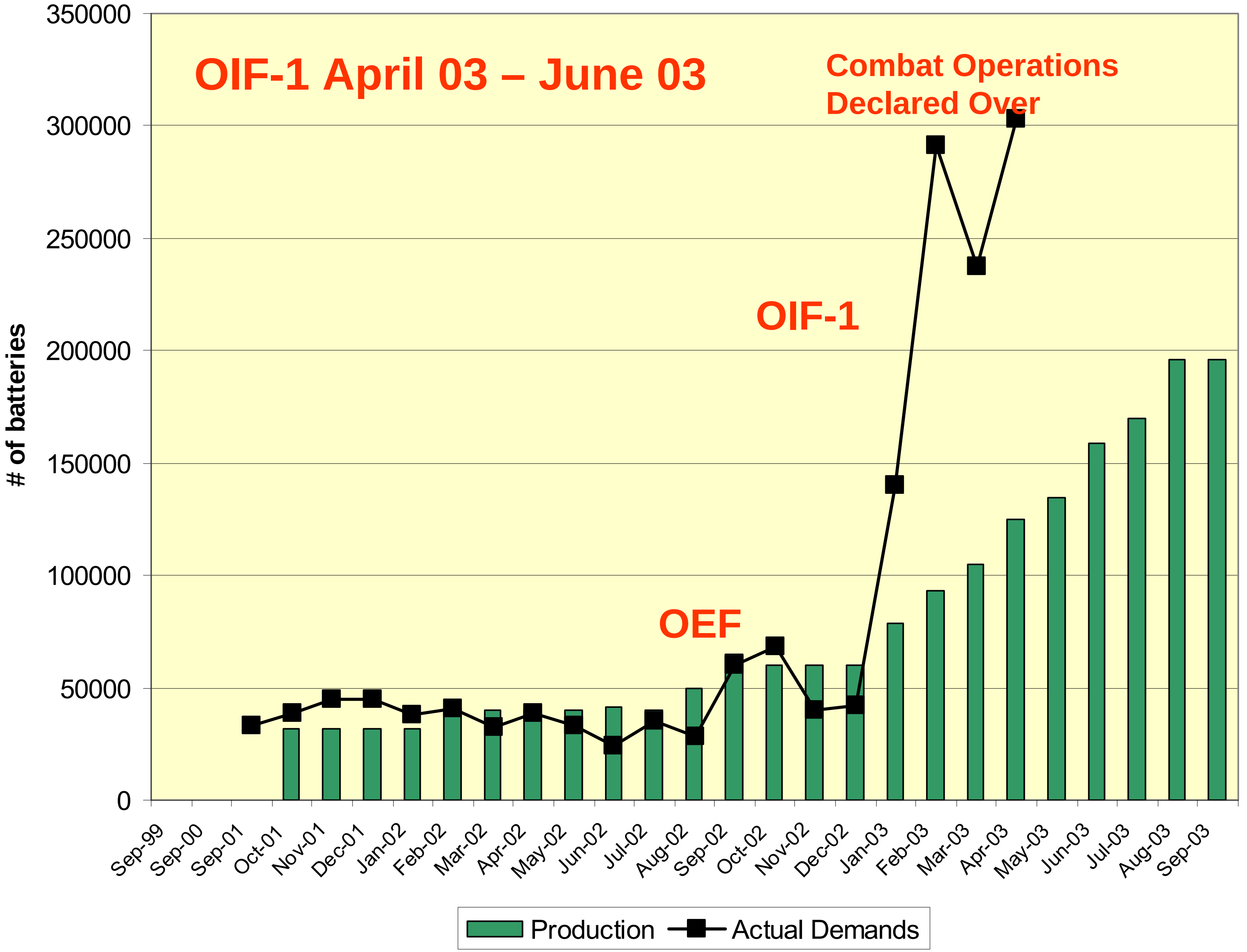
  - Training "Every Marine a Rifleman"

  " Every Marine a Radio Operator"

  - Initial battery supply, resupply, annual budgets, HAZMAT & disposal

BA-5590 BA-5390 BA-8180

BA-5590/U **MONTHLY** Battery Demands



PM EPS Current Inventory

- **Suit of alternative power devices to support different mission profiles (RPA's / Power Supplies / Battery**

The "Last 10 Yards" …

- Resulting from the TCM program what additional alternative power capabilities does the Marine Corps need in order to support this increase in the tactical radio inventories?

Radio Power Adapters

Current Inventory

SSPA 12V
QTY 1599

MSPA 12V
QTY 1382

MRPA 12V
QTY 1303

MRC-93B 24V
QTY 1295

With increased fielding of PRC-117 & PRC-150 24V radios and drawdown of PRC-119 SINCGARS 12V radios the Marine Corps will need additional 24V RPA's

With increased fielding of PRC-152 & PRC-153 12V Hand Held radios the Marine Corps will need additional 12V unique RPA's

50K PRC-153 / 8K PRC-152

Radio Power Adapters

NEXT GENERATION

HH-RPA

Testing in progress

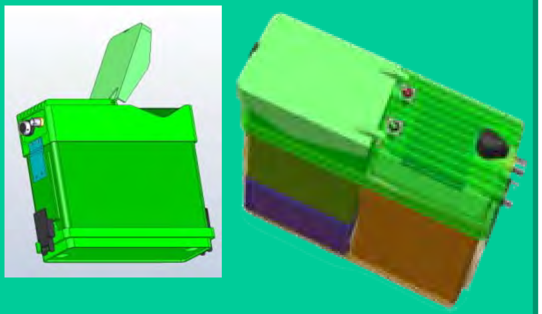
Power PRC-148, PRC-152 and PRC-153 from XX90 battery

24V Tower

RFP Released

Source Selection in progress

Single 24V RPA



Dual input Battery/120VAC

Outputs to 24VDC, radio, UPS capable

DC to AC Inverters

Current Inventory(QP-1800)

- Semi-ruggedized.
- Runs from vehicle 24VDC.
- Connects using supplied NATO slave cable.
- Output is 115VAC True Sine Wave, 1800W.

Next Generation

3 Phase 2000 Watt Inverter

RFP pending release

QP-1800 Inverter

COMM-ELEC Battery Charge

Current Inventory

SPC Bench Top Charger

VMC Vehicle Mounted Charger

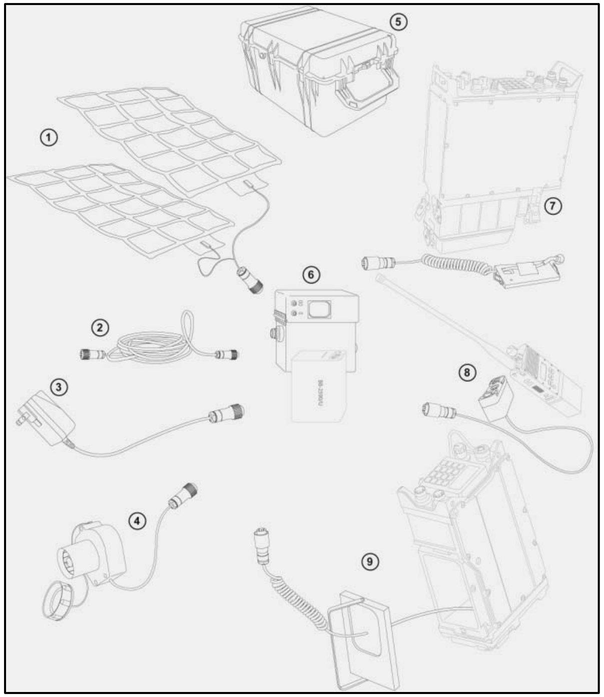
Next Generation

VMC Lite
Less weight
Small foot print
Focused on Rifle Company requirements

RFP Mid May 2009

Renewable Energy for the Small Tactical Unit

SOLAR PORTABLE ALTERNATIVE COMMUNICATION EQUIPMENT SYSTEM (SPACES) & MULTIPURPOSE SOLAR DEVICE (MSD)



Notional Multipurpose Solar Device (MSD) Kit

1) Solar Panel(s)
2) Power Cord
3) AC Adapter Cord
4) NATO Adapter Cord
5) 12V DC Car Adapter
6) Zinc Air Battery Adapter
7) Waterproof Case
8) Power Manager

12) Two-wire Output Cable

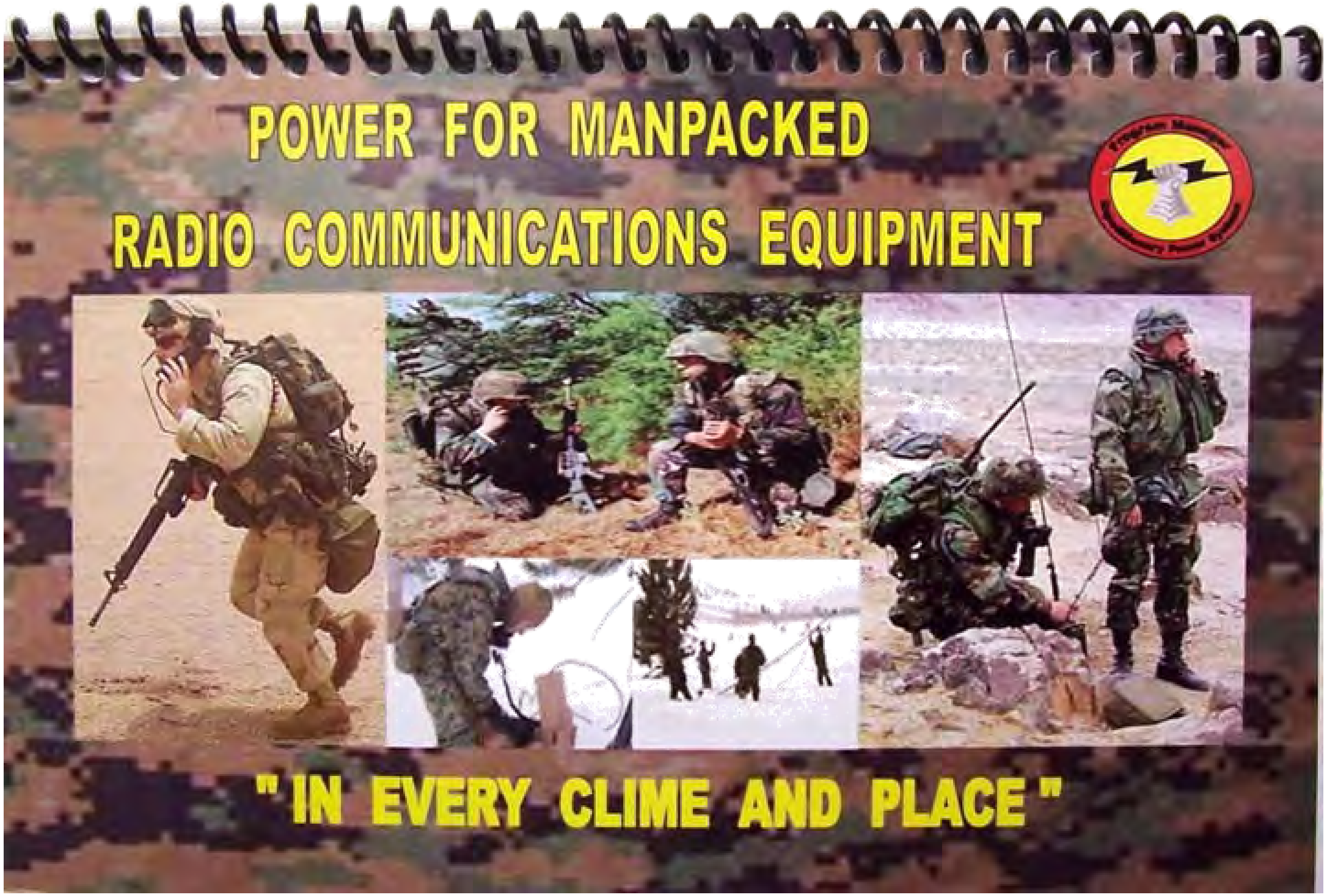
Currently undergoing User Evaluation

The SPACES MSD collects energy from various sources (solar, DC/AC, Vehicle) to recharge BB-2590 batteries and to power external devices (12V radios).

Every Marine a Radio Operator

TRAINING REMAINS A CHALLENGE

Available from pm_eps@nmci.usmc.mil



Every Marine a Radio Operator

TRAINING REMAINS A CHALLENGE

Power Management for Communication Equipment Operators.

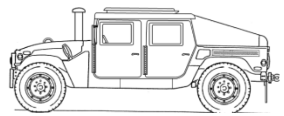
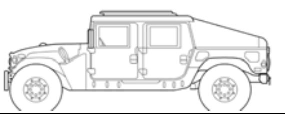
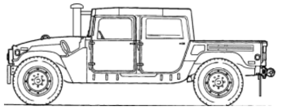
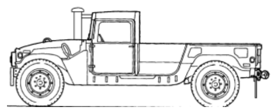
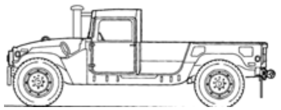
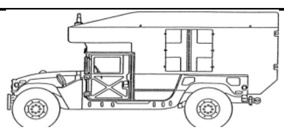
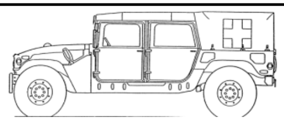
Available at www.marinenet.com

TCM Impact on Tactical Vehicles

- **Capabilities continue to be added to HMWWV platforms**
  - Blue Force Tracker
  - EPLRS
  - IED Jammers
  - DVA/SVA
  - Inverters

THHR Vehicle Adaptor

TCM Methodology

D-TAMCN	Vehicle Type	Radio Type/Configuration	
D00307K		Dual Vehicle Adaptor (DVA)	
D00327K		Dual Vehicle Adaptor (DVA)	
D00347K		Dual Vehicle Adaptor (DVA)	
D00227K		Single Vehicle Adaptor (SVA)	
D00337K		Single Vehicle Adaptor (SVA)	
D10017K		Dual Vehicle Adaptor (DVA)	
D10027K		Dual Vehicle Adaptor (DVA)	
All Other	**MTVR, LVSR, etc.**	Single Vehicle Adaptor (SVA)	

Vehicle Battery Support

Been around for a long time

Vehicle Battery Support

- **Challenges**

  - Vehicle battery preventive corrective maintenance not taught in formal schools

  - Use of battery consignment programs

  - Replacement costs are hidden from the user

Vehicle Battery Support

- **Marine Corps efforts**

  - Continue to procure/field battery maintenance equipment

  - Continue to provide on-site training

  - Introduction at formal schools

Marine Net

Welcome to the USMC Distance Learning Training - Microsoft Internet Explorer

Automotive Battery Maintenance Management:
Motor Transport Officers and SNCOs

Menu | Resources | Help | Audio Replay | Show Text | Back | Next | Exit

Five Phases of the Battery Maintenance Management Plan

Dispose of Batteries

Batteries that you deem unrecoverable (Code H) must be disposed of properly. You are responsible for packaging lead acid batteries for turn in to the local Defense Reutilization and Marketing Office (DRMO) or for pick up through the Vehicle Battery Consignment Program (VBCP).

References:

- SOP chapter 9 – Battery Charging and Battery Shop Operations

Click the icon to access the SOP and review this section.

SOP

Click the NEXT button to continue.

Expeditionary Power Systems

www.marcorsyscom.usmc.mil/sites/pmeps

QUESTIONS ?

Operations in Afghanistan, August 2008

NDIA Military Power Sources Committee

Chair: Jim Gucinski, Tiburon Associates

Vice - Chairs:

– Rebecca Morris, ACI Technologies
– Tom Byrd, Lockheed Martin MFC

May 6, 2009

Background

- Round Table at 2007 Joint Service Power Expo
  - Topic: Ability of R&D and manufacturing base to meet current and future DoD man portable power needs
  - Industry and Government Participants
    - Industry
    - JDMTP – Joint Defense Manufacturing Technology Panel
    - PSTWG – Power Sources Technology Working Group

Military Power Sources Committee

Result of the 2007 Round Table

- Agreement to continue discussions
- Sponsorship of NDIA Manufacturing Division
  - NDIA Military Power Sources Committee
  - Industry Communication Interface with DoD
  - Quarterly Meetings

Military Power Sources Committee

Charter:

To be the collective voice of industry to DoD / US Government on issues related to electro-chemical power systems while keeping the Warfighters' interest number one.

The above will be accomplished by quarterly information exchange meetings that encourage networking and joint issue resolution.

Objectives and Approach

Objective: Raise Importance of Power Systems

- Interaction with Government program officers and Defense Logistic Agency

Objective: Maintain / Establish Domestic Manufacturing base

- Forecasting
- Acquisition Strategy
- Minimum Sustainment and Ability to Meet surge Demands

Objective: Promote Technology Improvements

- Inputs to the power technology development roadmap
- Technology Insertion Processes

Objective: Standardization efforts- battery families, connector families

Military Power Sources Committee

Recent Activities

Industry Review of PSTWG Roadmaps

- Reserve Batteries
- Secondary Batteries
- Fuel Cells

- Meeting at Defense Logistics Agency (DLA) – Richmond
  - Industry Representatives: 25
  - DLA and Government Representatives: 14
  - Discussions between government and industry about procurement
  - Agreement to continue discussions at DLA - Columbia
- Discussions with Army and Air Force representatives
  - Communication of Industry issues to DoD
  - Communication of DoD needs to Industry

Current and Future Activities

- Creation of white paper on Military Power Sources issues for circulation amongst US government policy makers
- Support Power Sources Roadmap evaluation
- Review of proposed DoD lithium rechargeable battery standard
- June Meeting with DLA - Columbus
- Participation and audience with applicable DoD personnel, DLA, CERDEC, PM-MEP, etc.
- Articles for National Defense and AMMTIAC Magazine
- Investigation of Communication Electronics (CE) Interfaces

Open Discussion

- Rebecca Morris - ACI Technologies

  Phone: (610) 362-1200 x102

  Email: rmorris@aciusa.org

- Tom Byrd - Lockheed Martin MFC

  Phone: (972) 603 – 7009

  Email: tom.e.byrd@lmco.com

- James Gucinski – Tiburon Associates

  Phone: (812) 825-4355

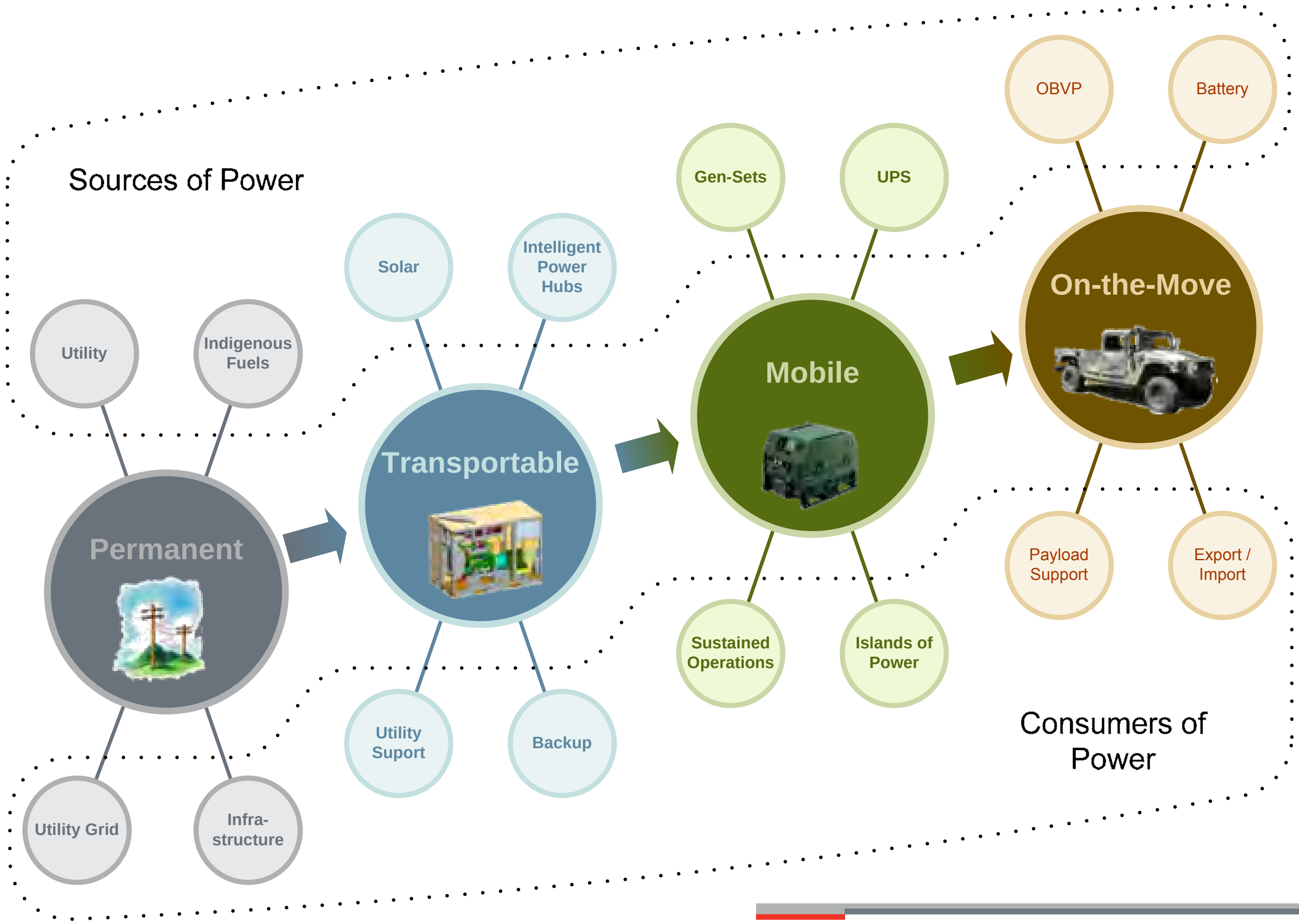
  Email: jag@tiburonassociates.com

OBVP from Legacy to Next Generation

2009 Joint Service Power Expo

Brent Brzezinski, Ph.D., Mike Marcel, Ph.D. & Jay Schultz
DRS Test & Energy Management, Huntsville, AL

Battlefield Power



Pushes Mission Power Forward to the Warfighter

Initial OBVP Contracting Agency

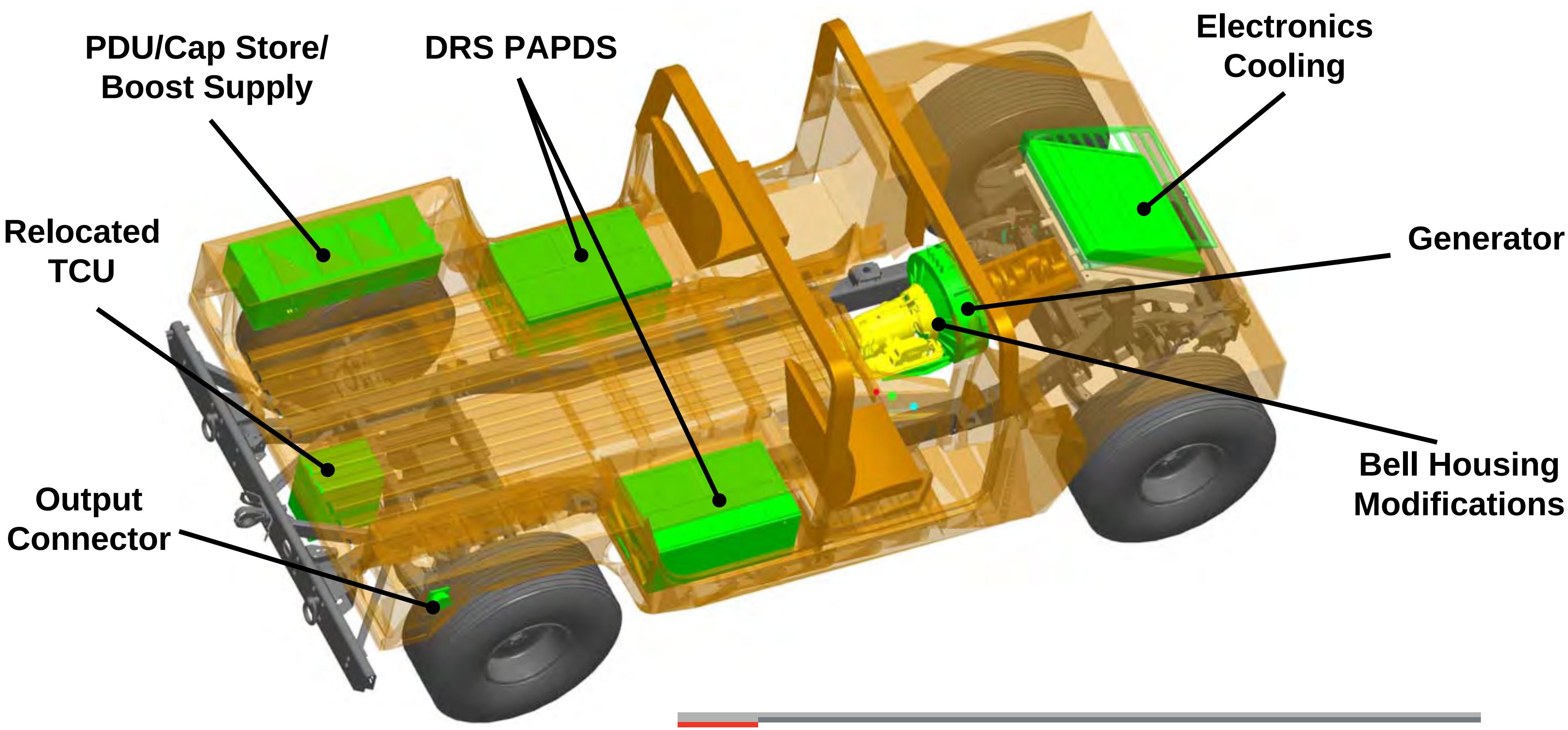
Office of Naval Research S&T ONR

Revolutionary Research . . . Relevant Results

Key Requirements

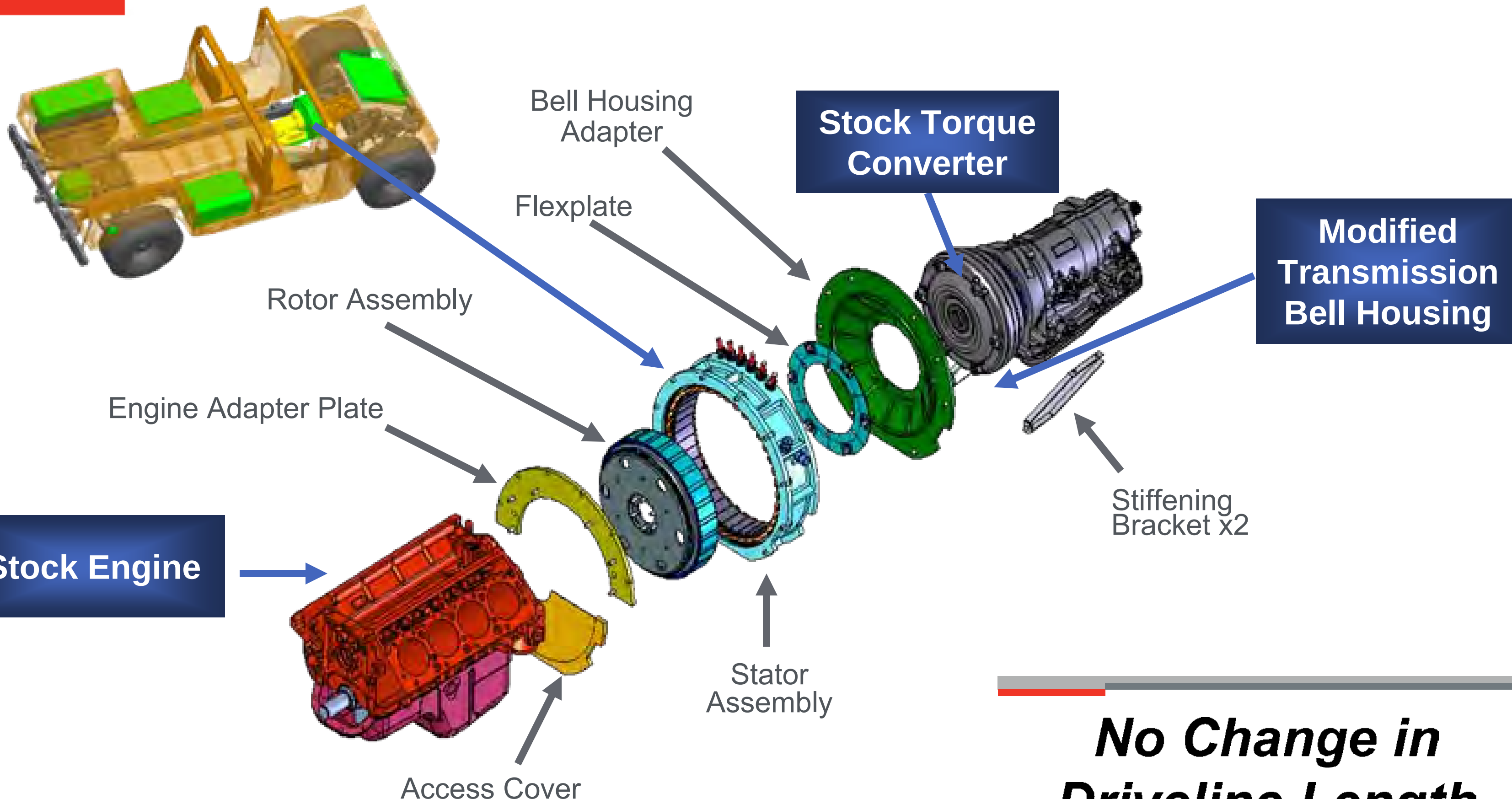
- 30 kW Stationary Power (120/208V)
- 10.5 kW On-the-Move Power
- Power Quality No Worse Than MEP-805 TQG
- Weight Less Than 25 Pounds / kW

Baseline OBVP System



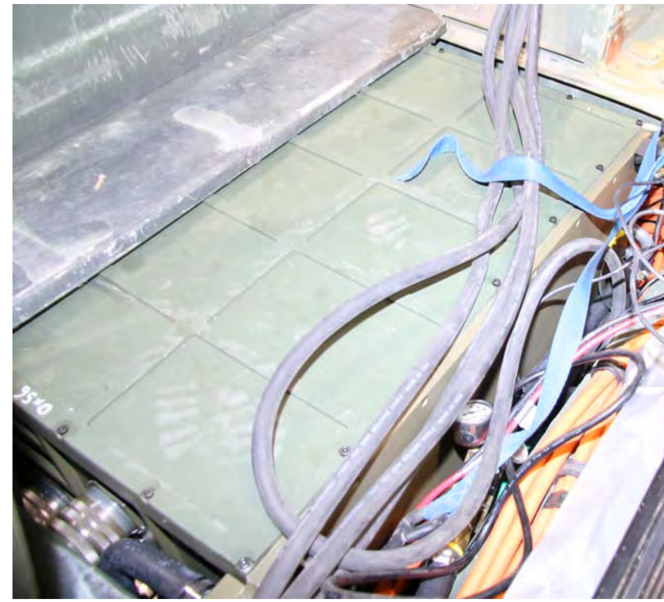
OBVP System is Integral to Vehicle

Baseline OBVP Drive Line Integration



No Change in Driveline Length

ONR OBVP Component Integration



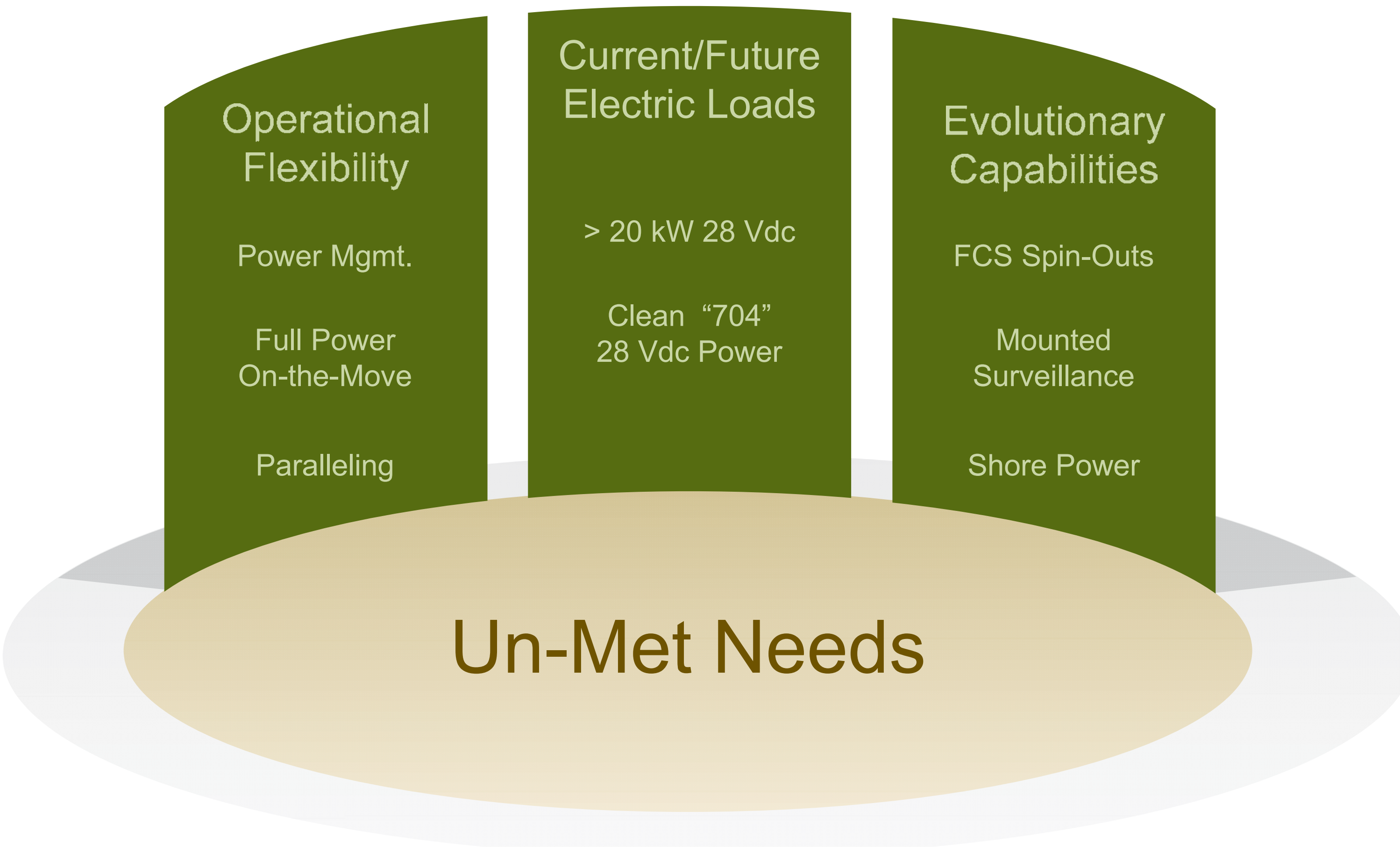
Installed by OEM or Field Depot Retrofit

ONR OBVP

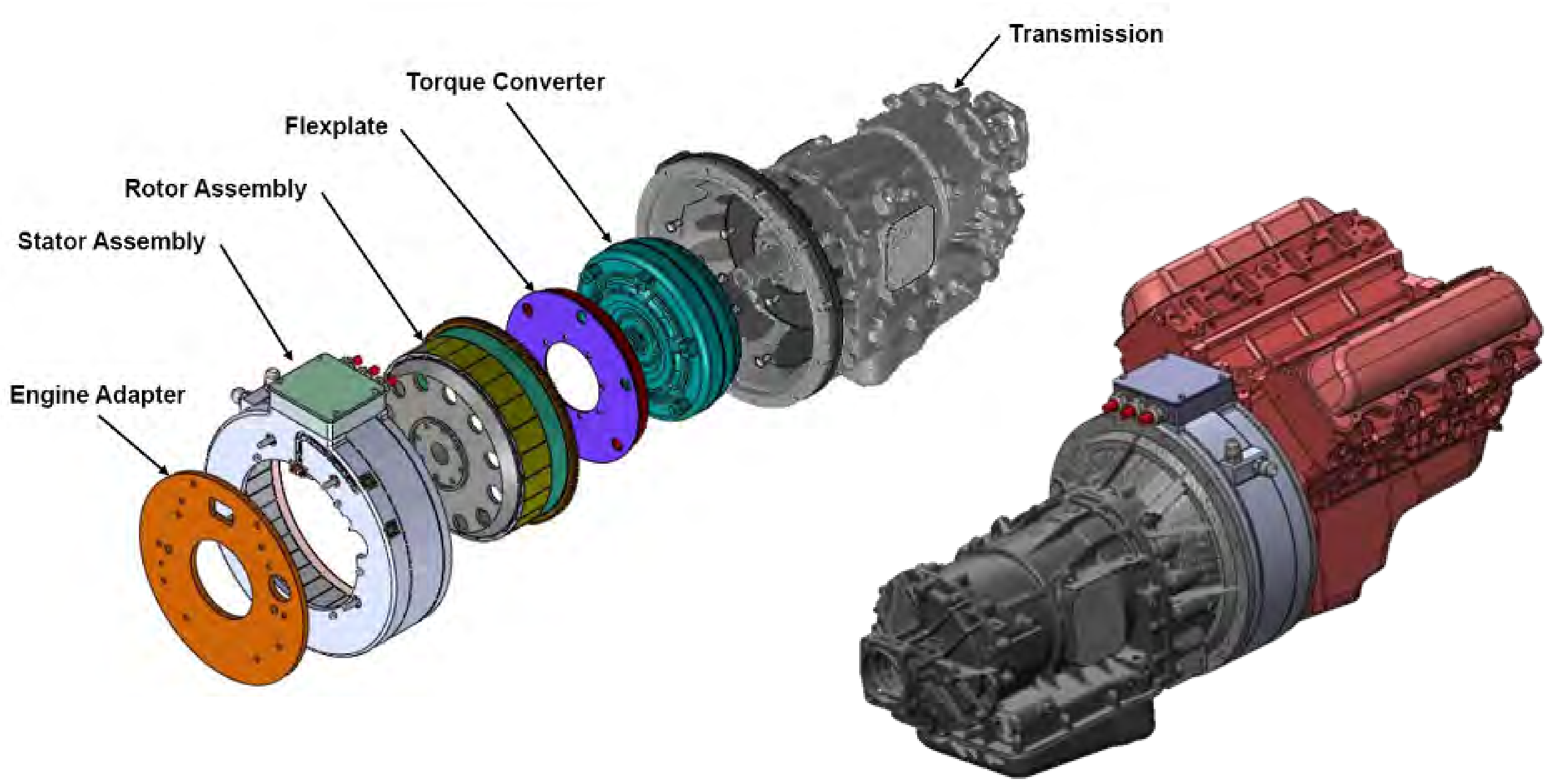
Integrated and Delivered

Next Generation OBVP Architecture

What's Next?


Operational Flexibility
Power Mgmt.
Full Power On-the-Move
Paralleling
Current/Future Electric Loads
> 20 kW 28 Vdc
Clean "704" 28 Vdc Power
Evolutionary Capabilities
FCS Spin-Outs
Mounted Surveillance
Shore Power
Un-Met Needs

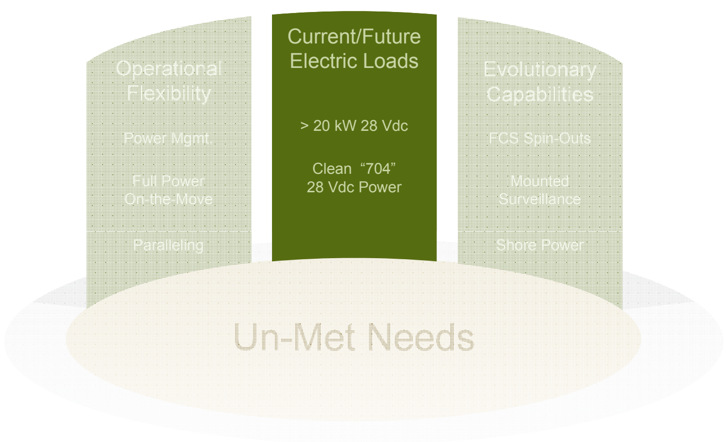
70 kW In-Line Generator



Common Architecture / Cross Platform Solution

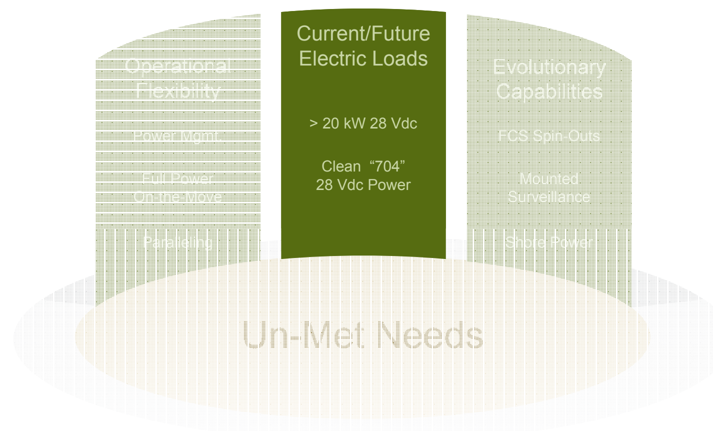
Parallelable Auxiliary Power Converter

- Sized for Next Generation Tactical Vehicles
- Parallelable for Higher Levels of On-Board Power
- MIL-STD-1275 Conditioned 28 Vdc Power
- MIL-STD-810



Pulse Width Modulated-Rectifier/Controller (PWM-RC)

- Field Enhancing/Weakening
- Power Factor Correction
- Active Bus Regulation
- MIL-STD-810



Summary

- Pushes mission power forward to the warfighter
- Integrates with no change in drive line length
- Provides flexibility in installation by OEM or field depot retrofit
- Delivers common architecture / cross platform solution

Mike Marcel, Ph.D.
mmarcel@drs-tem.com
Components

Brent Brzezinski, Ph.D.
bbrzezinski@drs-tem.com
System

Jay Schultz
jschultz@drs-tem.com
Programmatics

8394 ~ by Edward J. O'Rourke

Kestrel - Falcon III Radio Power Adapter / Charger (AN/PRC-117G)

Abstract

- The new Iris Technology Radio Power Adapter for the Falcon III (AN/PRC-117G), the Kestrel, is scheduled to debut at JSPE. This adapter is built upon a heritage of successful devices servicing the SINCGARS and Falcon product lines. The Kestrel can be powered from both DC and AC sources, houses and charges full size BB-2590/U batteries, and is interoperable with StarPower. Planned availability for this adapter and selected radio accessories is 2Q09.

Overview

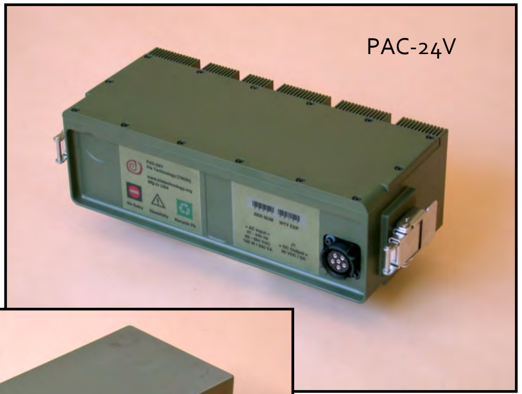
- The ***Kestrel*** adds to the family of alternative power adapters from **Iris Technology**, leveraging the high performance of **PAC-216**, **PAC-24V** and **VB-90**.
  - Power from AC or DC sources
  - UPS & Power conditioning
  - Internal full capacity battery
  - Built-in battery charger
  - 26V Amplified speaker output
  - Vehicle mounts and Accessories

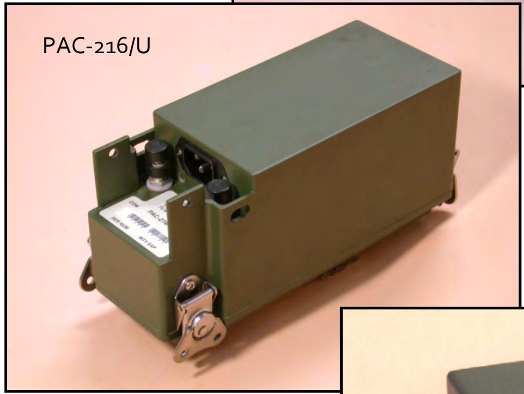
Kestrel Heritage

- AN/PRC-117F
  - PAC-24V

- AN/PRC-119D
  - PAC-216/U

- AN/PRC-119F
  - VB-90





Military Adapters

Kestrel AC/DC Adapter

- (radio not included)

Side View

Specifications

- Electrical
  - AC Input — 95-265 VAC; 47-440Hz
  - DC Input — 9-36 VDC
  - DC Output — 24VDC @ 4.5amps
- Environmental
  - Operating Temp — -30° C to 70°C
  - Storage Temp — -50° C to 70°C
  - Operating Alt — 27,000 ft.
  - Storage Alt — 55,000 ft.
  - Humidity — 95% relative
- Physical
  - Size — 3.2”H x 7.2W” x 7”D
  - Weight — 2.7lbs / 6.6lbs w/battery
- Battery Types
  - Rechargeable LiIon — BB-2590 / UBI-2590

Vehicle Mount

StarPower Interoperable

- Operate from Solar / Vehicle / AC Sources

Feature / Benefit

Feature	Benefit
Separate AC and DC Power Supplies and Cables	Buy only what you need; Carry only what you need
Uses full-size 2590 series battery	Common logistics item; Three times the runtime from high reserve energy battery (6.2 A-Hr v 2.0 A-Hr)
Operates with BB-2590 and UBI-2590	This is a growth option as the unit can operate from and recharge both types
Compatible with installed base of RMT-2 Mounts	Buy only the adapter plate
International AC Power Supply	Operate successfully anywhere in the world including aircraft operation
Independent charging of both battery cells	Positive recharge of each battery cell

Accessories

- Powered Speaker
  - In development
- Vehicle Mounts
  - New, Dedicated Mount
  - MRC RMT-2 Adapter
- 2590 Series Batteries
- StarPower Cable

Administrative

- Pricing and Availability 2Q09
- Kestrel being added to GSA Contract
  - Iris Technology Corporation / GS-07F-0131N

Questions

- Equipment on display in Booth 314

ENTERPRISE POWER SELECTION

Vincent Polino

23020 Eaglewood Court #100, Sterling, Virginia 20166

PRESENTATION OVERVIEW

- Power reliability
- Protect COTS equipment
- Use efficient components
- Save $$$

NOVA
POWER SOLUTIONS, INC.

NOVA POWER SOLUTIONS, INC.

- Woman-Owned Small Business
- Product Solution Offerings
  - Rack-Mount **Power Conditioners and Battery Back-up**
  - Designed for Shipboard **C4I systems** and Military Ground Installations

- *Unprecedented* Pre- and Post-Sale Customer Support
  - **Customer-Driven** Projects & Requirements
  - **20+ Years** of Successful Contract Performance
  - **Large install base,** 8,000+ UPS Systems Deployed Worldwide

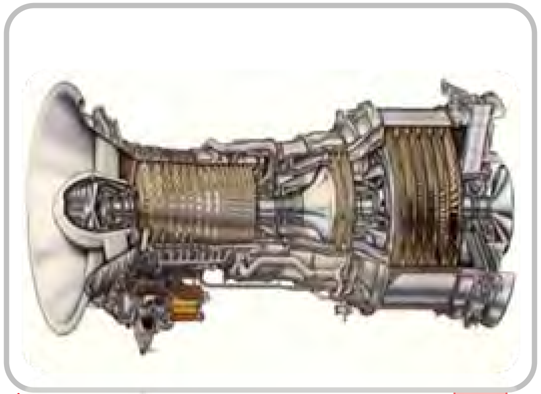
NOVA
POWER SOLUTIONS, INC.

TYPICAL AMERICAN RESIDENTIAL ELECTRICAL SYSTEM

Consistent, Reliable, Taken-for-Granted

NOVA
POWER SOLUTIONS, INC.

TYPICAL SHIPBOARD ELECTRICAL SYSTEM



Clean Power is not a Given

NOVA
POWER SOLUTIONS, INC.

TYPICAL FIELD GENERATOR ELECTRICAL SYSTEM

Clean Power is not a Given

NOVA
POWER SOLUTIONS, INC.

WHY USE POWER CONDITIONING AND BACK-UP?

- Two Primary Functions of an UPS
- Online versus Offline
- Appropriate Battery Technology

Type	Energy/Weight	Energy/Vol.	Self-Discharge rate
VRLA	30-40 Wh/kg	60-75 Wh/L	3%/mo
NiCd	40-60 Wh/kg	50-150 Wh/L	10%/mo
NiMh	30-80 Wh/kg	140-300 Wh/L	30%/mo
Li Ion	150-200 Wh/kg	250-530 Wh/L	5-10%/mo

NOVA POWER SOLUTIONS, INC.

TYPICAL C4I SYSTEM DESIGN REQUIREMENTS

- COTS Equipment in Mil-Std Environment
- Space, Weight and Power
- Standard 20A Circuit
- Life Cycle Costs

NOVA
POWER SOLUTIONS, INC.

UPS SELECTION CONSIDERATIONS

- Online
- Rugged and Rack-mount
- Shipboard 20A Circuit
- Delta -> Wye
- Redundancy
- Standard Features

NOVA
POWER SOLUTIONS, INC.

PROPOSED C4I SYSTEM IMPROVEMENTS

- Common UPS
  - Avoid Proprietary Features
- Rugged versus Ruggedized
- Open Architecture
- Efficient System Components

NOVA POWER SOLUTIONS, INC.

EFFICIENCY EXAMPLE

- Assumptions
  - Gas-turbine generator produces 3,000 kW/hr
  - Burns 100 gal/hr @ $2.00/gal
  - Per GTG cost $200/hr, or $1,752,000/yr
  - 115 watts costs $5,000/yr per GTG

Fuel-cost Savings in the Millions!

NOVA POWER SOLUTIONS, INC.

ALTERNATIVE UPS OPTIONS

- 2300 Watts Maximum
- Power Efficiency
- Online AC UPS = 1955 Watts → $15,187/yr/GTG
- 48VDC UPS = 2070 Watts → $ 10,124 /yr/GTG
- Increased Power Available
- Reduced Heat
- Avoid Unnecessary Hot-Work

$1,020,000

Total Savings

NOVA
POWER SOLUTIONS, INC.

PRESENTATION SUMMARY

- Shipboard COTS Equipment Requires Clean Power
- Rugged Components for Tactical Applications
- Power-Efficient Components:
  - ↑ Computing Power
  - ↓ Wasted Heat Energy
  - ⃠ Re-Wiring
  - ↓ Fuel-Costs

Ideal :
A **rugged, common UPS** that fits on a **20A Circuit** and powers **efficient computers.**

NOVA
POWER SOLUTIONS, INC.

QUESTIONS/MORE INFORMATION

Vincent Polino

Applications Engineer
NOVA Power Solutions, Inc.
23020 Eaglewood Court, Suite 100
Sterling, VA 20166
800-999-NOVA (6682)
vincent.polino@novapower.com

This presentation is based on a white paper that can be found at www.novapower.com under the Applications/ATCA Standard Rugged Power page. Copies can also be found at the **NOVA Power Booth # 408**.

NOVA
POWER SOLUTIONS, INC.

Joint Service Power Expo

On-Board Vehicle Power

Jonathan Carpenter, P.E.
Lead Engineer
Marine Corps Systems Command
May 5-7 2009

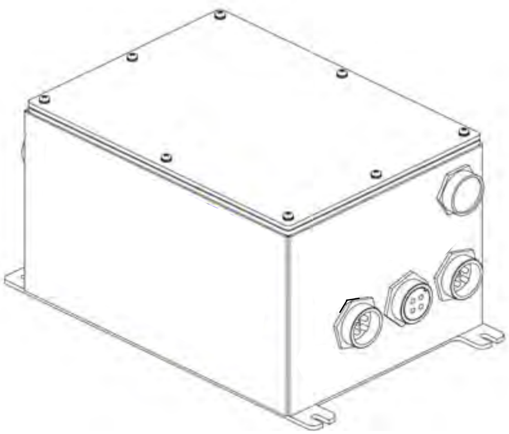
Briefing Topics

- **OBVP - Inverters (1-3 kW)**
- **OBVP – Small (10 kW)**
- **OBVP – Medium (20-30 kW)**
- **OBVP – Large (120 kW)**
- **Aux. Power Units (5-15 kW)**
- **Vehicle Mounted Battery Charger**

Why all the power?

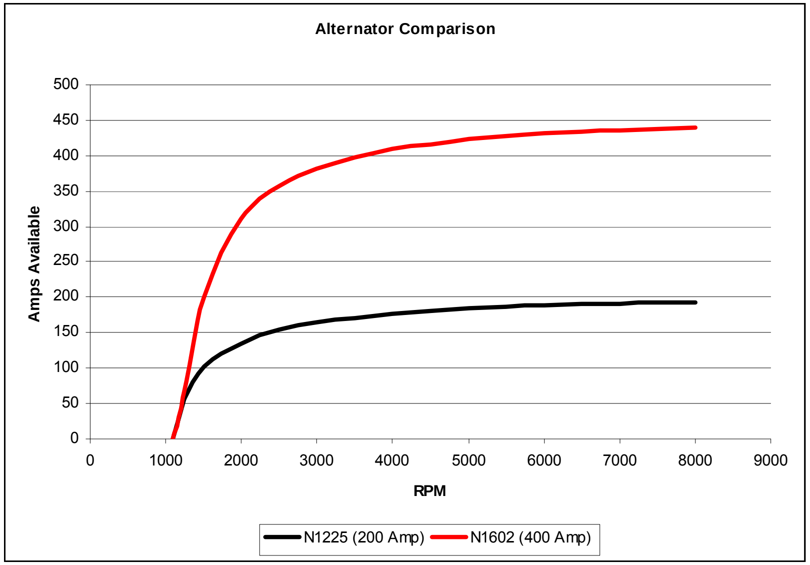
OBVP - Inverters

- USMC currently fields / centrally manages **QP-1800** Inverter
  - Competitively selected 2006
  - Semi-ruggedized
  - 1800 watts output
- Other USMC PMs have requested an **enhanced model**
  - Currently in Source Selection
  - Non-Developmental procurement
  - Critical Parameters:
    - 2000 - 2500 watts
    - Fully ruggedized (unprotected environments)
    - AC / DC input and output / battery charging



OBVP - Small

- 400 Amp Alternator
- Targeted for HMMWV A2 and ECVs (pre-2009)
- NSN: 2920-01-466-1855
- P/N: N1602-5
- Replaces 200 Amp Alternator
- Coupled with new pulley, provides ~4X power at idle.
  - N1225 @ idle: 55 Amps
  - N1602 @ idle: 190 Amps



OBVP - Medium

- HMMWV 20-30 kW
- RDT&E funded (ARRA Economic Stimulus)*
- RFP releases ~ June Timeframe
- Multiple Awards
- 60 days to respond
- Bid samples required

* For planning purposes only. Details are subject to change.

OBVP - Medium

▪ Proposed Process – Source Selection

Bid Sample

+

Proposed Solution

- Ability to achieve Program Objectives
- Engineering / Integration Plan
- Estimated Production Cost
- BEST VALUE

* For planning purposes only. Details are subject to change.

OBVP - Medium

- **Proposed Process – Phase I – 5 months**

Down Select

NTE $500k

+

GFE: M1152A1

* For planning purposes only. Details are subject to change.

OBVP - Medium

- **Proposed Process – Phase I – Down Select**

- **Product Verification Testing**
  - **Power Quality**
  - **Max Power**
  - **Limited Endurance**
  - **High / Low Temp**
  - **Limited EMI**
  - **(see SOO for more information)**
- **Testing at Aberdeen Test Center**

* For planning purposes only. Details are subject to change.

OBVP - Medium

- **Proposed Process – Phase II – 12 Months**

~ $2,500,000

+

GFE: 6x M1152A1 (B2)

* For planning purposes only. Details are subject to change.

OBVP - Large

- Objectives:
  - **120 kW** of stationary export power
  - 21 kW of power on the move (POTM)
  - Retrofit of existing MTVR platform
  - Maximize commonality with base MTVR
  - Retain MTVR vehicle performance
  - Minimize weight / payload impact

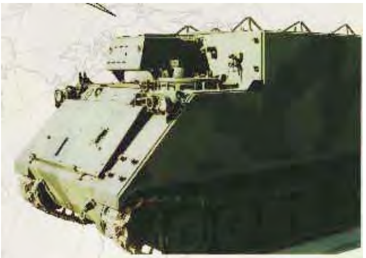
- Approach:
  - Diesel electric drivetrain
  - Common drive and export power AC Bus
  - AC converter provides power on the move (POTM)

OBVP - Large

ONR OBVP Prototype Contract Award	July 2005
OBVP Prototype Kit Installation Completed	January 2007
OBVP Testing at Aberdeen Started	January 2008
OBVP Program Transitioned to USMC	October 2008
Aberdeen Testing Completed	May 2009
USMC OBVP Contract Award	June 2009
First USMC OBVP Kit Installed	December 2009
Fifth USMC OBVP Kit Installed	August 2010
Aberdeen OBVP Assessment and Testing	March 2011

Auxiliary Power Units

- Auxiliary Power Units (APUs) have been around for some time now.
- Previous Defense Platforms and Systems
  - Abrams Tank APU – 2 kW 28 VDC
  - Armored Personnel Carrier – 5 kW 28 VDC
  - SICPS Shelter – 10kW 120/240 VAC



- Previous design focused on stationary power

Auxiliary Power Units

- APU needed for on-the-move power
- Two size ranges
  - 3 – 5 kW
  - 10 – 15 kW
- Defense Acquisition Challenge Program funds provided to buy and test COTS / NDI APU solutions
- Multiple vendors / multiple IDIQ awards

Auxiliary Power Units

MLS
MARVIN LAND SYSTEMS

M67854-09-D-5041

- Power Rating: 12.5 kW
- Dimensions: 24” x 28” x 48”
- Weight: < 490 lbs
- EPA Tier 4 Compliant
- Permanent Magnet Generator
- Liquid Cooled

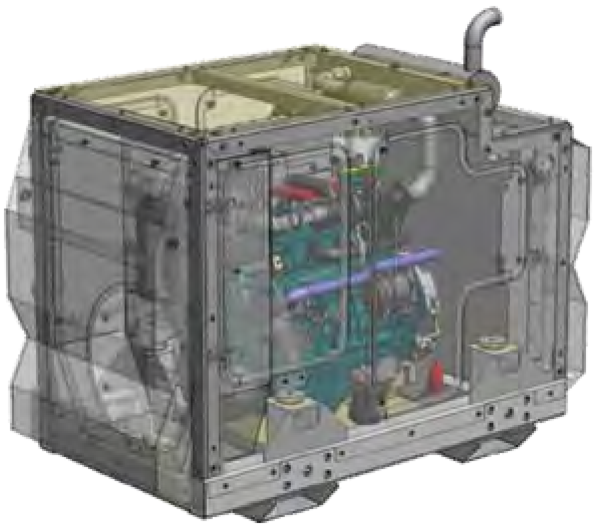
- Power Rating: 5.0 kW
- Dimensions: 24” x 24” x 36”
- Weight: < 330 lbs
- EPA Tier 4 Compliant
- Permanent Magnet Generator
- Liquid Cooled

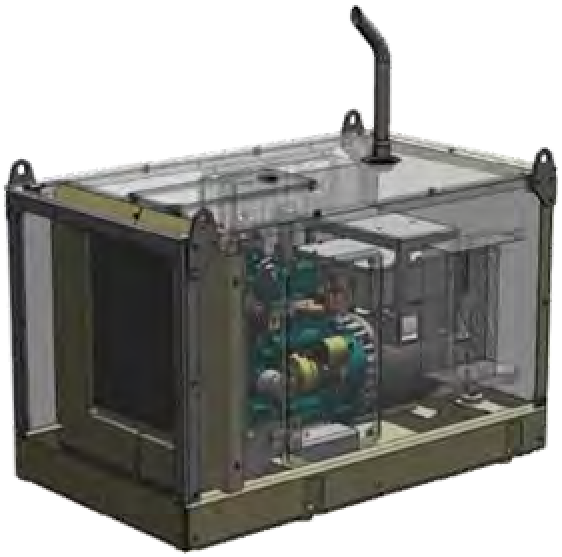
Auxiliary Power Units

MECHRON POWER SYSTEMS

A DIVISION OF TOROMONT INDUSTRIES LTD.

M67854-09-D-5043





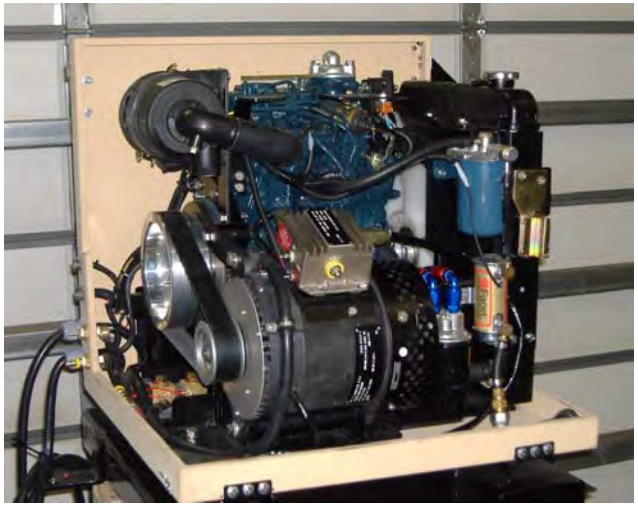
- Power Rating: 15.0 kW
- Dimensions: 31” x 37” x 56”
- Weight: 1500 lbs
- EPA Tier 4 Compliant
- Brushless, Homopolar Generator
- Liquid Cooled

- Power Rating: 5.0 kW
- Dimensions: 25” x 26” x 41”
- Weight: 675 lbs
- EPA Tier 4 Compliant
- Brushless, Homopolar Generator
- Liquid Cooled

Auxiliary Power Units

M67854-09-D-5044

- Power Rating: 15 kW
- Dimensions: 25” x 29” x 35”
- Weight: < 500 lbs
- EPA Tier 4 Compliant
- Neihoff 570A Generator
- Liquid Cooled



- Power Rating: 5.0 kW
- Dimensions: 24” x 24” x 26”
- Weight: < 325 lbs
- EPA Tier 4 Compliant
- Neihoff 250A Generator
- Liquid Cooled

Auxiliary Power Units

DEWEY

M67854-09-D-5042

- Power Rating: 4.0 kW
- Dimensions: 24” x 24” x 36”
- Weight: 300 lbs
- EPA Tier 4 Compliant
- Neihoff 250A Generator
- Air Cooled

Multi-Radio Power Adaptors

Current
12V Multi-SINCGARS
Power Adapter (MSPA)

- Powers 6 SINCGARS radios
- UPS capable when connected to both AC and DC power
- Power Input: 110VAC or 12VDC, 40-70 Hz
- Weight – 110 lbs with case

New Start
24V Radio Power
Adapter Tower

- 24V system with at least 4 radio bays
- Power Input: 110-280VAC or 24VDC, 40 – 400Hz
- < 80 lbs without case
- Currently in Source Selection
- Anticipated fielding start FY10

Questions

POC: Jonathan Carpenter

jonathan.carpenter@usmc.mil

Concept Design: Wind Powered OBVP

Improved Battery/Power Connectors for Aircraft and Other High Current Applications

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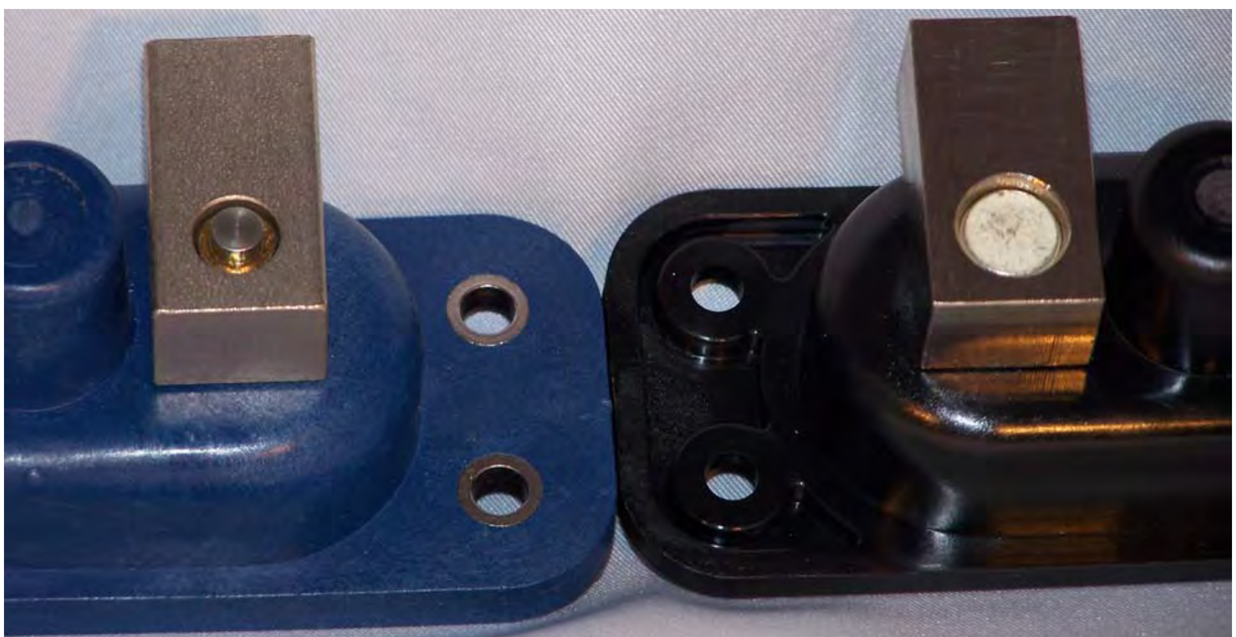
MS3509 Receptacle: Old vs. New



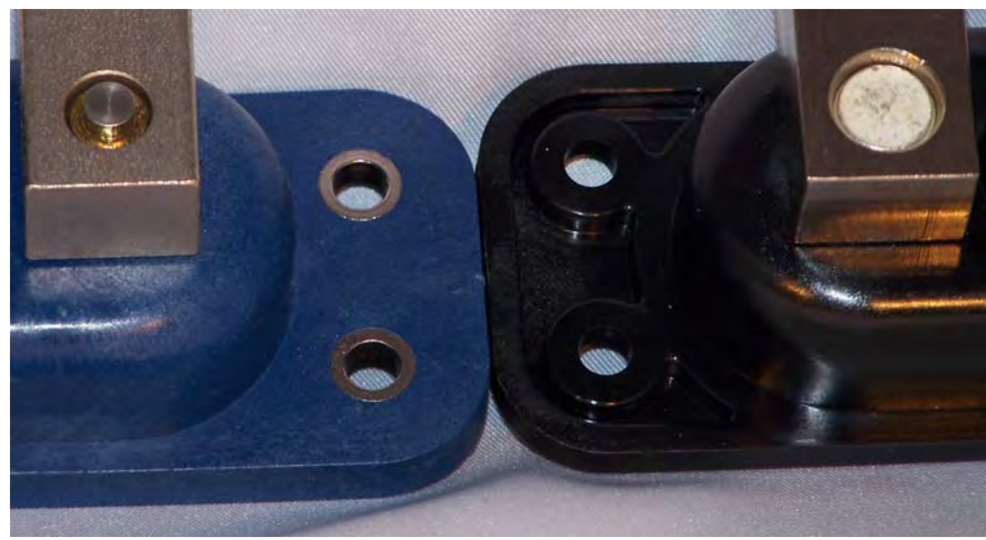
Molding Material Improvements

- Higher Heat Tolerance (HDT over 500ºF)
- Robust and Chemical Resistant
- Better Design for Manufacturing- no sink marks

MS3509 Receptacle: Old vs. New

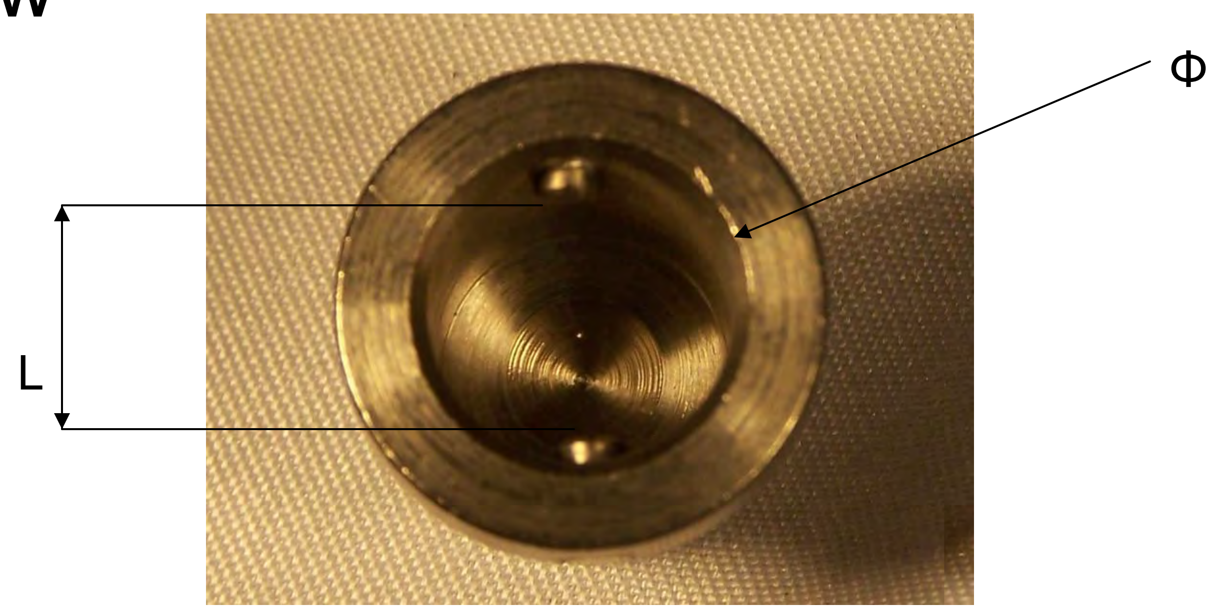
Mounting Holes

- Eliminated plated steel mounting ferrules
  - Reduced cost (4 less inserts)
  - Removed 4 rust sources



Improved Locking Pin Engagement

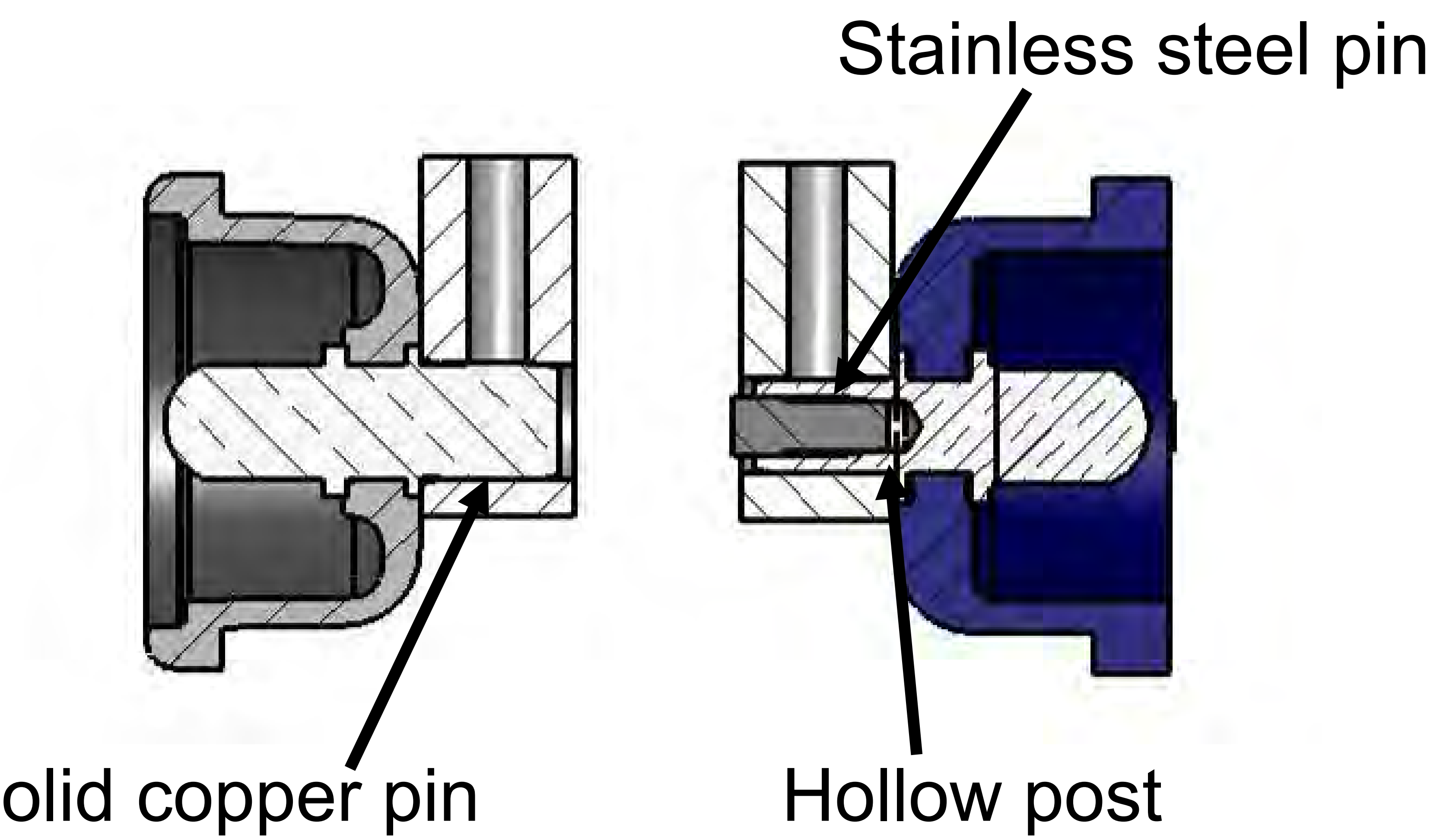
- Reduced tolerance on pin chamfer
- Reduced tolerance on hole diameter (Φ)
- Reduced distance between pins (L)
- Increased engagement with mating worm screw



Lower Resistance Terminal Adapter Assembly

- Improved consistency and quality
- Two less components in assembly
- Less mistakes in customer assembly
- Eliminated stainless steel and hollow post from circuit
- Uses same low-resistance design as 7007 Quick Disconnect (MS25182-2)
- Copper terminal adapter better than ledloy

Lower Resistance Terminal Adapter Assembly

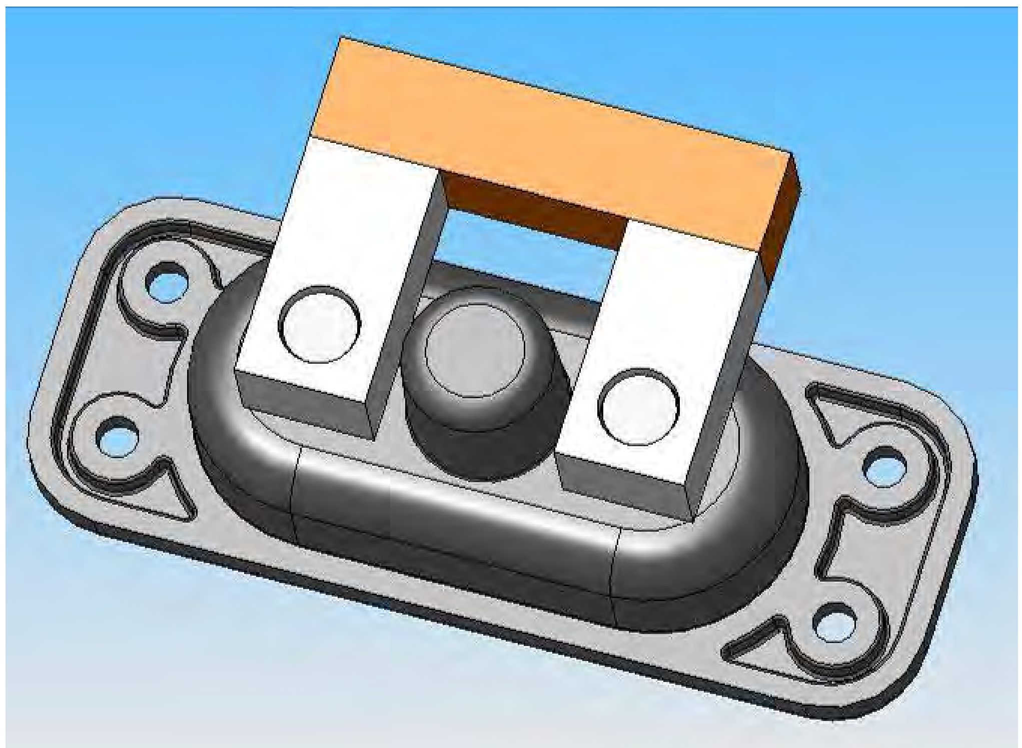


Test Program

- Prototype samples and standard Receptacles were mated to P/N 7007 & tested @ 1500A
  - 3 type 3509-28 receptacles
  - Prototype with steel terminal blocks
  - Prototype with copper terminal blocks
- Terminal blocks shunted with copper block of same C.S
- Volt drop measured at cable connections in mating connector P/N 7007

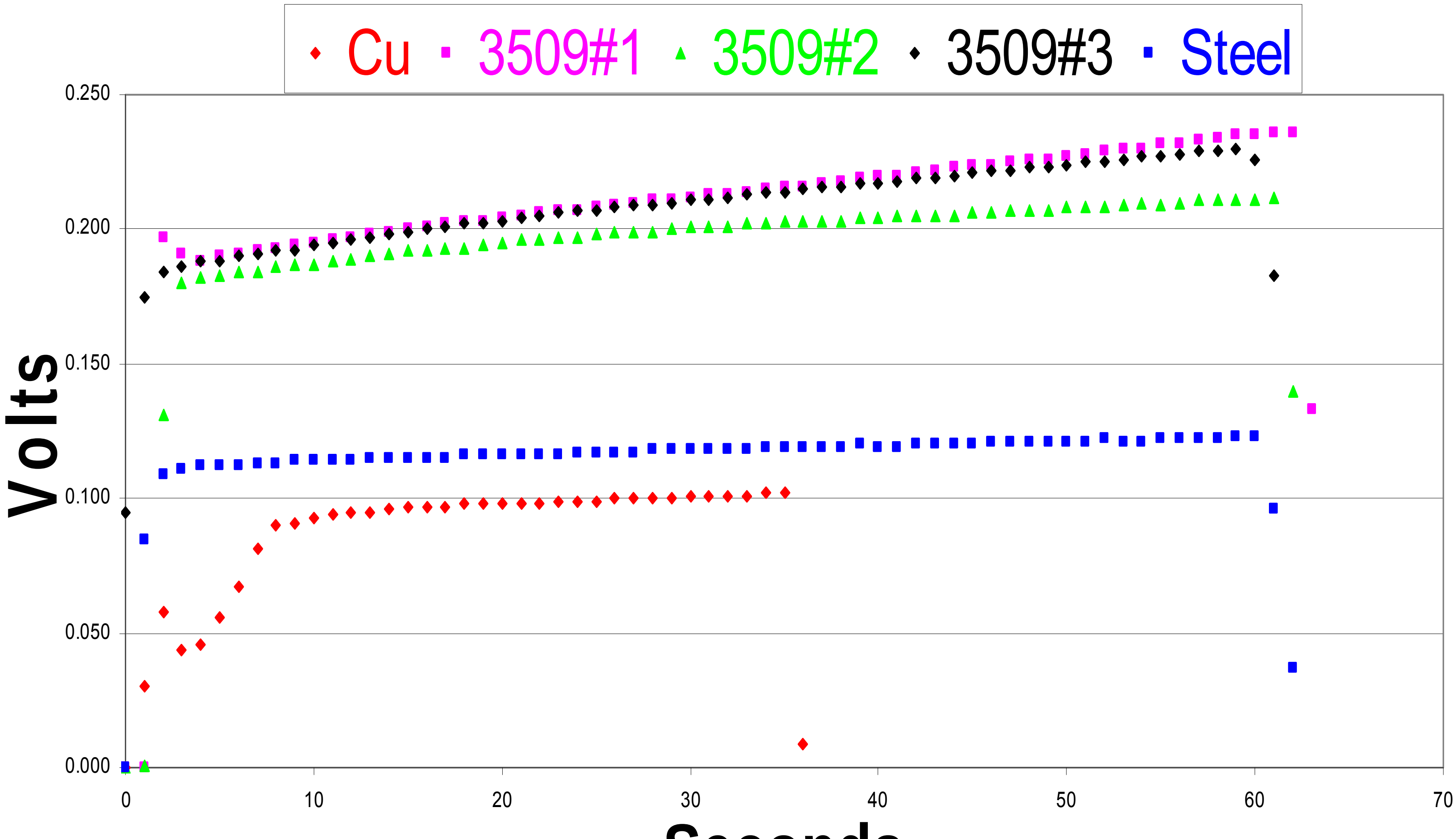
Receptacle Test set up

- Copper shunting bar bolted in place across adaptor blocks



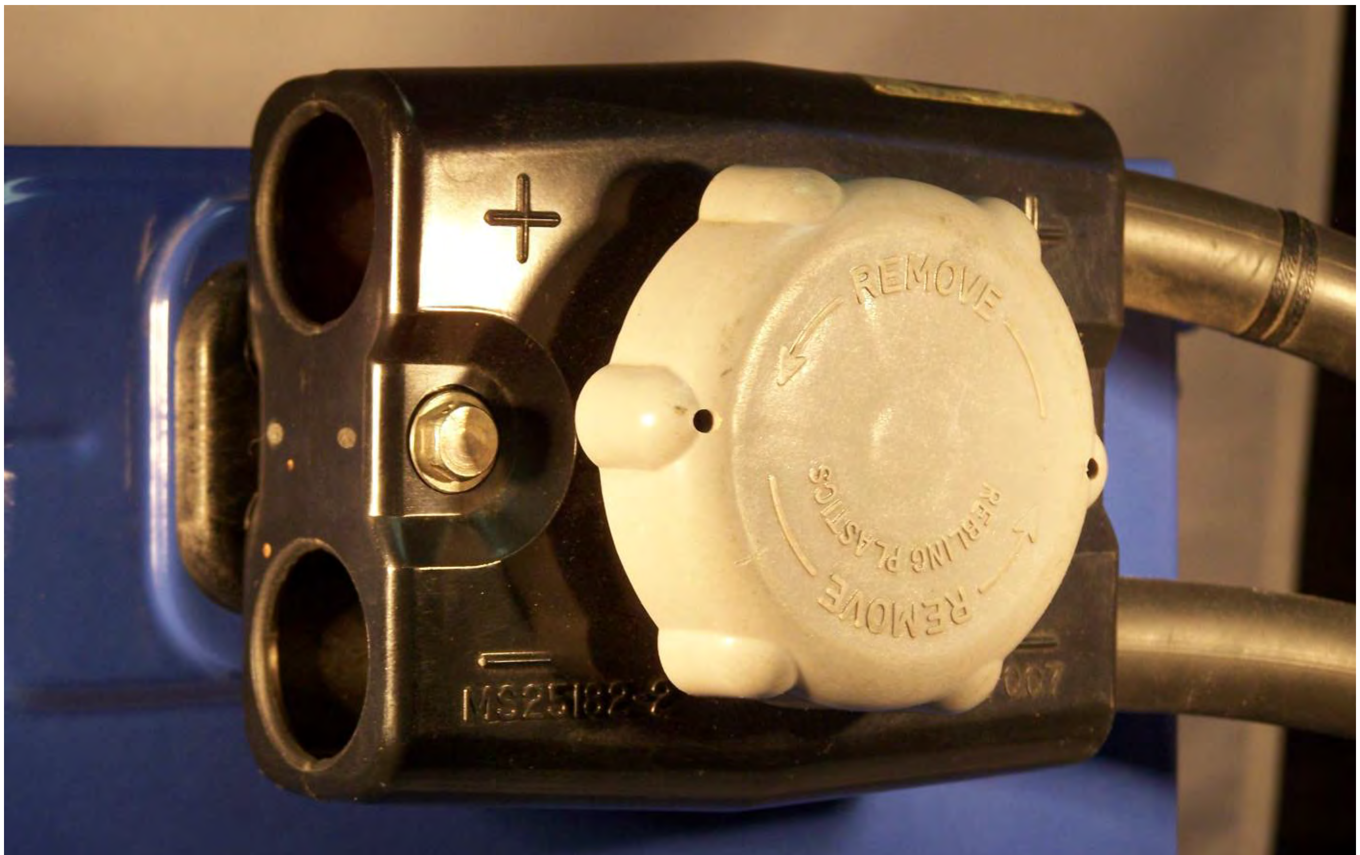
Volt Drop @ 1500A

P/N 7007 & 3509-28: Prototype, Standard



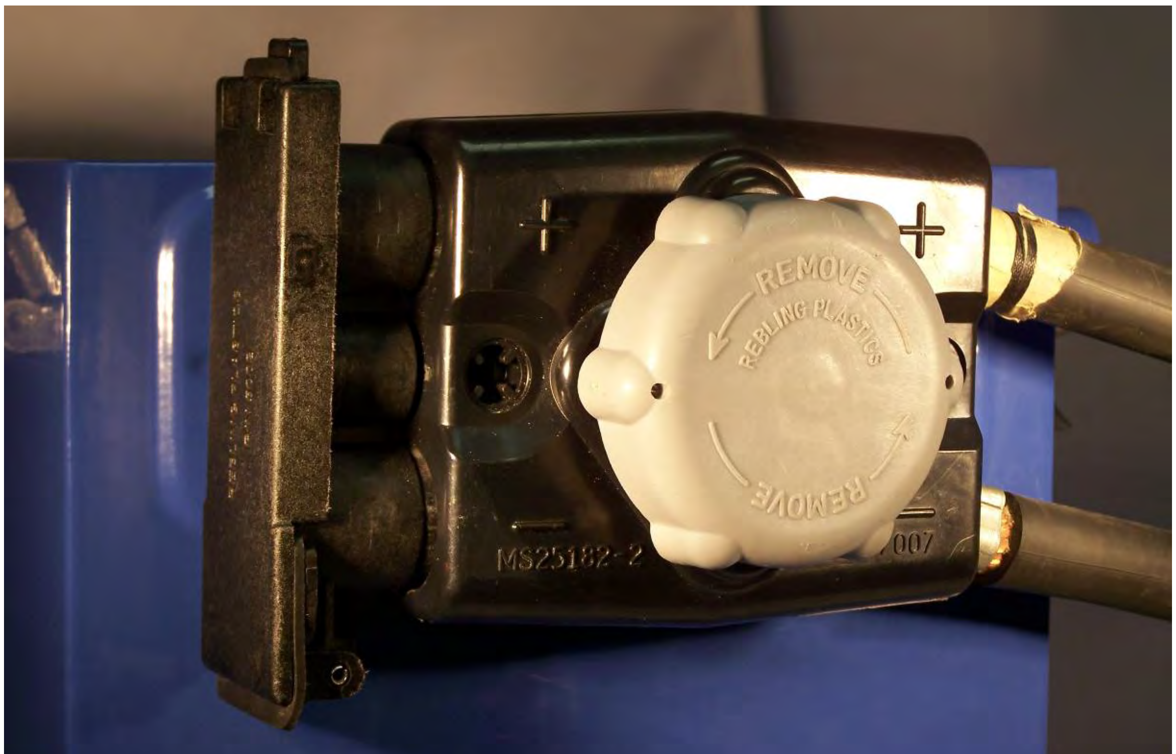
Add-on Connectors for Rebling Plastics MS25182-2

- Normal configuration- only one side used.



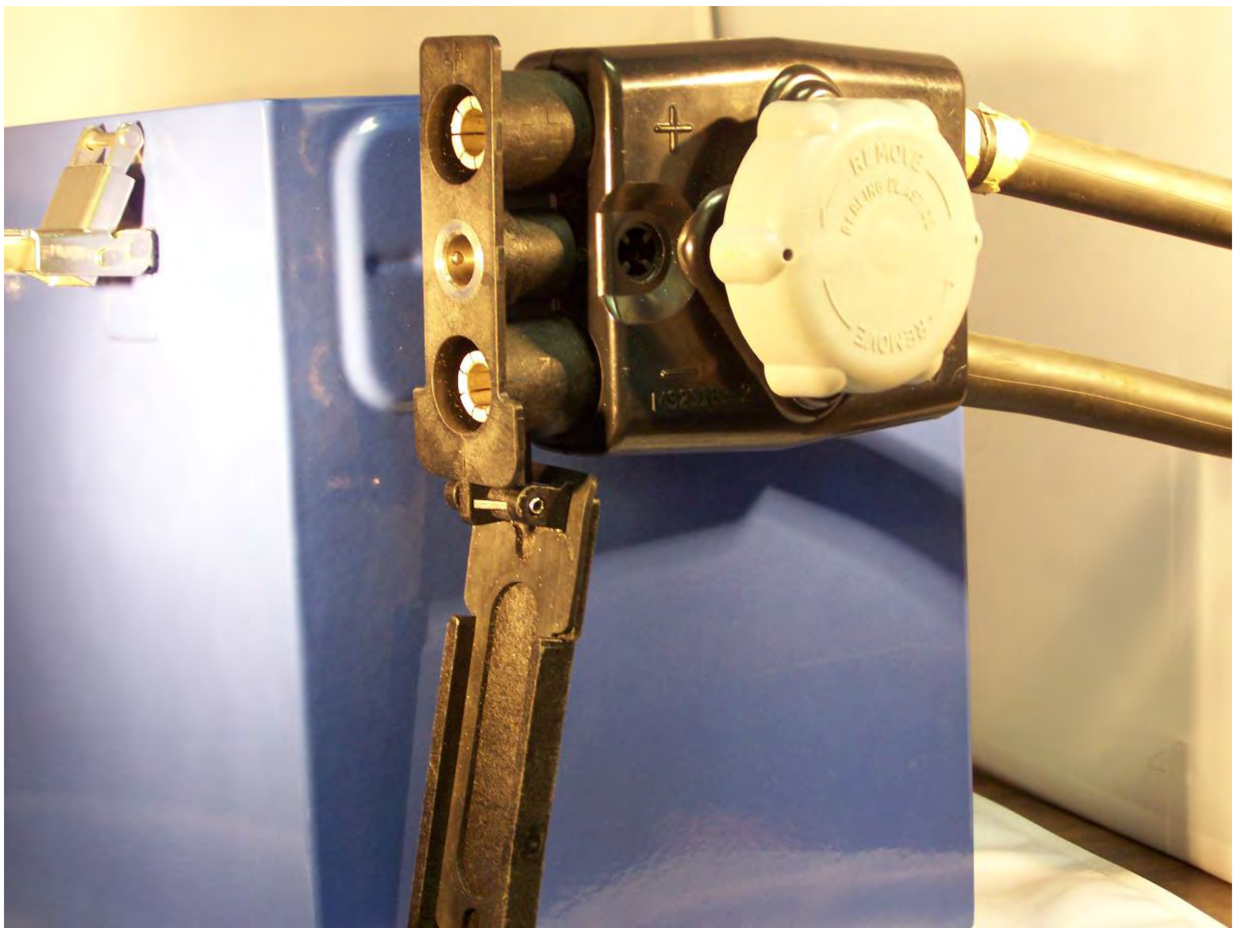
5002 “Add-on Receptacle”

- Design fits either unused side of MS25182-2
- Uses same low-resistance socket/pin design as in MS25182-2 & MS3509



P/N 5002 Open for Connection

- Integral dust cover with gasket keeps sockets clean and snaps open/closed



5003 Quick Disconnect

- Correct polarity guaranteed for either side
- Pivoting handle fits tight spaces

Rebling add-on connections

- Low resistance for high current applications
- Easily retrofit to either side of MS25182-2 connector
- Polarized
- Add-on Receptacle meets qualification requirements of MS25182-2 (MIL-P-18148C)
- Battery always connected

Rebling add-on connections

- Qualified to requirements of MS25182-2
- Installs in Rebling P/N 7007, 4-Wire Connector, Type MS25182-2 Connector
- Makes Available side a Low Resistance Power Receptacle: Micro-ohm resistance
- Allows connecting external power directly to aircraft battery without breaking battery-to-aircraft connection.

Support-Side Add-on Connector

- Installs on support Cable
- Has Comparable high current capability
- Shell Material: High-Temperature Nylon to Endure Mechanical Shocks that can occur during handling

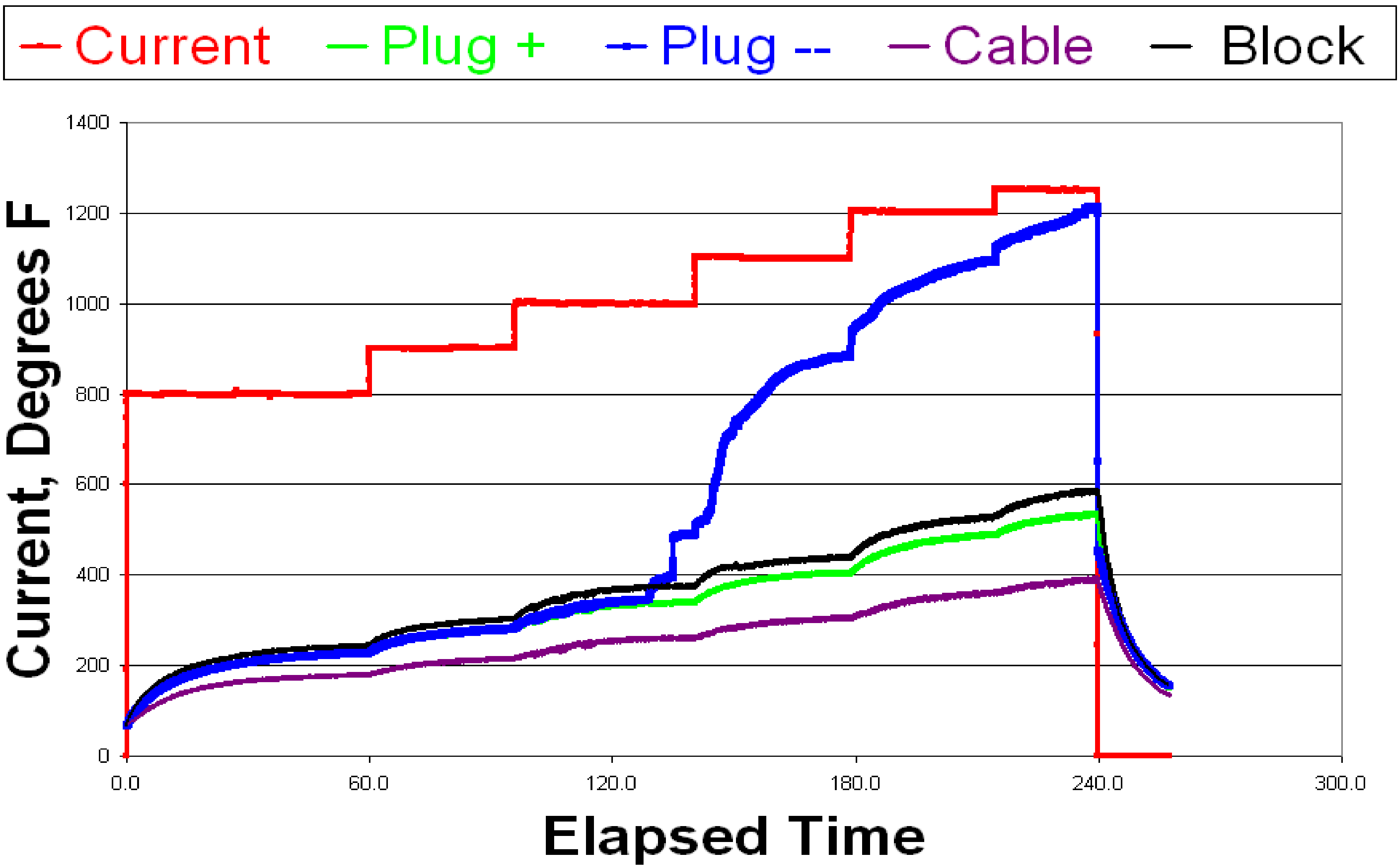
MS25182-2 Four-Wire Connector

- Shell
  - High Temperature Plastic
  - Shell adequately protects contact sockets so that plastic caps are not needed on sockets

MS25182-2 Four-Wire Connector

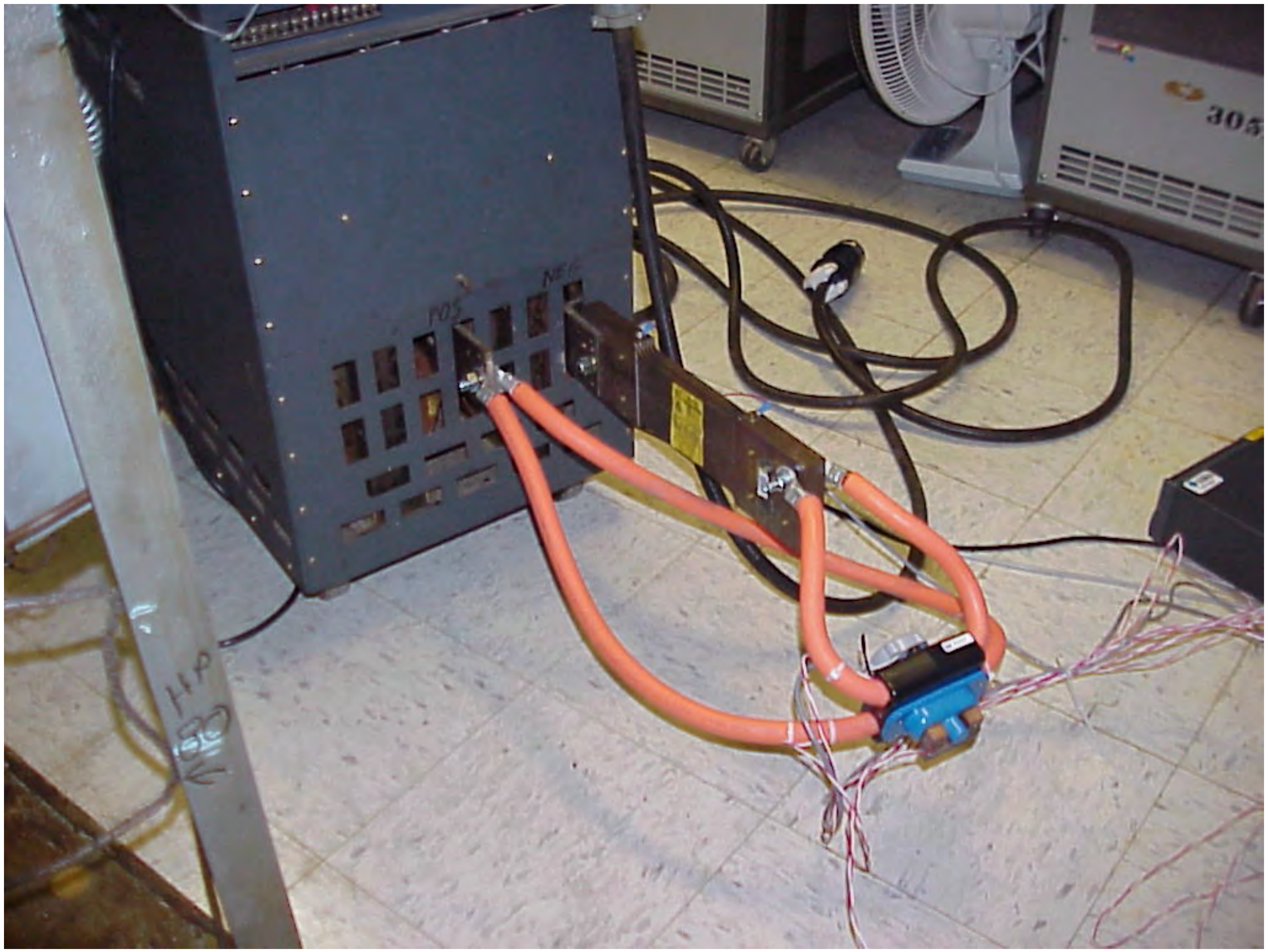
- Contacts
  - Low resistance copper alloy
  - Maximum surface contact with mating pins
  - Floating for precise alignment with mating pins
  - Capable of continuous high current.

P/N 7007, 4-Wire Max Current

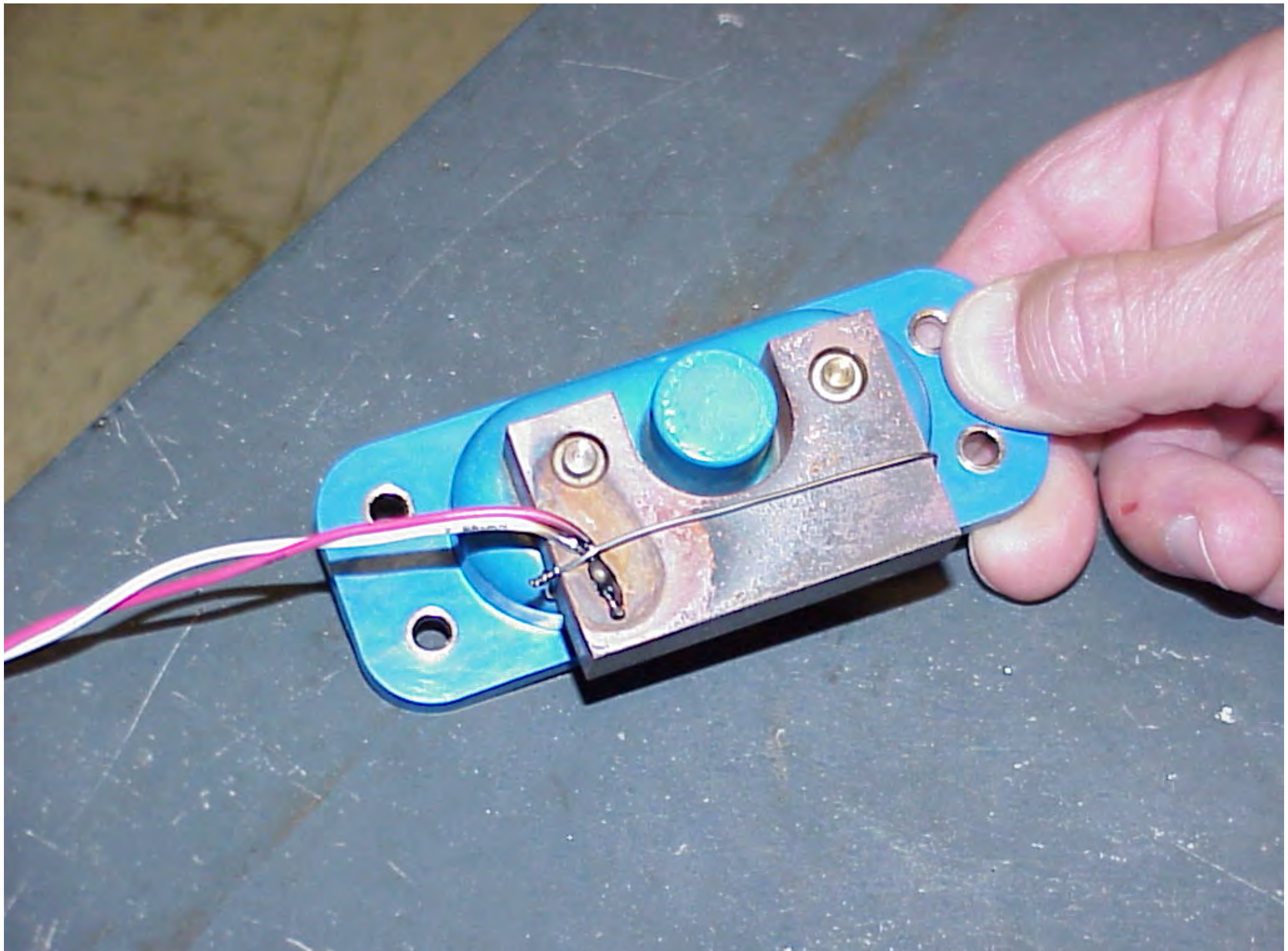


Power Supply Used for Test

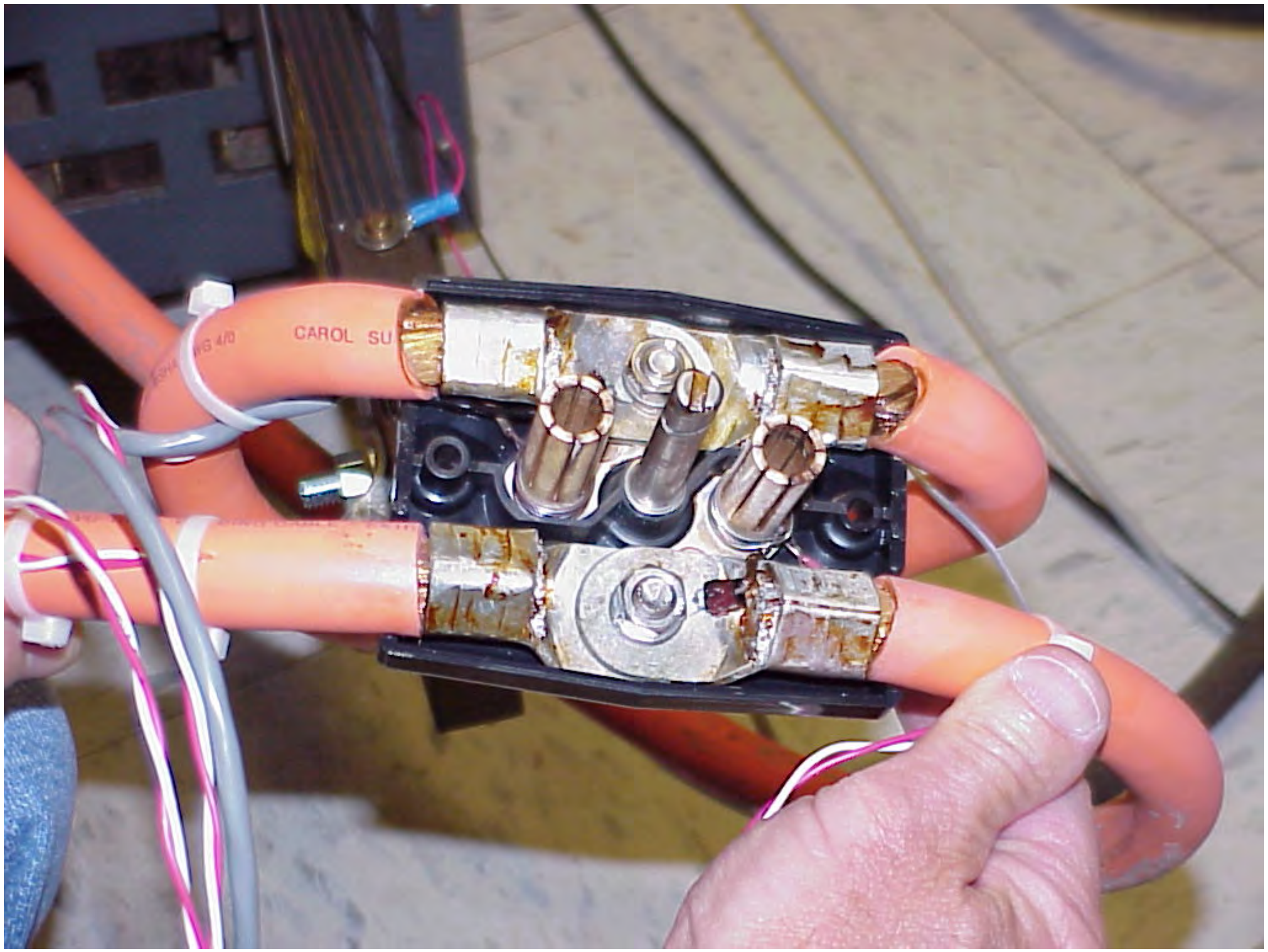
Power Supply, Shunt and Connector



Test Receptacle



Dual Cable Installation



Questions?

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Ni-Cd Battery Separator Improvement

Based upon Mr. Paul Scardaville's research and Crane testing

DSCR and NAVAIR Sponsored program to develop a Ni-Cd battery separator system that will increase battery safety and life to highest levels

Ni-Cd Battery Separator Improvement

2009 Joint Service Power Expo

New Orleans, LA

6 May 2009

OUTLINE

- **Background: Problems that prompted program**

- **Tests:**
  - **Gurley airflow (time to pass air volume)**
  - **Rewet-ability in KOH (soak15%, rewet 30%)**
  - **Temperature-Rise & Float Charge (TR&F)**

- **Comparisons: Results of TR&F**
  - **Wetting agents**
  - **Absorbers**
  - **Gas barriers**

Background

- **Production Battery Performance began to decrement**
  - **Celgard increased average porosity of gas barrier by tightening tolerance toward high porosity limit**
  - **Kimberly-Clark (KC) dropped melt-blown polypropylene (mbPP) absorbers.***
  - **As manufacturers reached end of their KC supply, battery performance decrement accelerated.**

(Reason: “Wayfos A” no longer available)

High/Low Gurley Testing (2004)
Type M81757/16, KC mbPP Absorber

- **Celgard gas barriers with Celgard standard wetting agent**
  - **One with 37 Gurley-second (G-s) porosity**
  - **One with Celgard 3400 (24 G-s)**

- **Both performed essentially same in TRF & Life Cycling.**

- **No difference in post life capacities**

Sulfur Contamination

Sulfur in electrolyte was believed to cause a permanent decrement in capacity.

Source of the sulfur was determined to be from water-soluble dispersants that were used to apply the wetting agent to the mbPP absorber.

NAVSEA WARFARE CENTERS CRANE

Surfactants Suspected

- **Dissections exhibited separator dryout and poor rewet ability in production batteries made after the 1980's**

- **Investigated why wetting agent appeared to leaving gas barrier**

- **Determined Celgard Inc was applying a wetting agent that was fugitive**

Surfactant Comparisons

- Performed a wetting agent rewet-ability using membrane with Celgard's & 2 candidate W.A.s* from Mr. Paul Scardaville's search
- Test: Samples soaked in 15% KOH solution, air dried and returned to 30% solution for rewet.
- Results of soak durations to 12 months
  - A) Celgard 3400: Lost rewet ability in 1 day
  - B) Surfonic L24-4 (alcohol/ether): Rewet
  - C) Deforest HP-739* (anionic ester): Rewet

*HP-739 is a clone of 1970- 2000 Wayfos A & has same CAS #

Baseline Testing

Type M81757/16 batteries with Celgard 37 G-s porosity gas barrier

Separators:

- **#1: Manufacturer's absorber & gas barrier with fugitive wetting agent (N3400G1-P)**
- **#2: Grafted H&V MBPP and N3400G1-P**
- **#3: Grafted H&V MBPP and nonsoluble wetting agent on gas barrier, DePHOS HP 739 (CAS # 12645-31-7)**

Baseline Conclusions

- **Porosity in 20-40 G-s range has large impact on charge stability***
- **Wetting agents**
  - **Nonionic (Huntsman) was unusable**
  - **Fugitive afforded no safety***
  - **Dispersant residues were generally harmful**
- **Coated & grafted absorbers have same performance**

***Influenced by wetting agent transfer**

TR&F Cycling Test

Type M81757 35Ah Batteries

- **Initial charge: 2-Step CC with water addition**
- **TRF cycles:**
  - **Stabilize battery in Chamber @ 120ºF**
  - **315A discharge to 14.4V or 5 minutes**
  - **24-hour CP @ 28.5V**
  - **Repeat -315A and CP charges (M–F)**
  - **Sat AM: Rest open circuit and return to amb.**
  - **Sun PM: Repeat sequence above**
  - **Water additions: As needed**

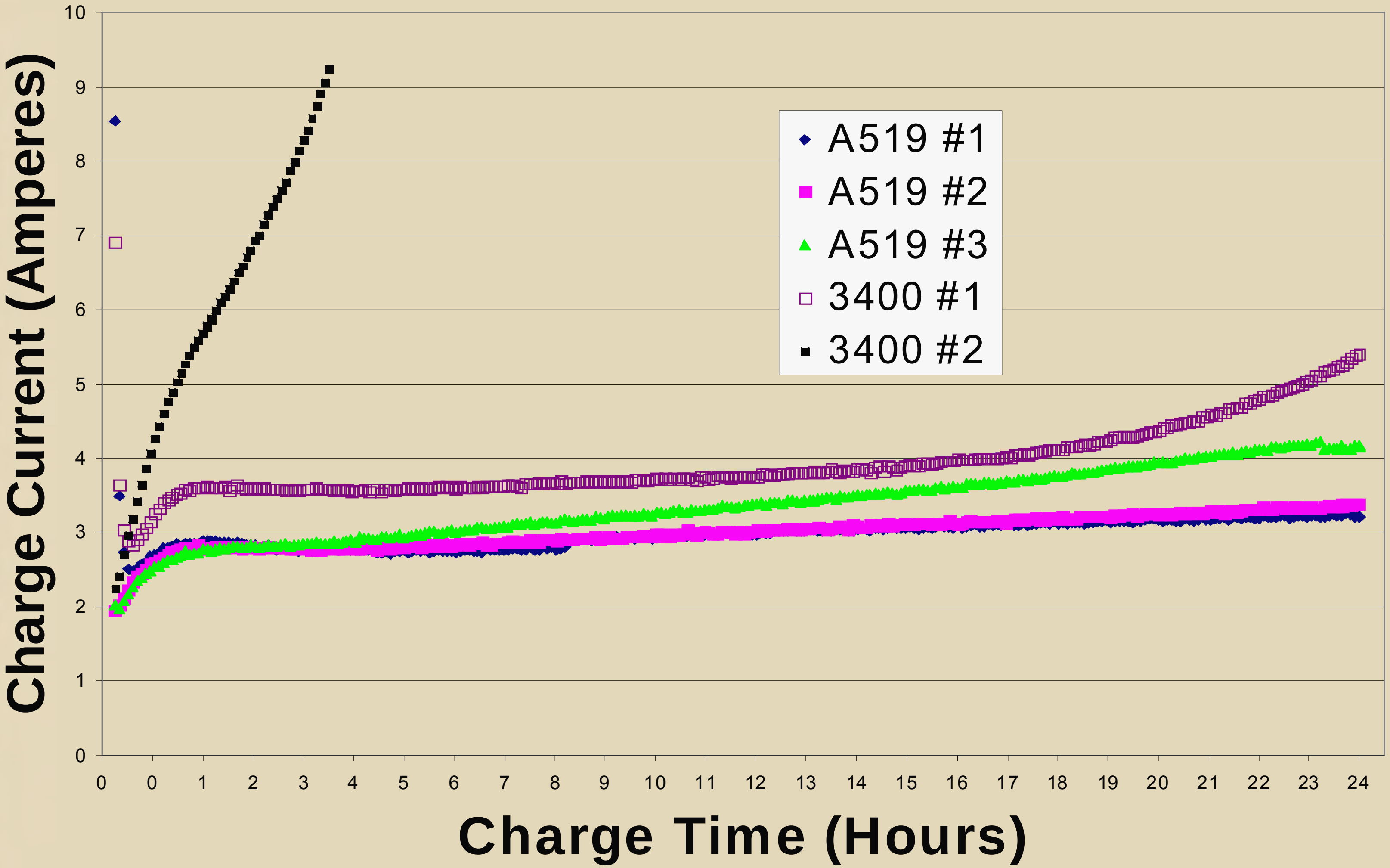
Effects of Gas Barrier Porosity and Applied W.A. on Safety

- **35Ah Batteries using Woven Nylon absorber and different gas barriers**
  - **3400: 24G-s porosity and fugitive wetting agent**
  - **A519: 37G-s porosity & insoluble wetting agent DePHOS HP 739**

    (CAS # 12645-31-7)

Charge Current TR&F Cycling

W.N. & A519 VS. W.N. & 3400



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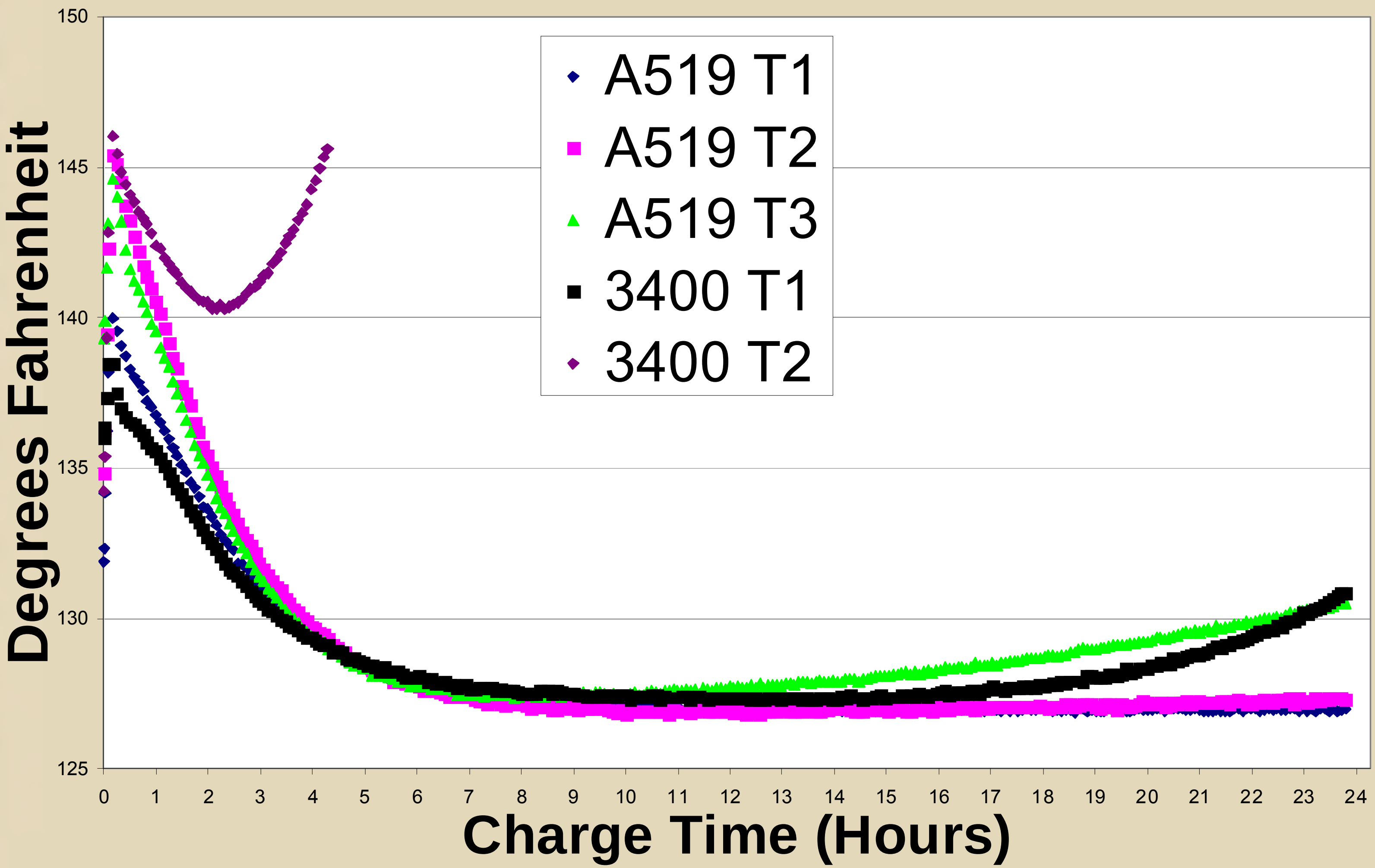
Battery Temperature TR&F Cycling

W. N. & A519 VS. W. N. & 3400



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Wetting Agent Mobility
Effect on gas barrier performance

- **Gas barrier (N3400G1-P)**
  - **Porosity: 37G-s**
  - **Wetting agent: Fugitive - Celgard proprietary**

- **Absorbers**
  - **Grafted mbPP**
  - **Coated mbPP (CAS # 12645-31-7)**

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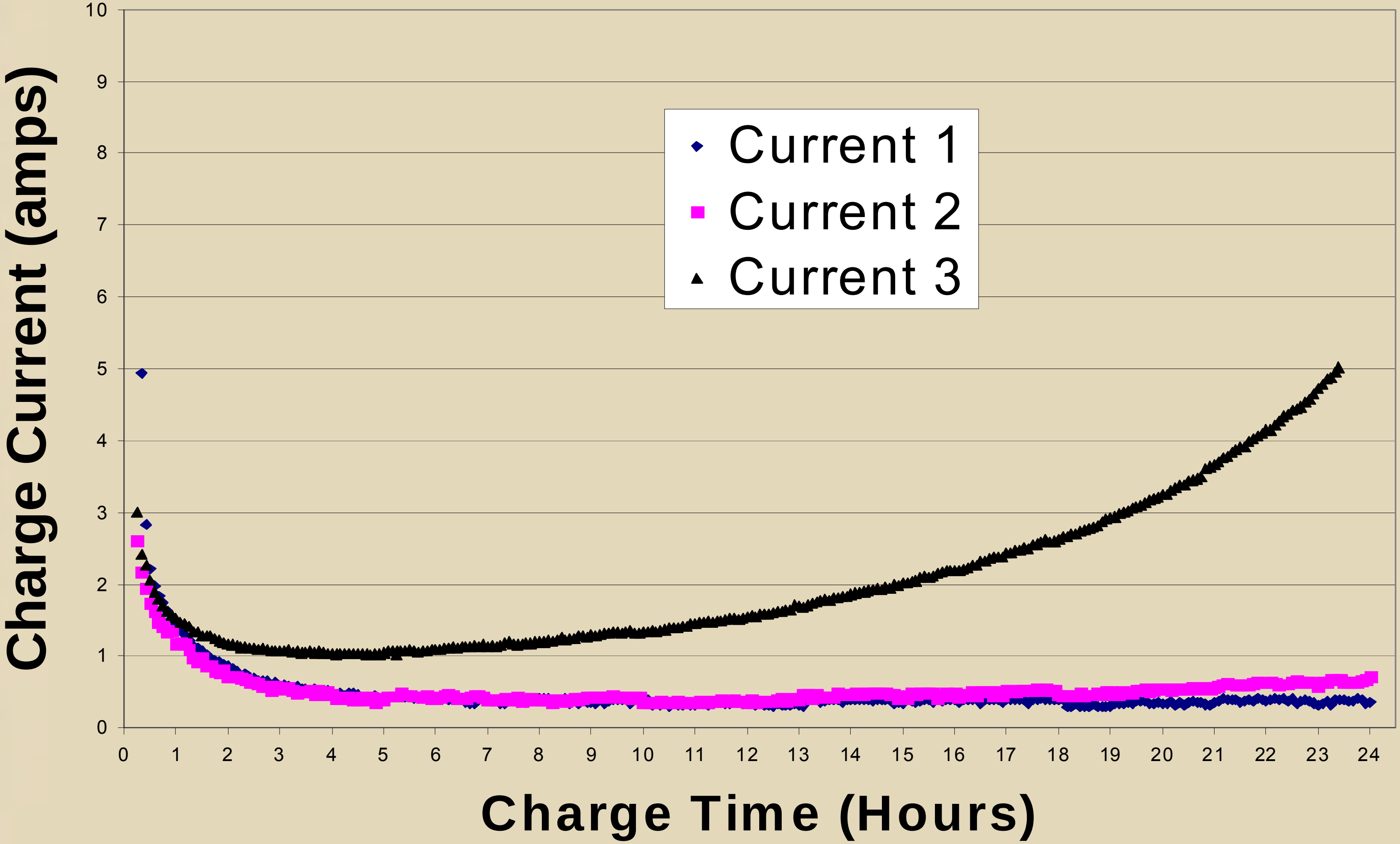
TR&F Charge Current (PL)
Grafted Absorber, N3400G1-P



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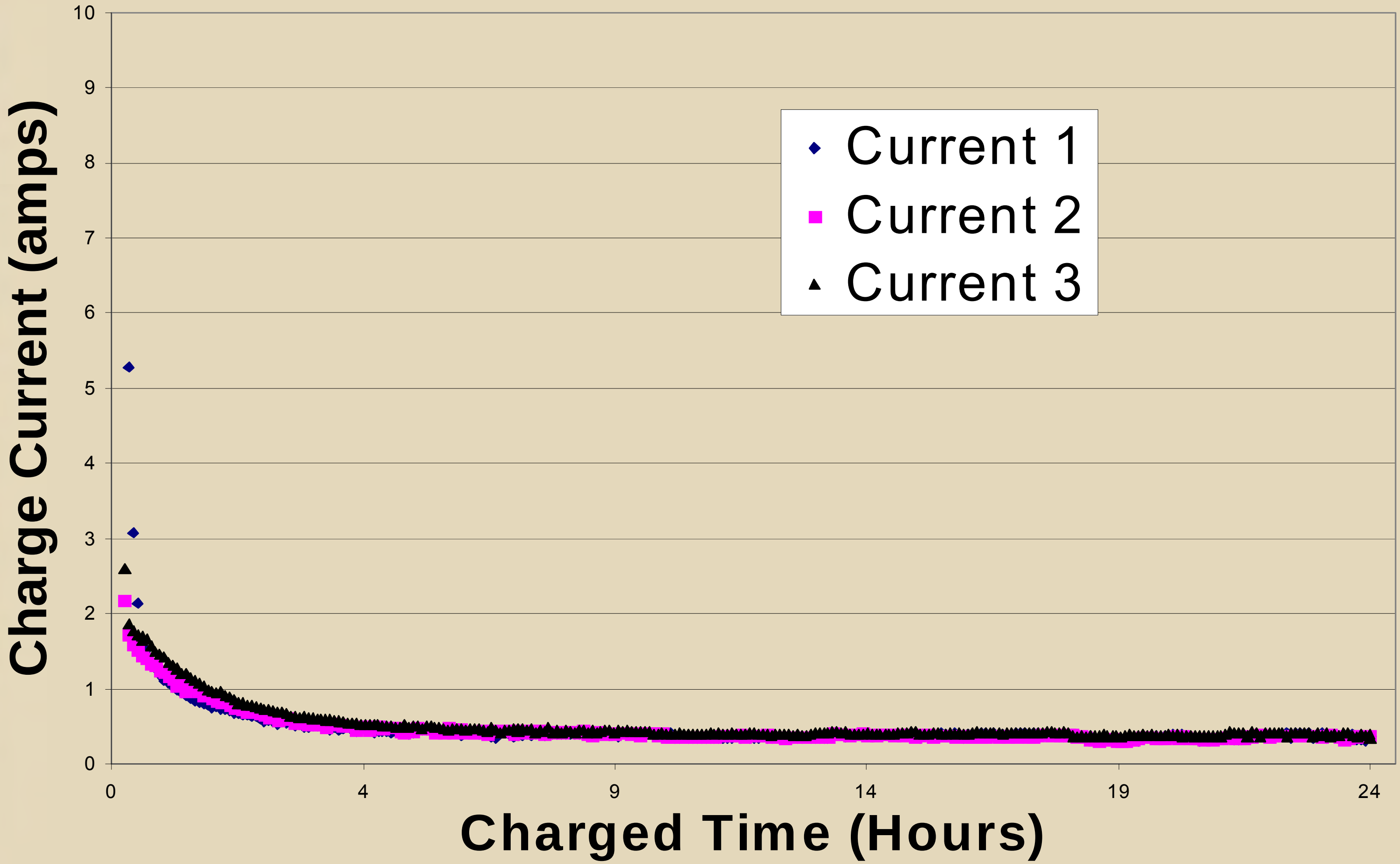
TR&F Charge Current (PL)

Coated Absorber, N3400G1-P



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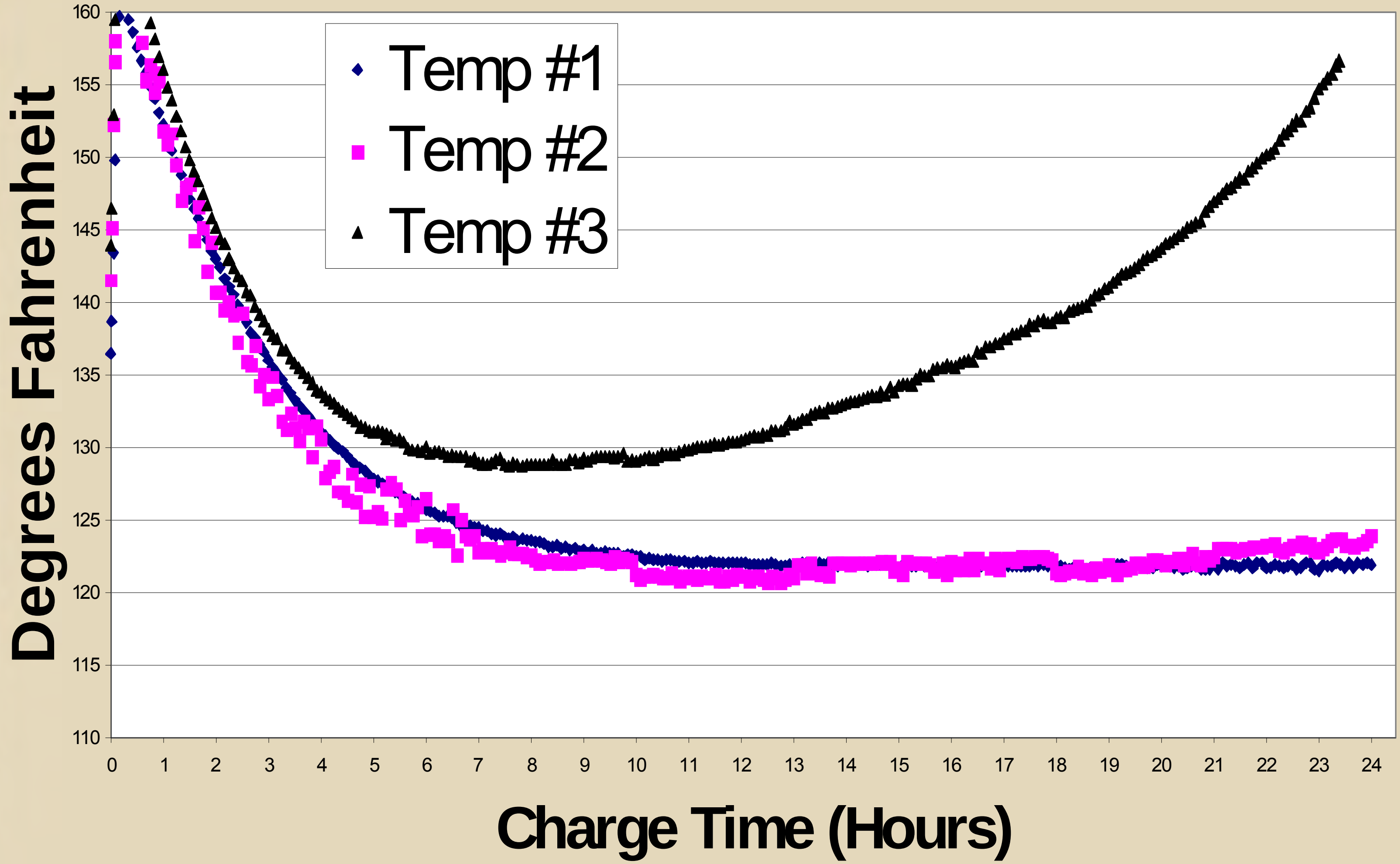
TR&F Charge Temperature (PL)
Grafted Absorber, N3400G1-P



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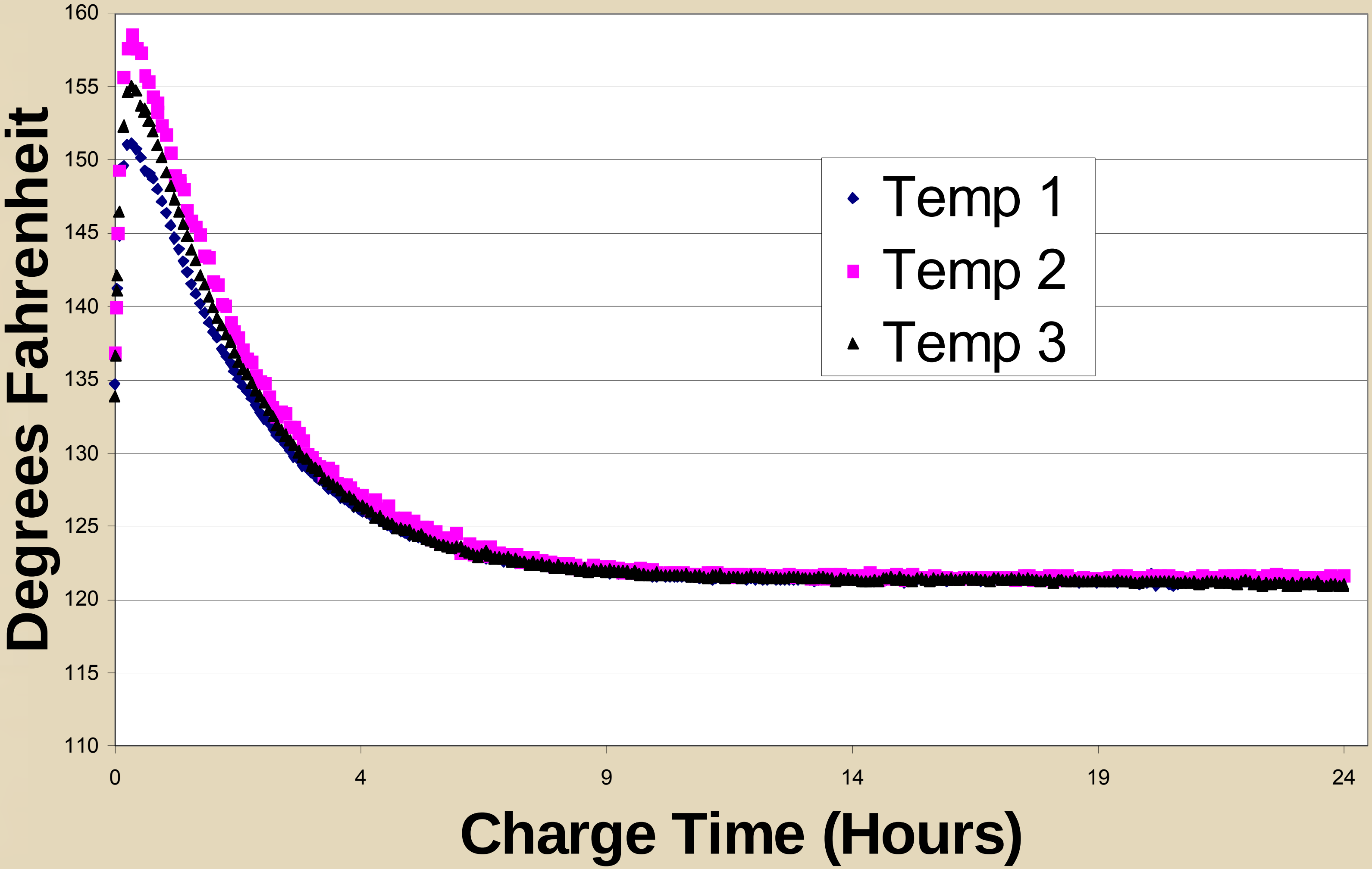
TR&F Charge Temperature (PL)
Coated Absorber, N3400G1-P



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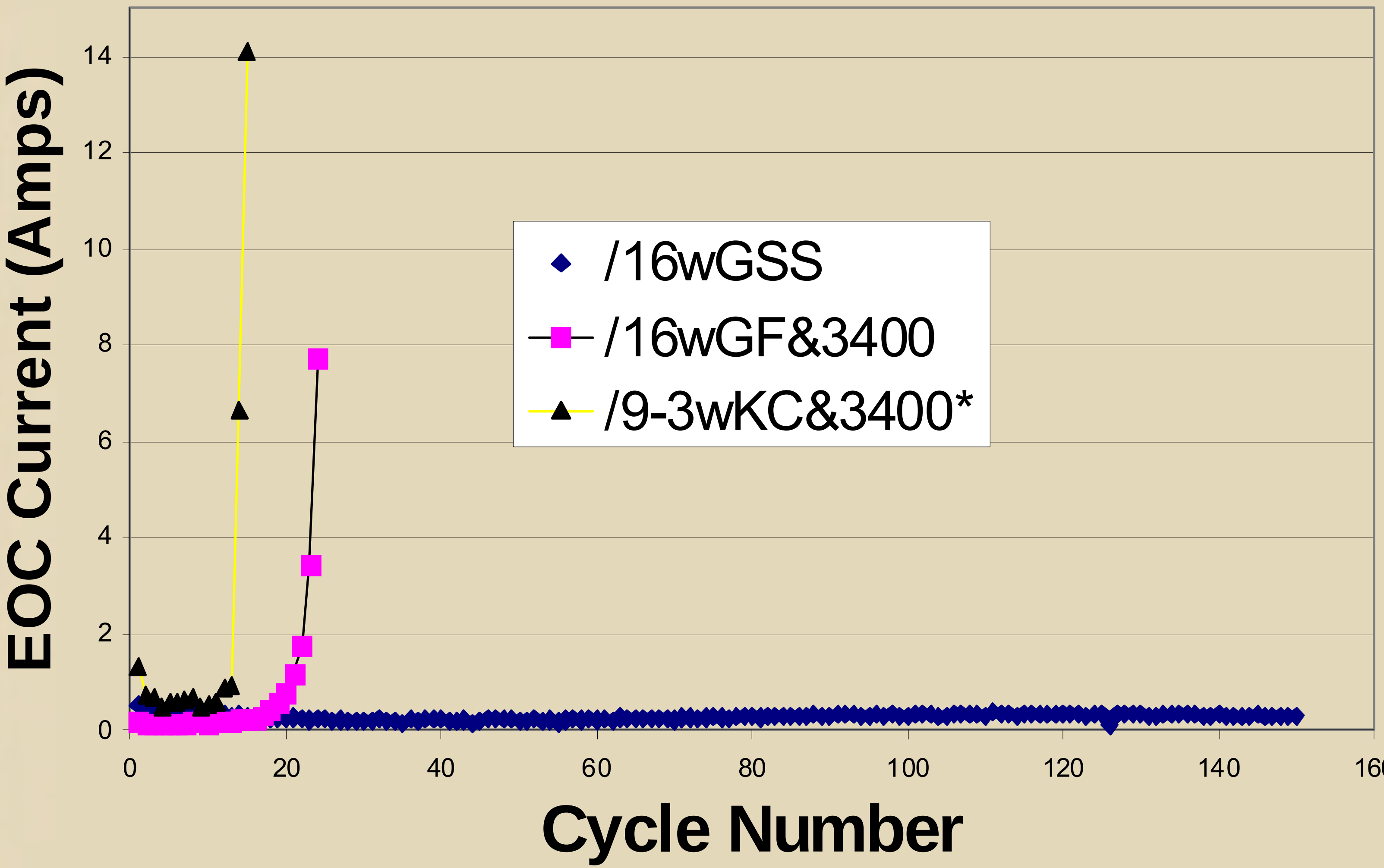
TR&F Conclusions

- **Gas barrier porosity does not control charge stability if wetting agent is absent.**
- **Anionic wetting agent (CAS 12645-31-7) on absorber “caused" charge stability. It appears W.A. can transfer from absorber to the gas barrier.**
- **The wetting agent in the pores IS the gas barrier.**

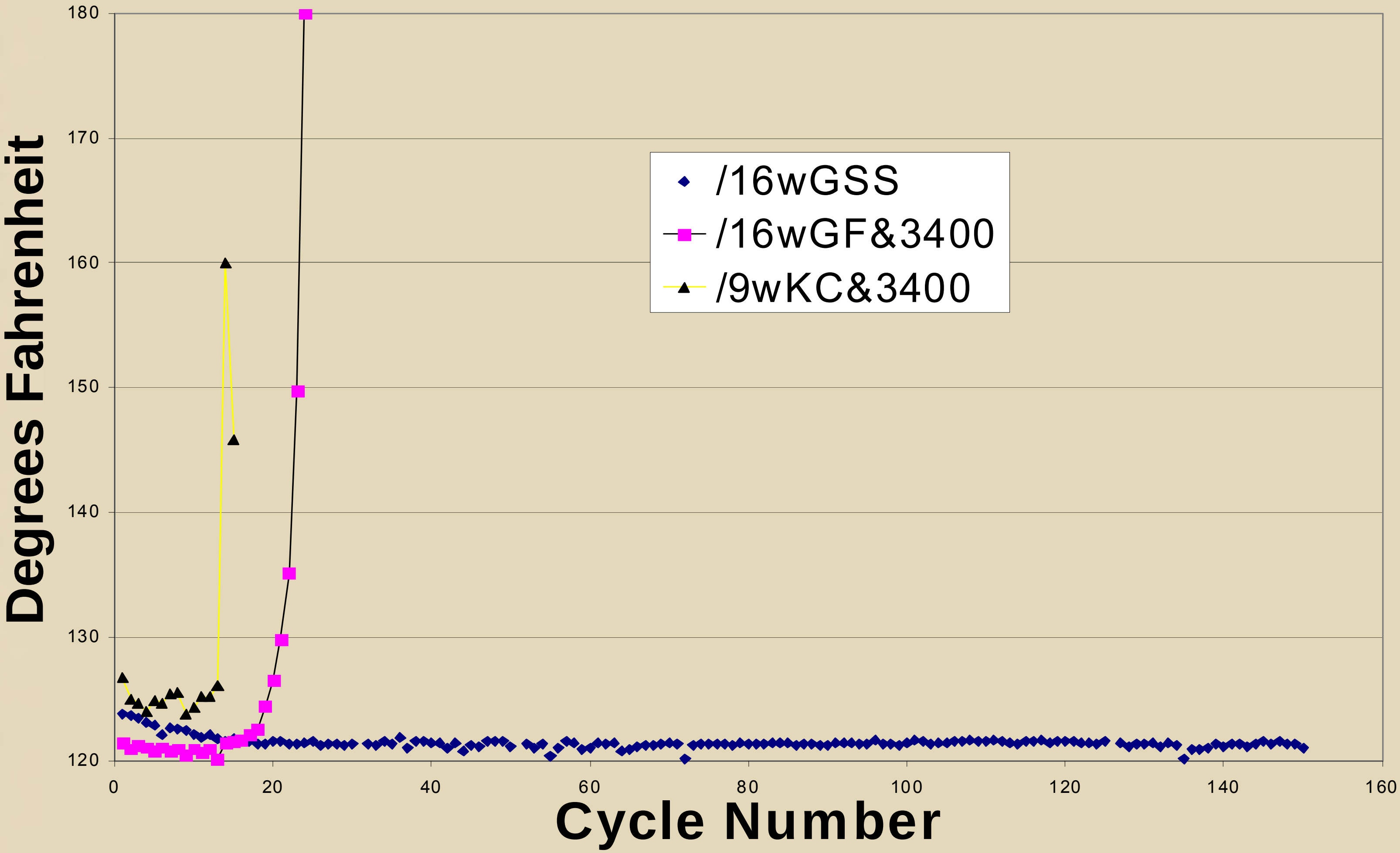
How Good is Good?

- **Type M81757/16 battery with GSS was subjected to continuous TR&F cycling**
- **Results:**
  - **Battery’s charge stability remained completely stable throughout test.**
  - **Testing was terminated after 226 days on test and completing 150 TR&F cycles**

TR&F Cycling Comparisons
EOC Currents



TR&F Cycling Comparisons
EOC Battery Temperatures



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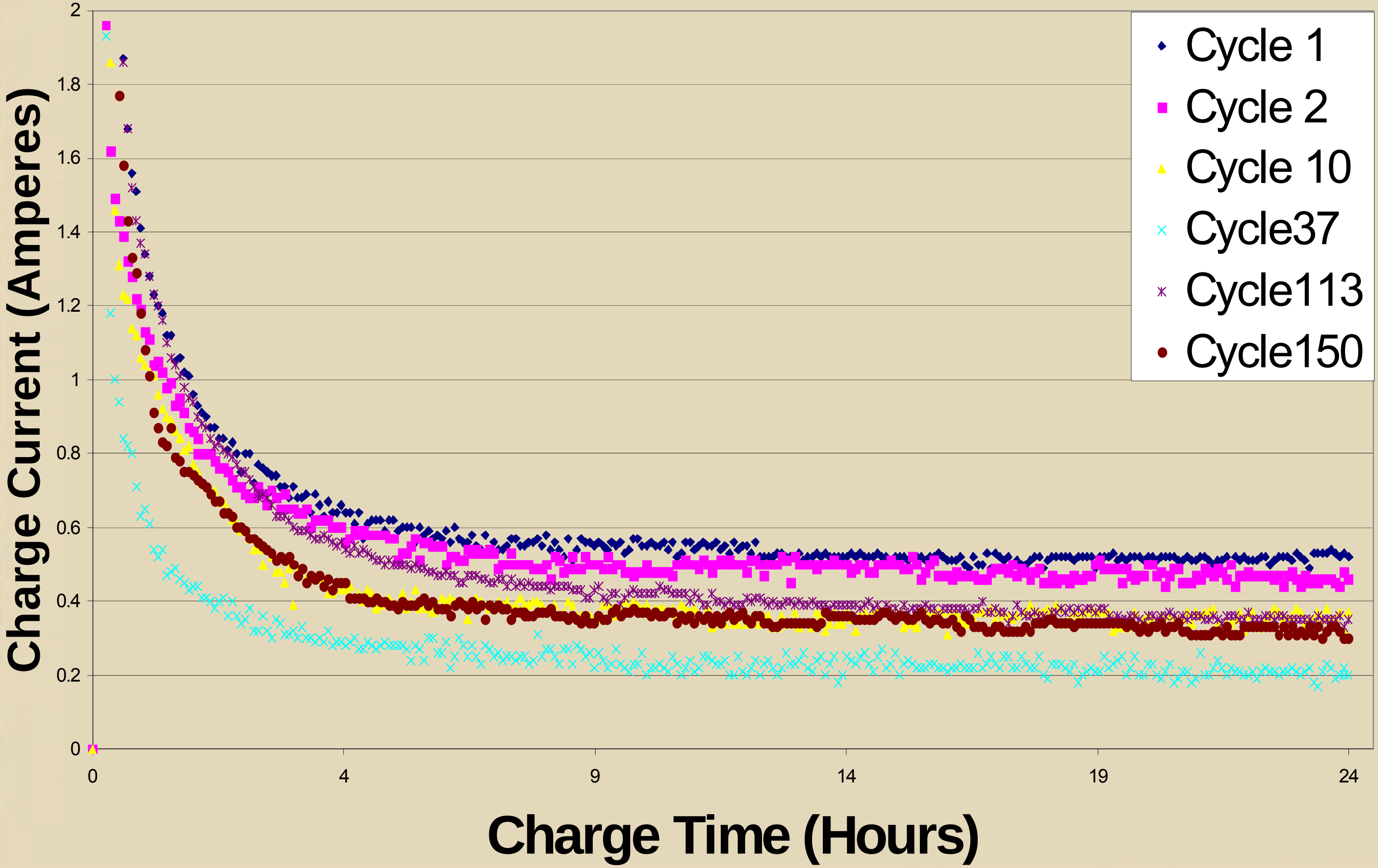
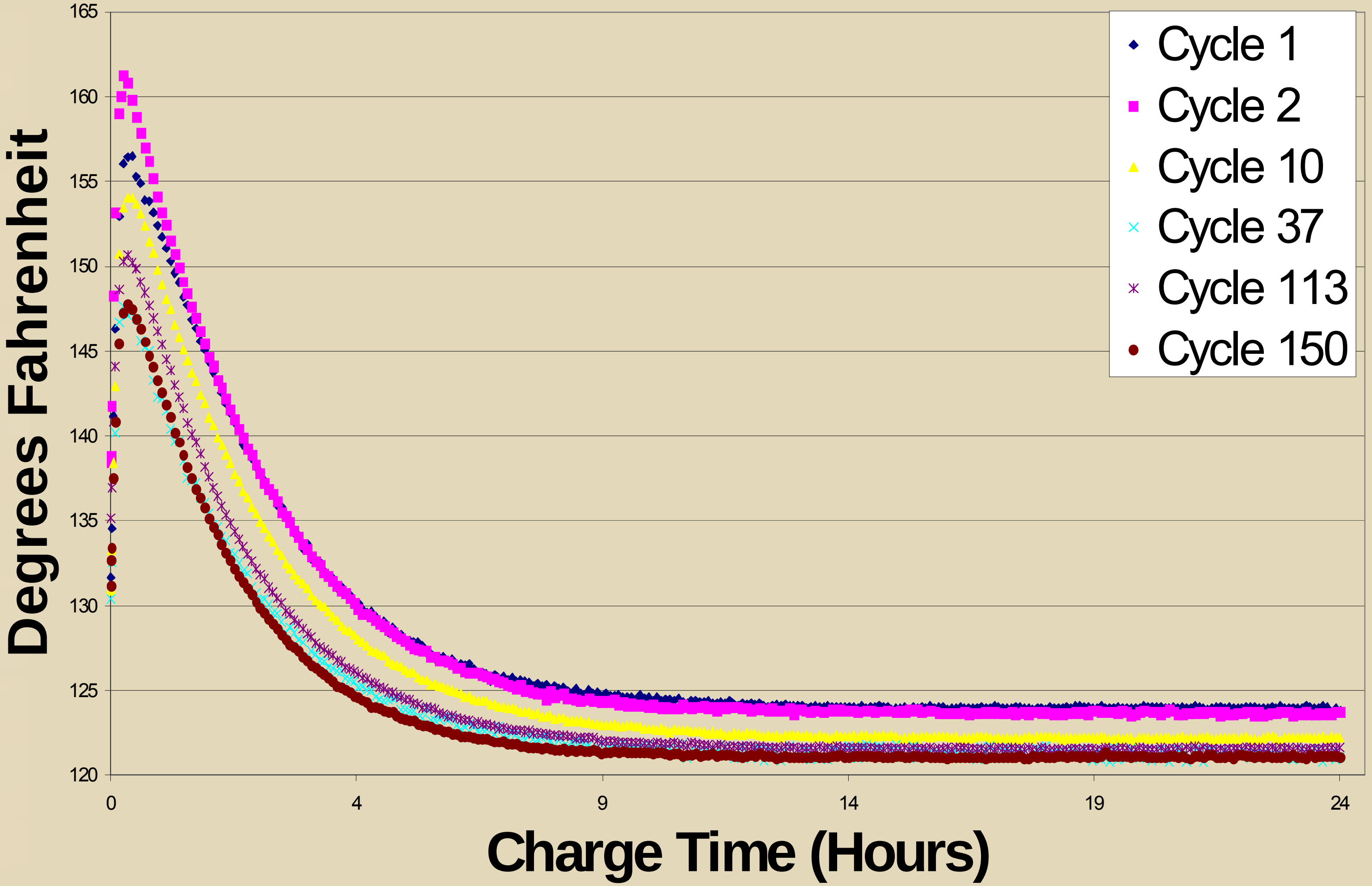
Charge Current
Individual TR&F Cycles



Battery Temperature Individual TR&F Cycles



Specifying a Separator System

- **Wetting agent**
  - **Anionic**
  - **Unaffected by charge V using special test cell**
  - **Insoluble in electrolyte**
  - **Dispersant must leave no residue that can disperse into electrolyte**

Specifying a Separator System

- Gas Barrier
  - Polyolefin membrane
  - Thickness: 1mil ± 0.1 mil
  - Maximum Resistance: 18-milliohm-sq. inch
  - Porosity (35 to 40 G-s)
    - High enough for low resistance
    - Low enough to keep wetting agent in pores.

Specifying a Separator System

Absorber:

- Hydrophilic (W.A. coated preferred)
- Highly absorbent
- High tortuosity for better protection (mbPP)
- Weight: Governed by performance

Any Questions?

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Speaker POC Info

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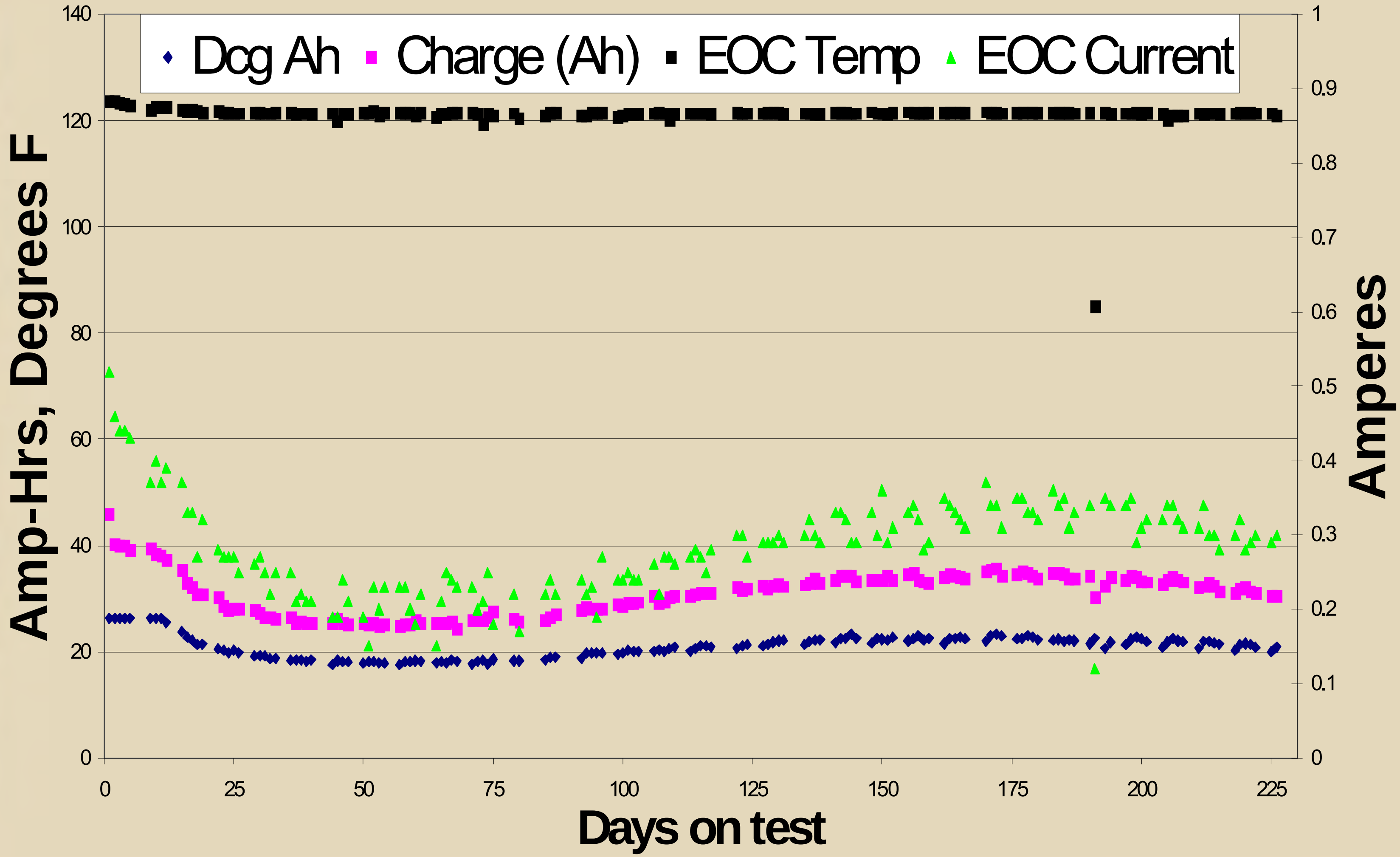
Email: baird.newman@navy.mil

TR&F Cycle Data by Days
on Test GSS: A519 & TRC0950KG



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JOINT SERVICE POWER EXPO 2009

CLARY CORPORATION

PRESENTS

CRITICAL POWER NEEDS TO EFFECTIVELY MAINTAIN CONTROL & COMMUNICATIONS FOR LIFE & SAFETY IN BOTH COMBAT AND NON COMBAT CONDITIONS

ELECTRICAL POWER

Basic Electrical Power is an essential element for all military operations regardless of command or country .

Loss of power as well as bad power causes all critical systems including logistics and weapons systems to fail.

From the military perspective, electrical power encompasses the entire spectrum of portable sources as well as primary power generation, and distribution systems that support all facets of military operations.

Command, control, communications and Intelligence functions are all highly reliant on clean and reliable power. The growing dependence on electricity is a continual increase in the quantity and quality of power to all support operations.

The need for power availability is critical-----but the need for power protection is just as critical and is paramount to the power source in many applications.

MILITARY POWER SOURCING

- *Military power ranges from the power produced by a civilian primary generation system or grid to stand alone military prime generation systems ranging from 0.5 kilowatt generators to 800 kilowatt generator systems.*
- *Complete portability and self containment are critical to all tactical as well as non-tactical systems.*
- *In addition to these typical power sources, greatly increased requirements have surfaced for man portable battery systems for the increased sophistication of soldier carried combat electronics.*
- *Vehicular and shipboard power systems present new and different challenges and new specialized power protection systems.*

MILITARY POWER SOURCING

- *Substantial research is being conducted and in field trials for man power packs to power battlefield electronics.*
- *Promising designs of miniaturized fuel cells sourced with methanol are being field tested today.*
- *In addition, a lightweight water-based fuel cell system is being field tested.*
- *Battery technology is of prime importance for hundreds of man pack applications as well as thousands of field and naval applications.*
- *Lithium, lithium-ion, zinc-air, nickel-metal hydride, technology is growing rapidly in addition to lead-acid, carbon-graphite, zinc-carbon & zinc-chloride dry cells.*

MILITARY POWER SOURCING

- *Present use of lithium sodium dioxide batteries is wide spread. Five to 10 years ago a soldier would consume 3 to 4 watts of power on a typical mission.*

- *Today, we are seeing numbers as high as 20/25 watts of power on a mission.*

- *To provide his 20 watts, a soldier carry as many as 8 2.2 lb LSD batteries in addition to smaller alkaline batteries for a total of about 20 lbs, more than his rifle ammo.*

- *New technologies such as Lithium carbon monofluoride and lithium manganese dioxide are showing promise.*

MILITARY POWER SOURCING

- *The advent of fuel cells research covers a wide spectrum of applications from the miniaturized versions for laptop computers to large systems to power hybrid vehicles, to straight electrical power generation for tactical as well as non-tactical operations.*
- *Fuel cell power is clean, easily regulated and totally self contained, no moving parts.*
- *While this is a promising technology with significant testing both in the lab and the field being done by the military as well as the civilian communities, it still is expected to be some years before it will become a significant source of power to the world.*

COTS vs MIL SPEC

- *In the early 1990's our political system decided that the military could more effectively upgrade all of its computer, electrical and electronic needs by utilizing COTS (commercial of the shelf) equipment to replace MIL SPEC components and more quickly upgrade electronics &computer equipment at a cost savings.*

- *It was ultimately found that this equipment had to be modified to work effectively in a military environment. There was some savings, however, MIL SPEC's were shown to still be needed and much modifications were required.*

- *MIL SPEC's must still be met and are required.*

POWER PROTECTION REQUIREMENTS

- While many power sources are required for the military, power protection is just as critical.
- Power protection is most critical to infrastructure, vehicle and naval shipboard applications.
- The increased sophistication of the computer systems utilized by all services required increased sophistication of power protection and uninterruptible power systems.

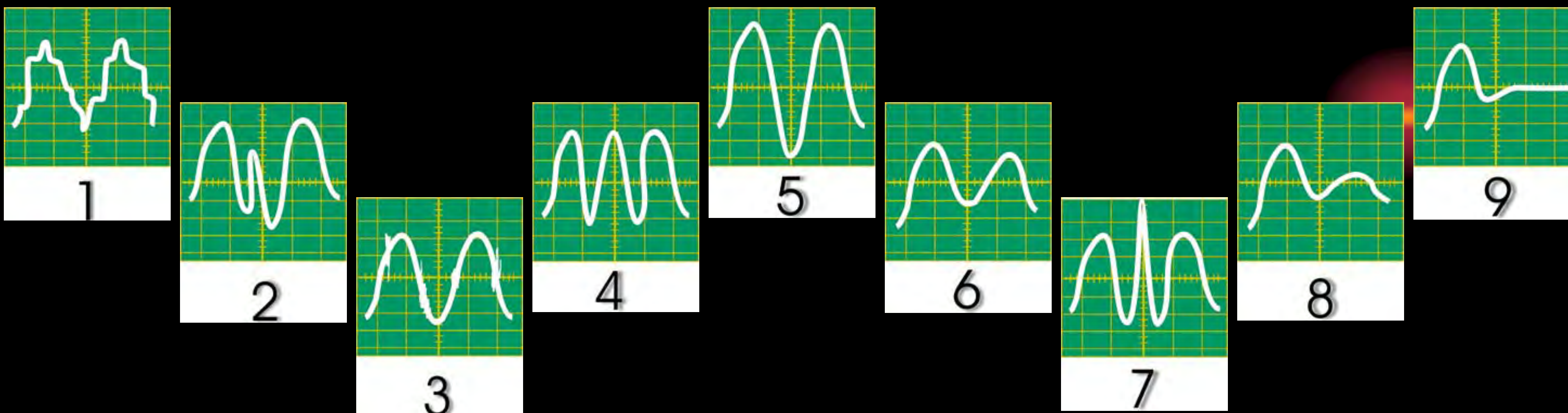
THREE CRITICAL POWER POINTS

- *RELIABLE Power-----Is CRITICAL to effectively maintain control and communications for life and safety.*

- *Power CAPACITY-----Is CRITICAL because power generation being from unknown sources or varied self contained generator systems that have unknown regulation capabilities.*

- *QUALITY Power----Is CRITICAL because of increased sophistication of equipment. Bad power decreases reliability, and increases damaged equipment as well as replacement costs for damaged equipment.*

The NINE greatest power quality problems



1 Frequency & Harmonics

2 Transients

3 Line Noise

5 Power Surges

6 Brownouts Sags

7 Spikes

8   Overvoltage

9. Power Failure

POWER PROTECTION & UPS SYSTEMS

- *Spike and surge suppression is first basic protection device utilized. This system Is inexpensive and provides minimal protection.*

- *Battery Backup Systems similar to APC products are part time protection, providing power only when utility power is lost.*

- *Uninterruptible Power Systems (UPS) are the only full time protection, providing clean regulated power to all loads, at all times.*

BATTERY BACKUP vs TRUE ONLINE UPS SYSTEMS

- *Available Power Protection for Computer & Electronic Systems is achieved by--- Multiple types of power protection systems.*
- *First there is the basic--- BATTERY BACKUP (BBS) system. This is least expensive system that only provides power from its batteries when utility power is lost. This is a standby LINE-INTERACTIVE design concept. This is only ----PART TIME protection*
- *The second is a reverse conversion/bidirectional design which is a hybrid (BBS) design that still provides only PART TIME protection.*
- *The third is the ONLINE DUAL CONVERSION UPS SYSTEM. This is the ONLY-FULL TIME protection design for all operational systems.*

LINE INTERACTIVE BATTERY BACKUP SYSTEM

- *NO Real-Time Voltage Regulation or conditioning*
- *Inverter ONLY Functions When Utility Has Failed*
- *NO continuous power regeneration capability*
- *2-20ms Transfer Time*
- *Generator compatibility ONLY under special conditions*
- *Various types of sine wave power output – pure-square-stepped*
- *Load is NOT isolated from Utility Power*

TRUE Dual Conversion Real-Time ONLINE UPS

- *Always:*
  - *Isolates the Load From the Utility Input AC*
  - *Rectifies the Input AC to DC then through DC to AC inverter*
  - *Real-Time Power Factor Corrects to Unity: pf=1*
  - *Generates A True Clean Sine Wave Output With the Inverter continuously inline to all loads*
  - *Supplies Fully Regulated & Isolated Voltage To all Loads*
  - *Synchronizes to the Input Phase of utility power*
  - *Online mode sync to utility with no break, maintains timing*
  - *Zero Transfer Time*
  - *Compatible with mobile 120 V inverters*
  - *Battery charging system fully temperature compensated*
  - *Battery charging system independent of inverter*

KEY DIGITAL UPS SYSTEMS COMPONENTS

- UPS is fully Programmable & Software Controlled
  - Controls all Calibration and Synchronization Circuits
  - Matches the Input and Output Frequencies (PLL)
  - Allows Safety and Manual Bypass to Function Correctly
  - Insures Constant, Clean and Regulated Output Voltage
  - Monitors & Protects Overloading
  - Monitors All Vital Statistics and Alarm Points
  - Controls, Monitors and Regulates All Operational Stages Within the UPS
  - Monitors and Corrects Utility input Power Factor
  - Provides full time LINE and LOAD Regulation

VOLTAGE REGULATION
The Key To Effective Protection

- *It is common knowledge that the greatest danger to hardware and software are daily power problems. A Bell Labs study has shown blackouts account for less than 5 % of power disturbances. The other 95 % is comprised of daily power problems like sags, surges, noise, brownouts and voltage/frequency deviations.*

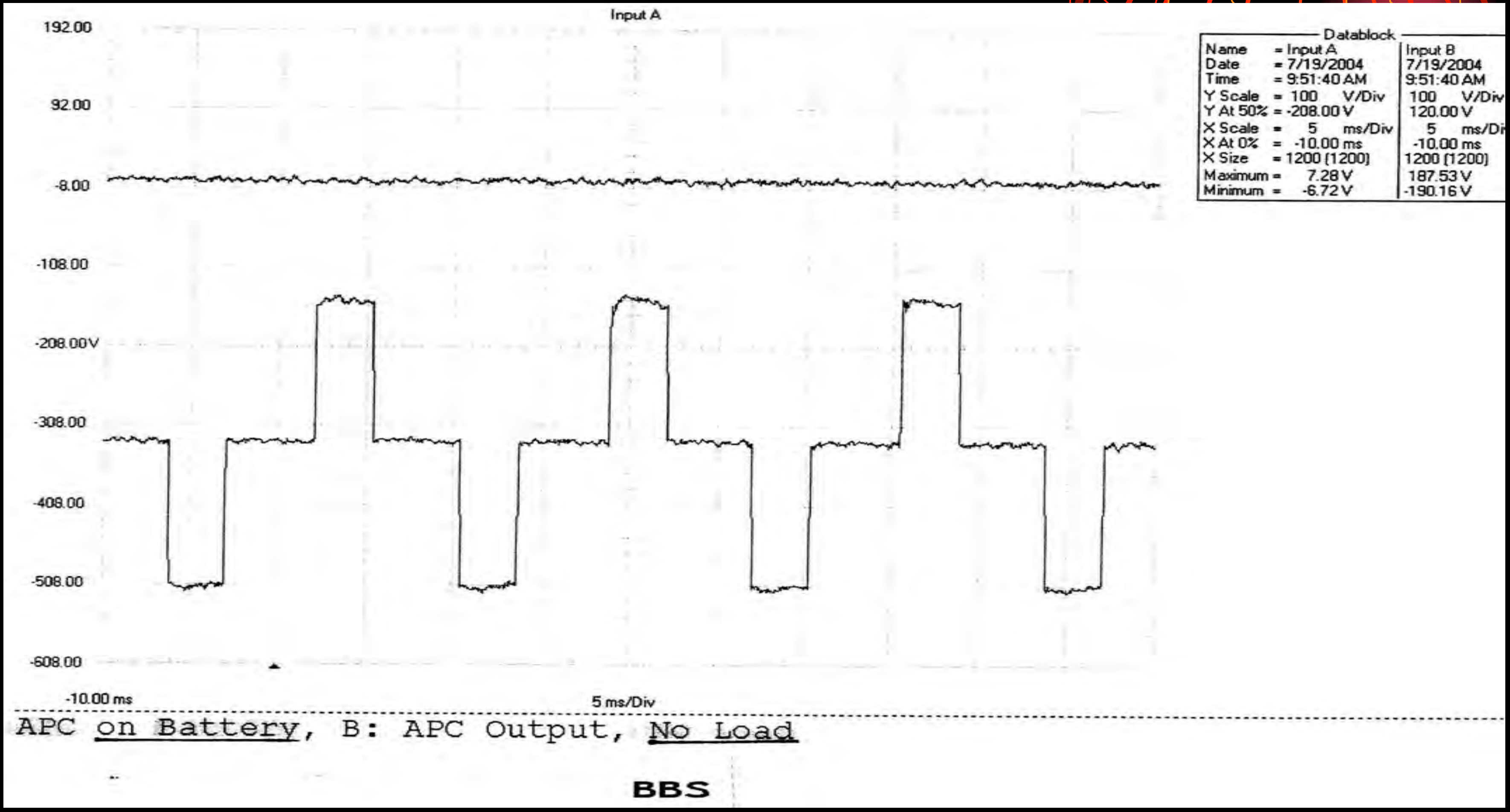
- *This "Power Pollution" wears and tears hardware and software, leading to premature failures and costly outages as well as major decreases in public safety.*

POWER WAVEFORM EXAMPLES

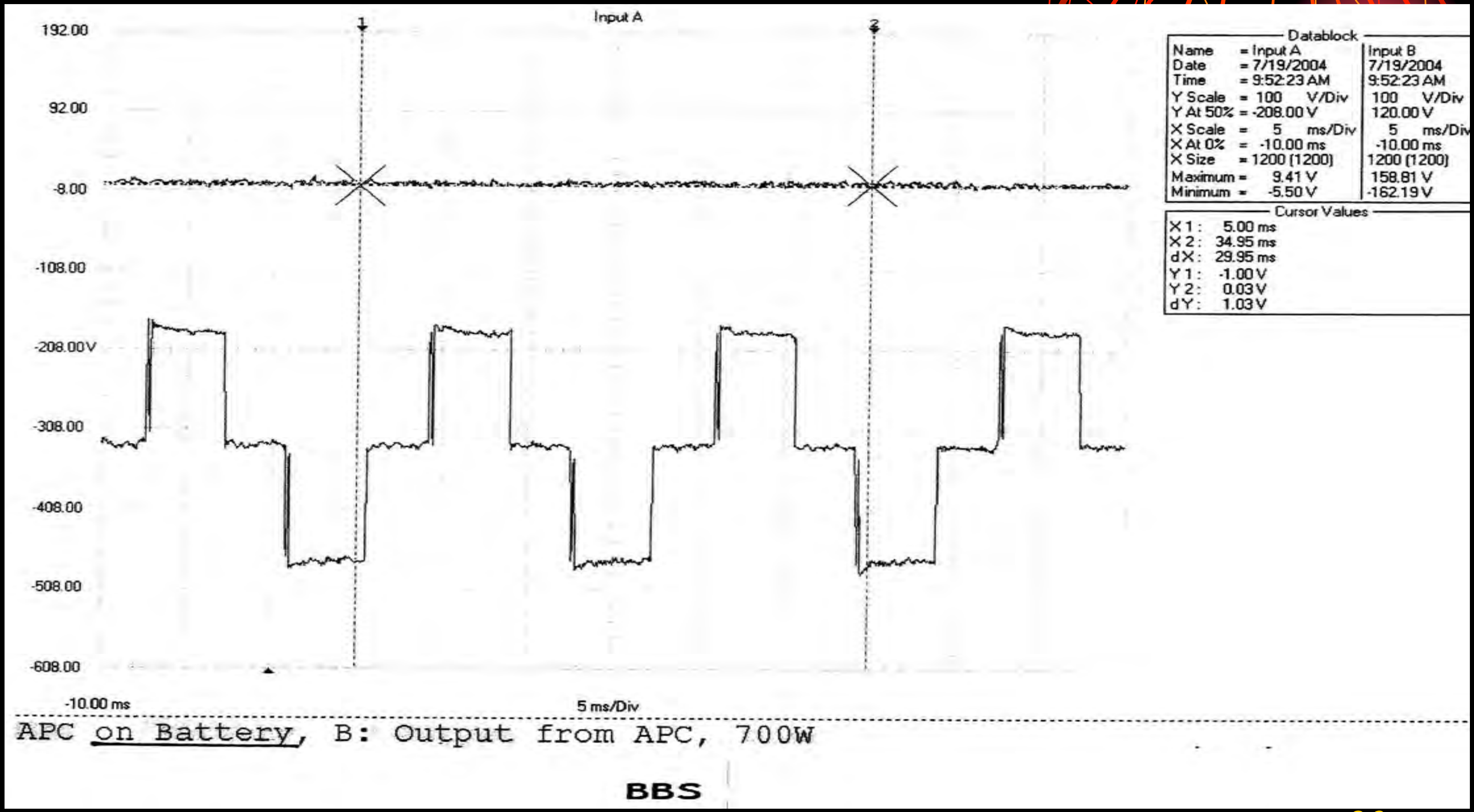
*1. The following slides are actual waveforms which show dirty or bad power sources as input to a **ONLINE UPS** system and the resultant **CLEAN-REGULATED** power output from the UPS.*

2. Additional waveform examples show the relationship of dirty or bad power and the effects of using a typical BBS-Line interactive system for protection.

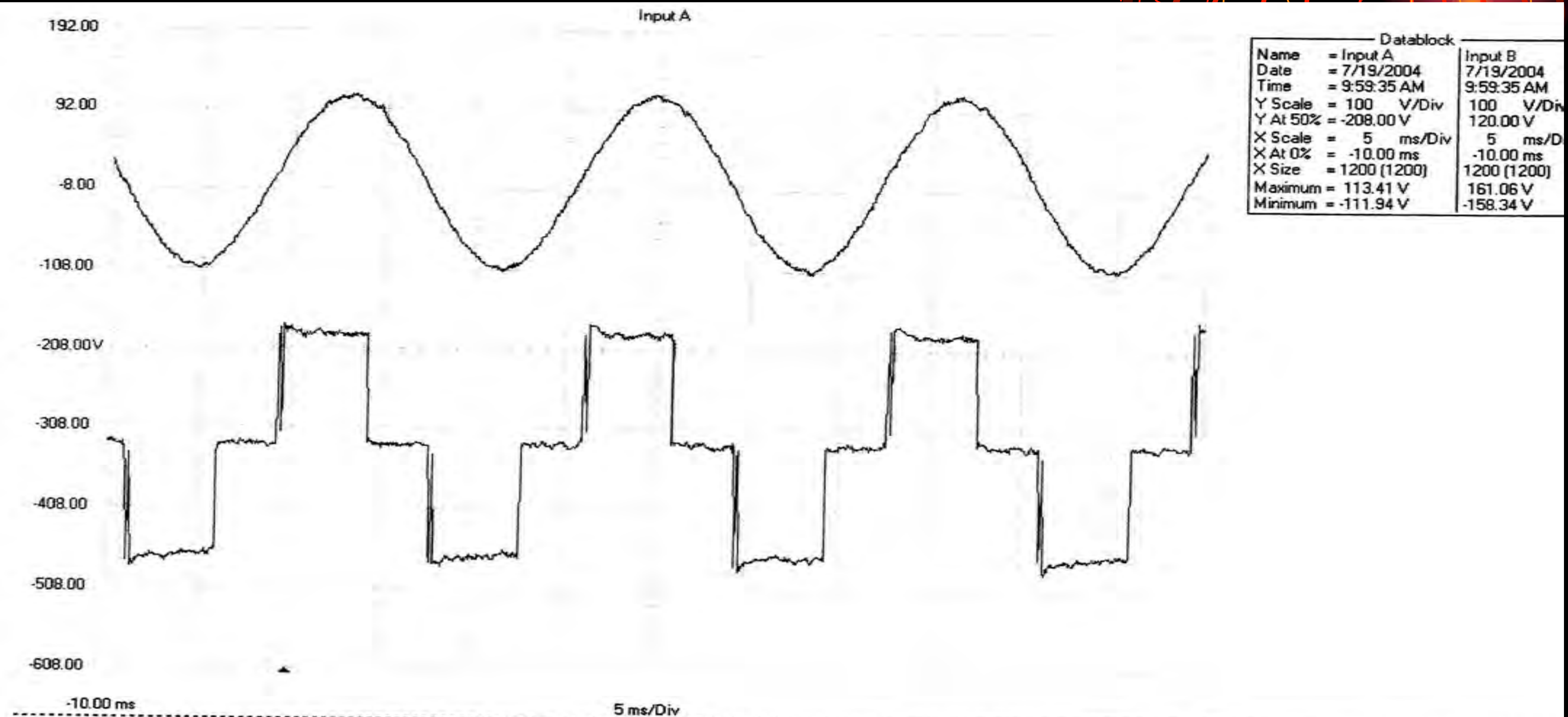
TYPICAL BBS – NO AC INPUT & NO LOAD



TYPICAL BBS WITH NO AC INPUT & ON BATTERY SUPPORTING 700W LOAD



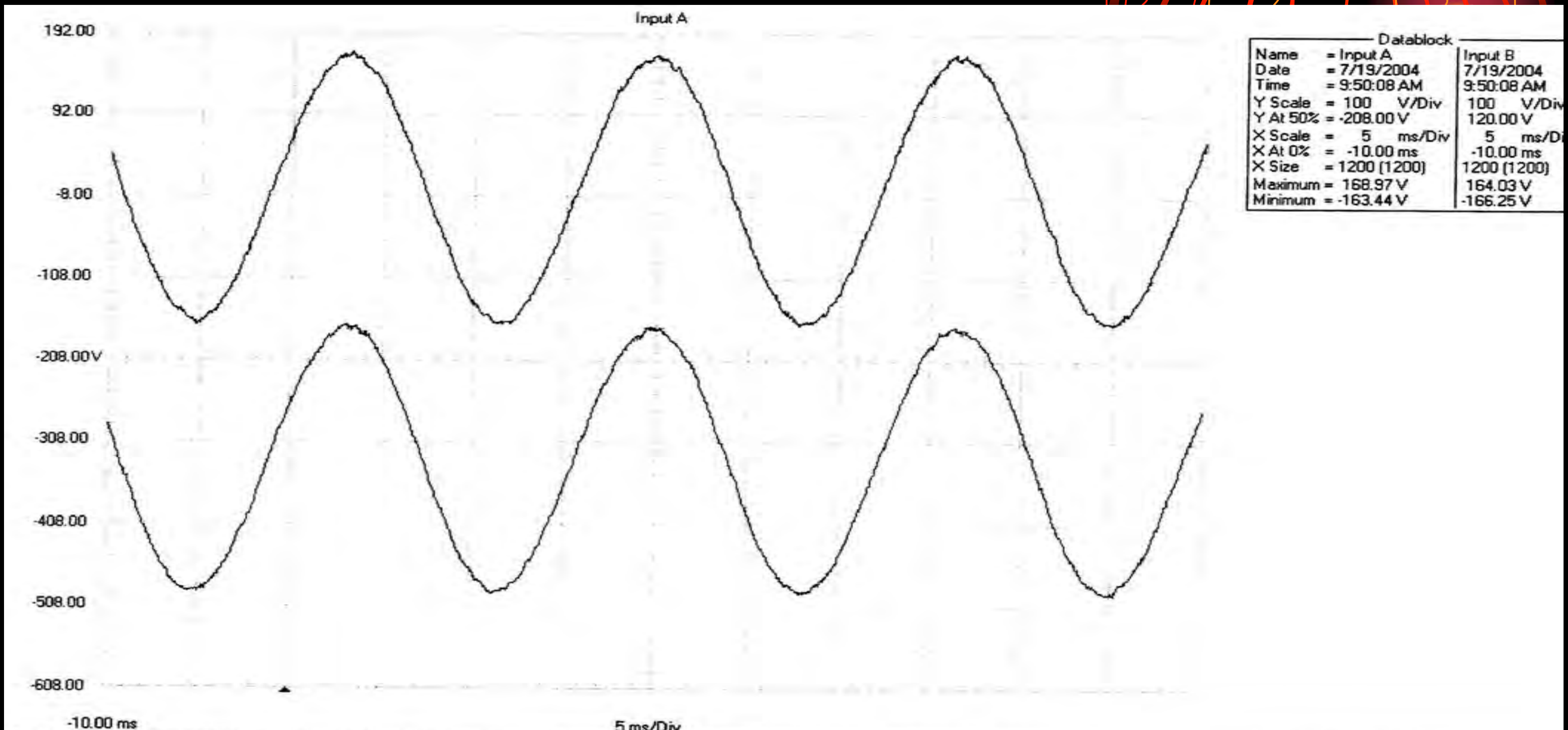
TYPICAL BBS WITH 77VAC INPUT & ON BATTERY OUTPUT WITH 700W LOAD



A: Input Waveform to APC, 77V, B: Output waveform from APC, 700W, APC is on Battery

BBS

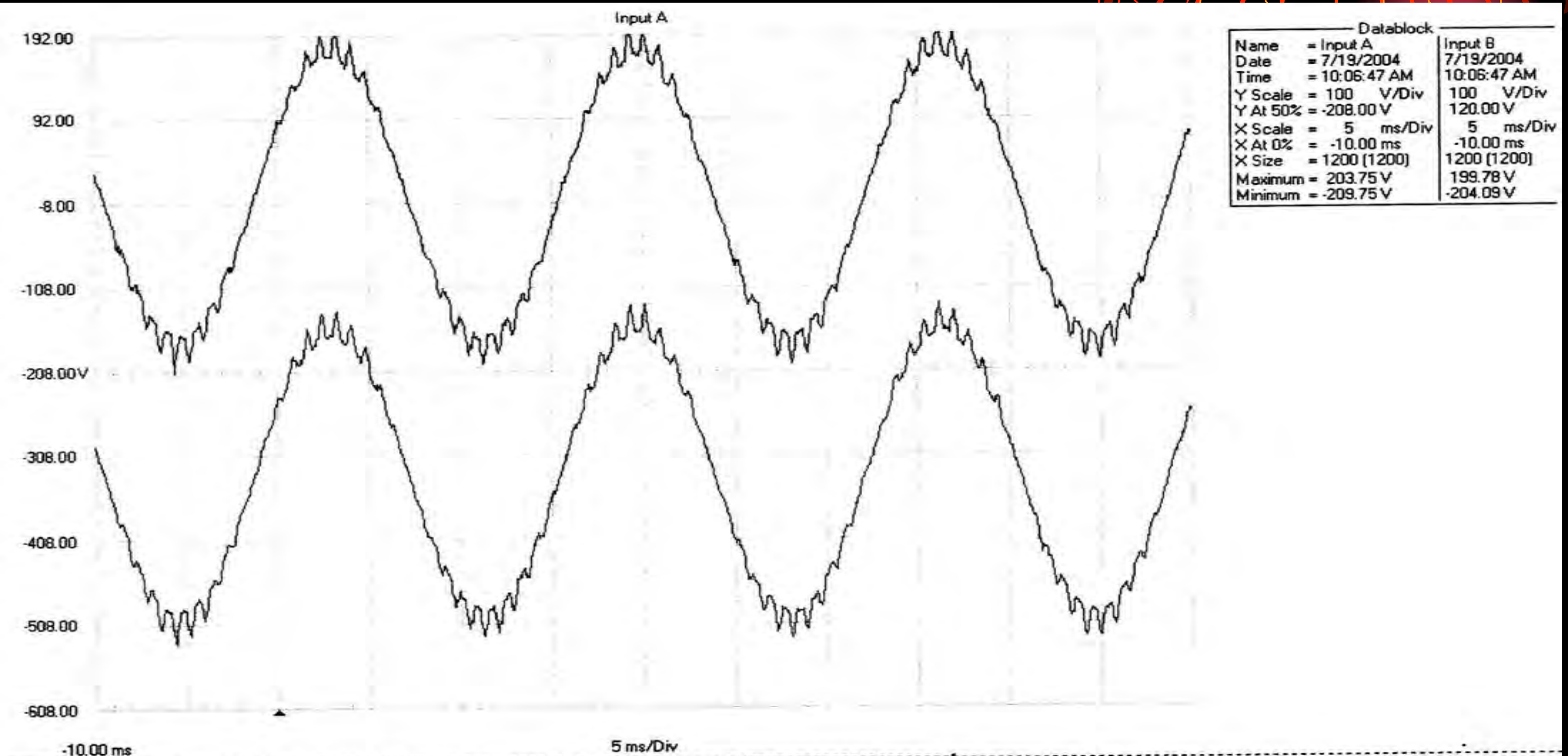
TYPICAL BBS WITH & 700 WATT LOAD SHOWING SAME UTILITY POWER IN & OUT



A: Input Waveform to APC, B: Output Waveform from APC, 700Watts

BBS

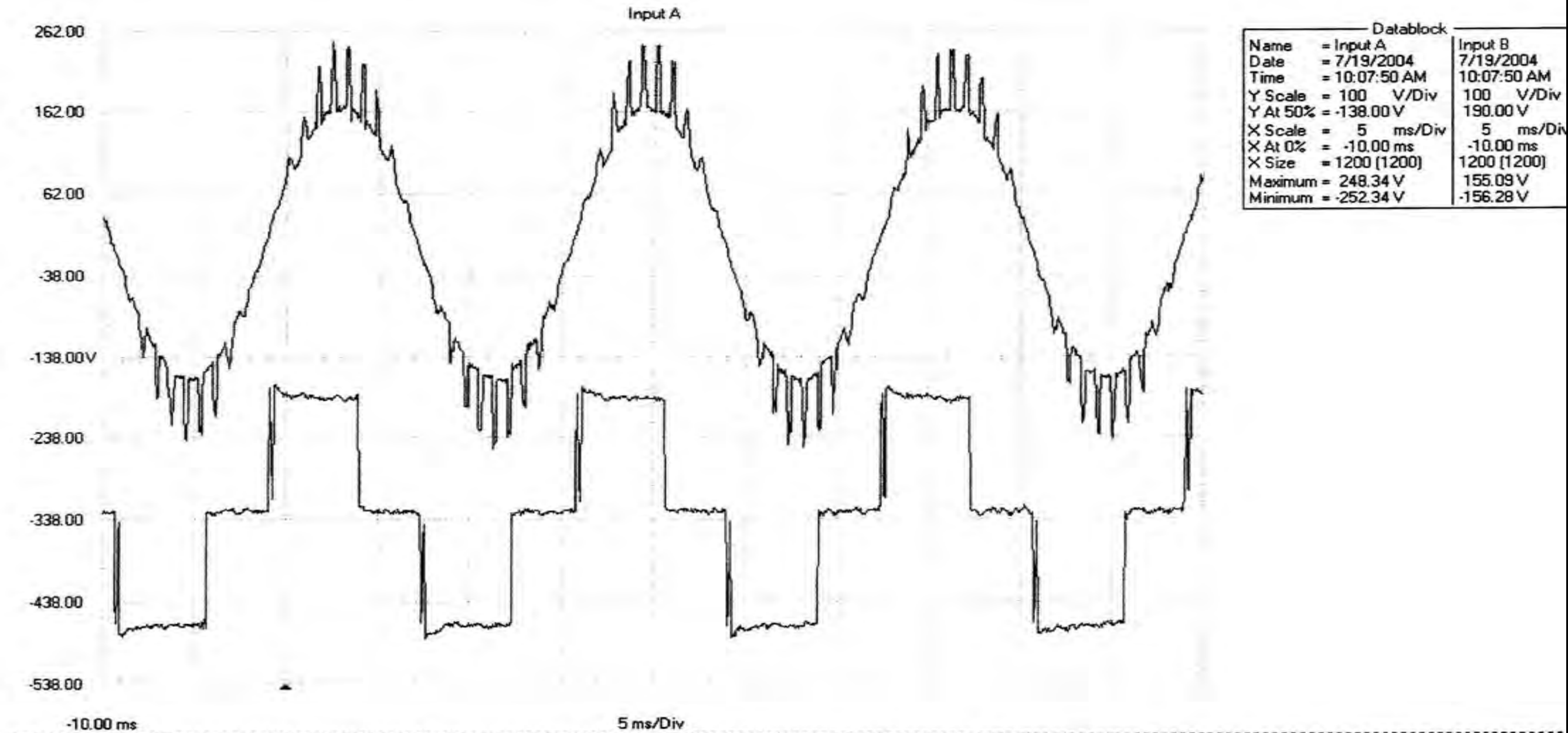
TYPICAL BBS UNIT PASSING DIRTY POWER THROUGH UNIT TO 700 WATT LOAD



A: Input Waveform to APC, B: Output Waveform from APC, 700W

BBS

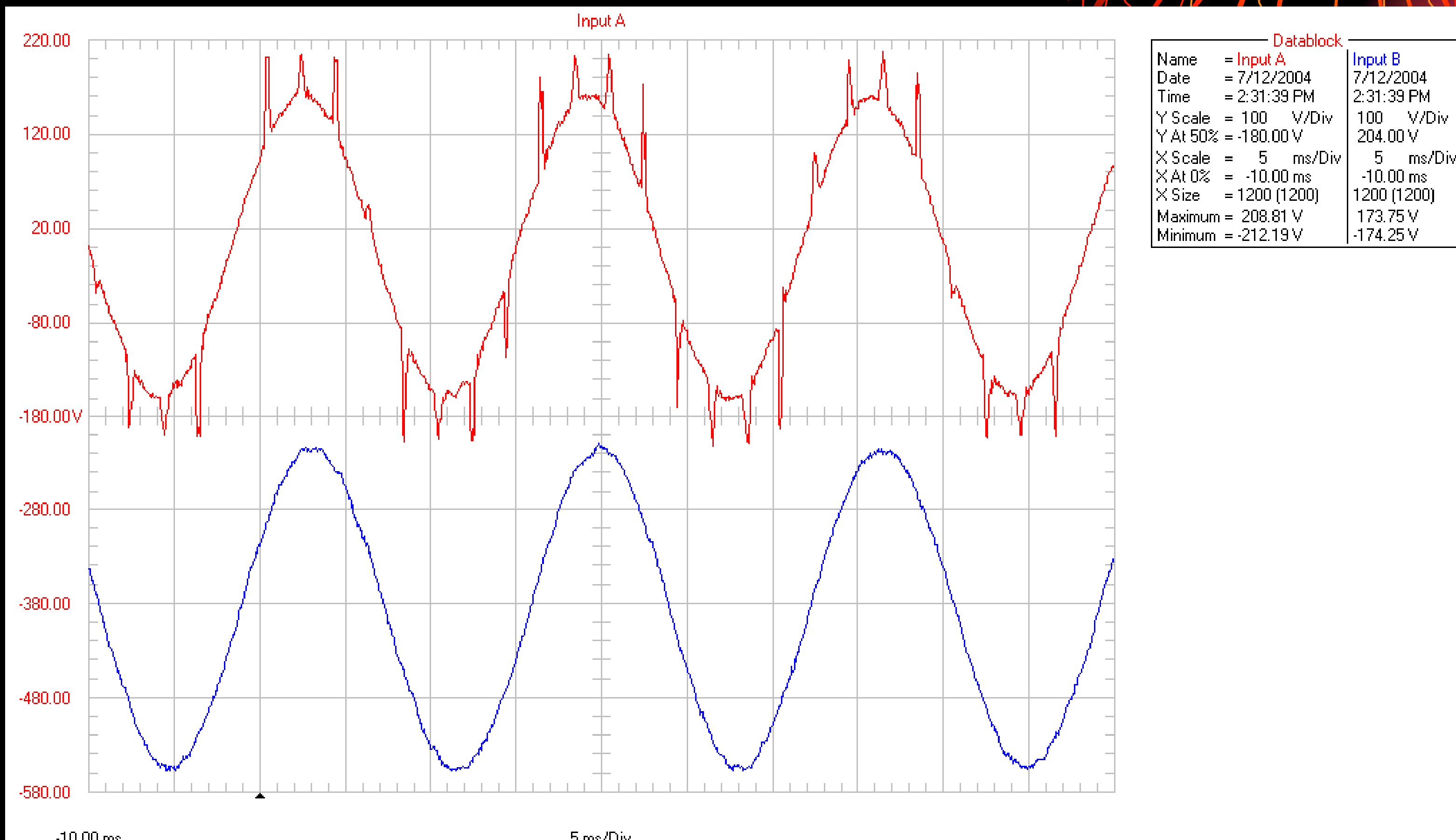
TYPICAL BBS - DIRTY INPUT POWER CAUSING BBS TO RUN OFF OF BATTERY POWER



A: Input Waveform to APC, B: Output waveform from APC, 700W, APC is on Battery.

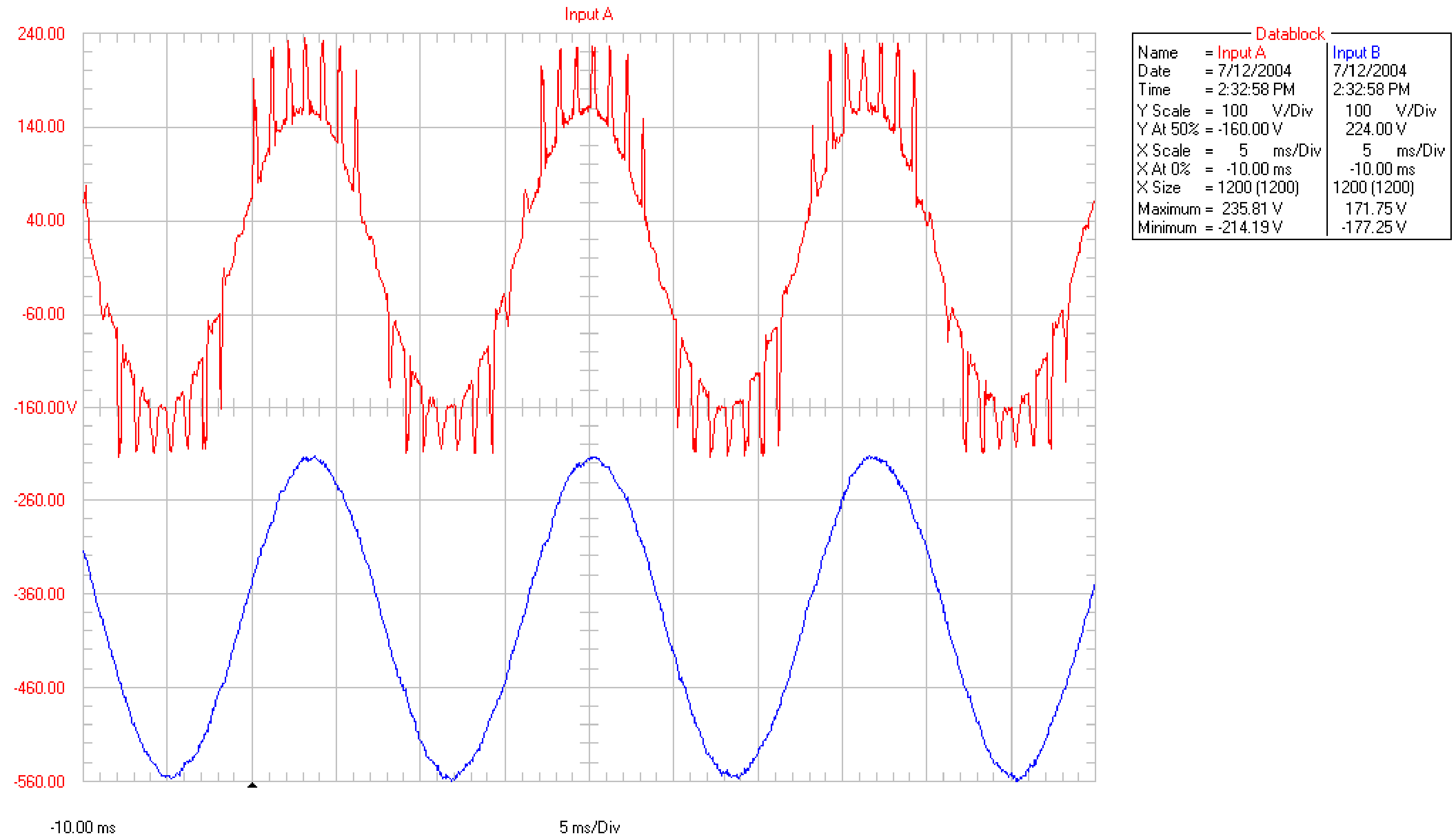
BBS

EXAMPLE OF DIRTY INPUT POWER AND CLEAN OUTPUT POWER OF A 1250 VA UPS



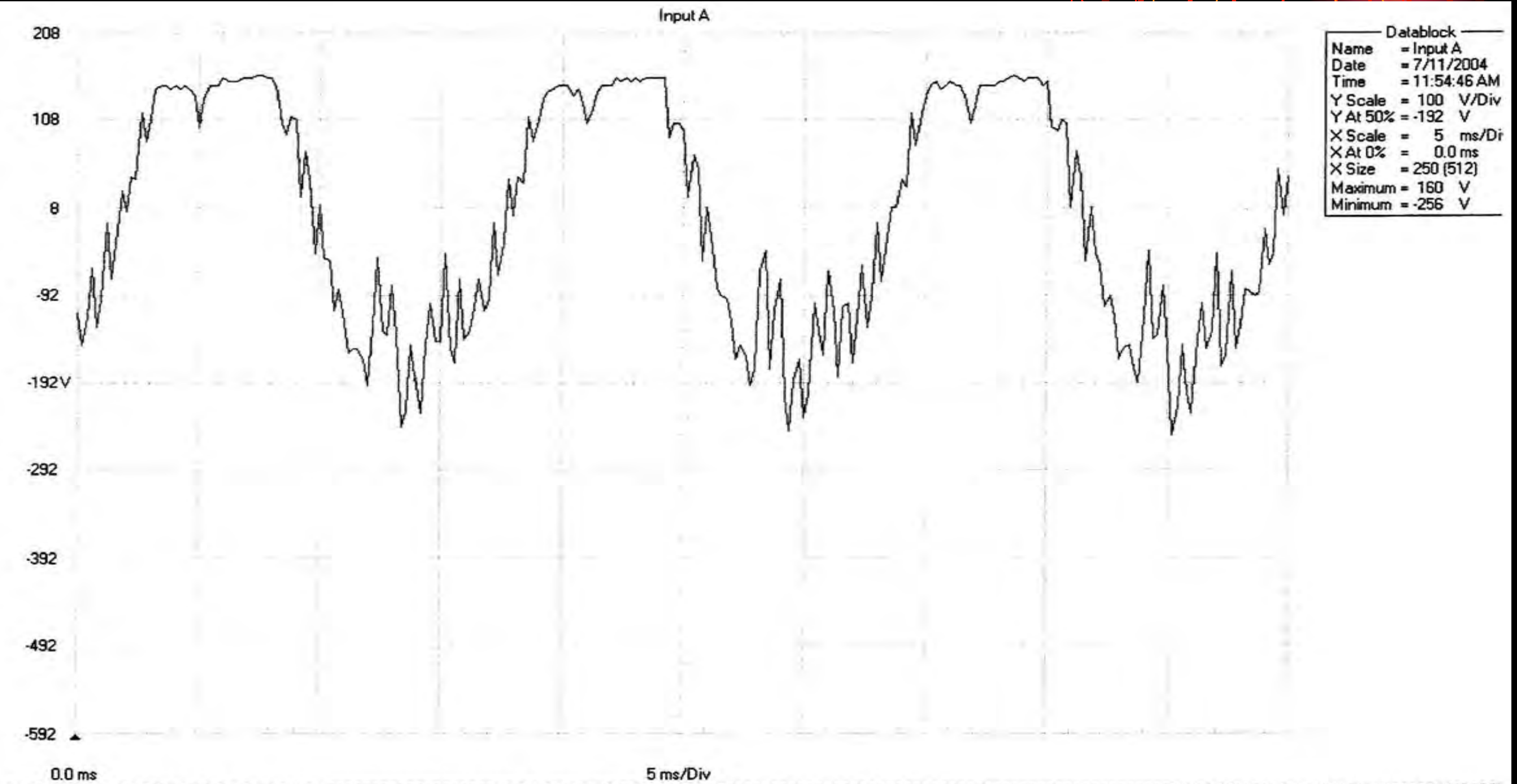
Input A: Input to UPS using Agilent AC Power Source. Input B: Output of UPS w/875 Watts Linear Load. SP1250PD, -44R3.99

EXAMPLE OF NOISY INPUT POWER AND CLEAN OUTPUT POWER OF A 1250 VA UPS



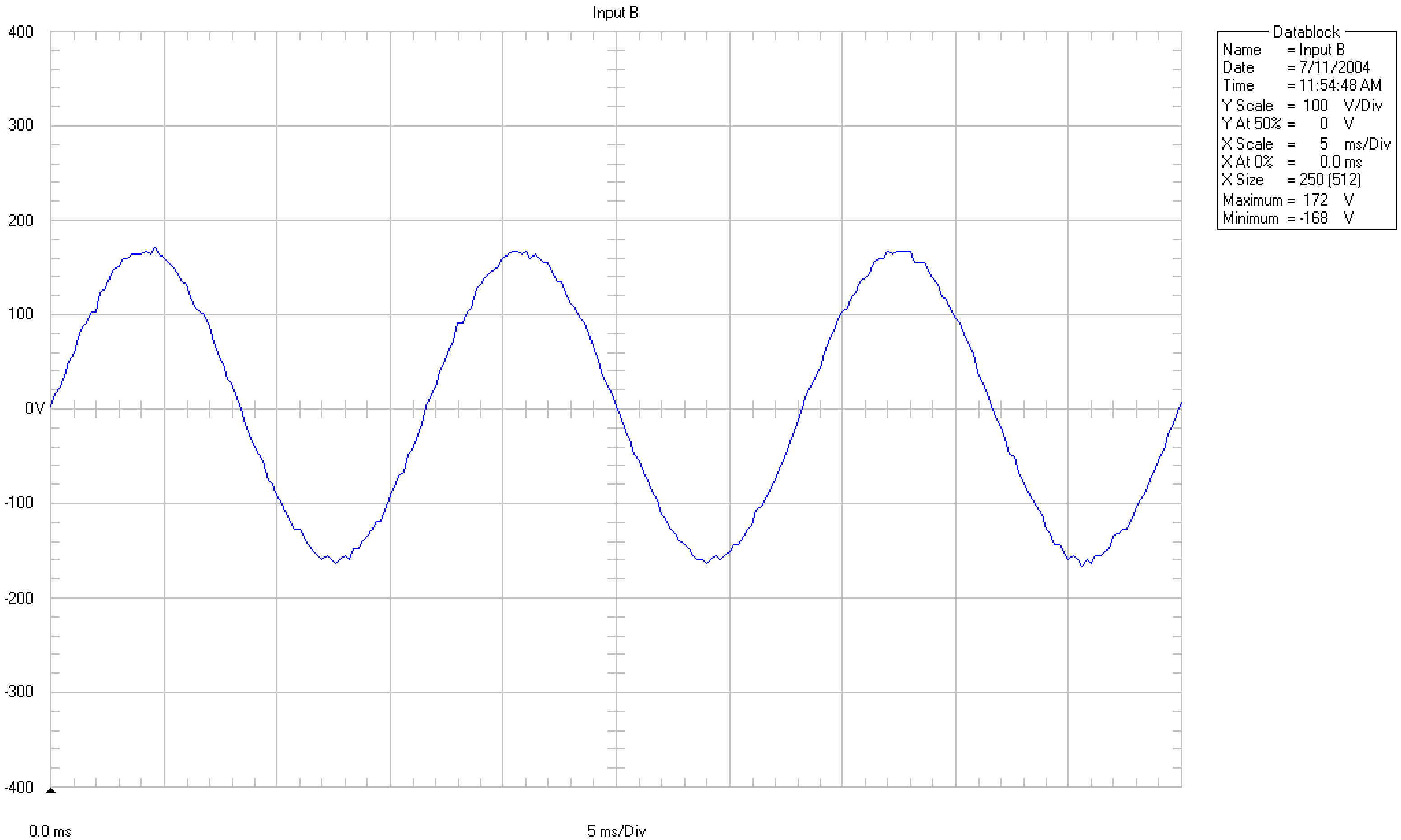
Input A: Input to UPS using Agilent AC Power Source. Input B: Output of UPS w/875 Watts Linear Load. SP1250PD, -44R3.99

ERRATIC GENERATOR OUTPUT TO UPS



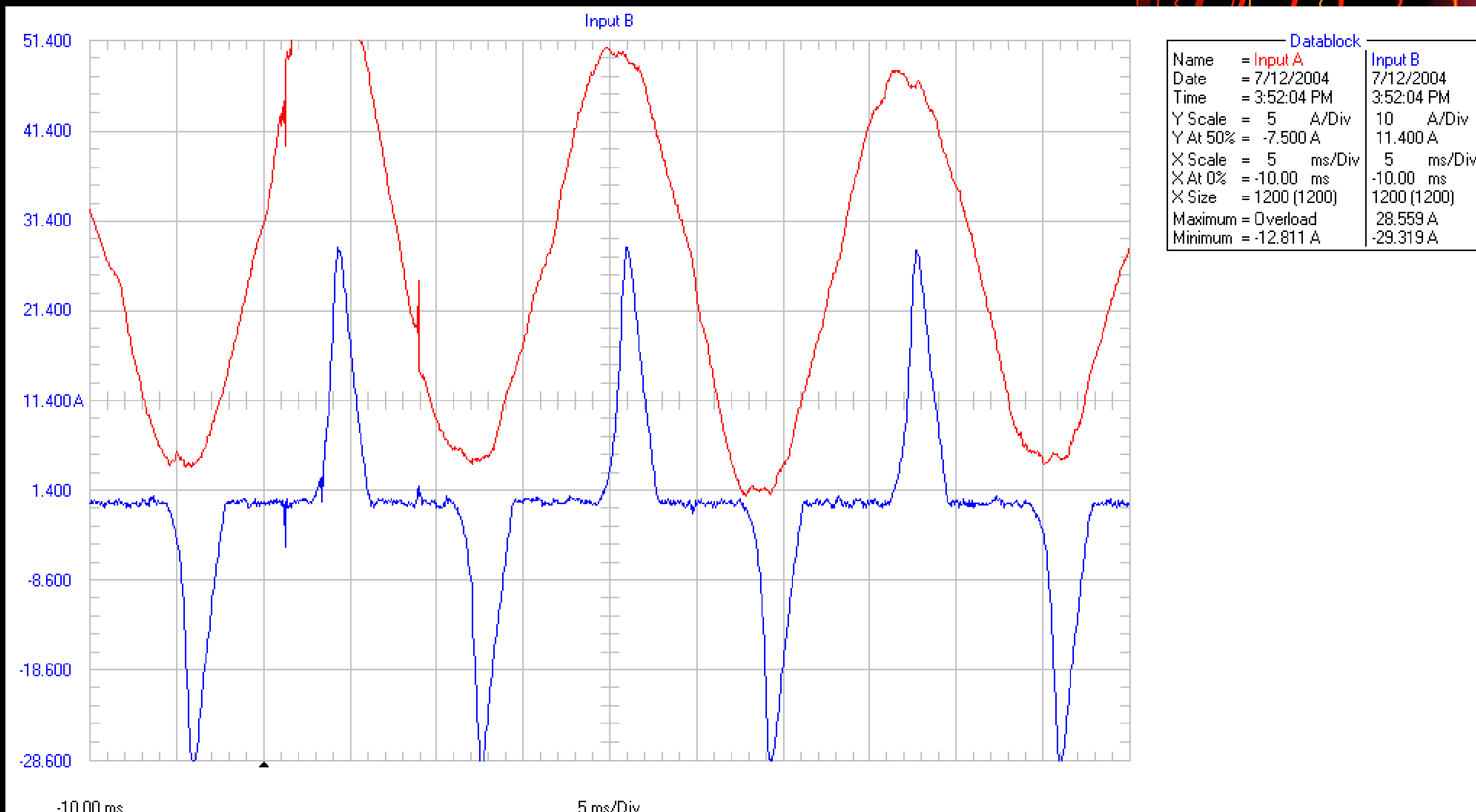
Generator Output to UPS Input

UPS OUTPUT WITH GENERATOR INPUT



UPS Output w/ 700W Linear Load. UPS input is from Generator.

TYPICAL INPUT/OUTPUT CURRENT OF A 1250 VA UPS



Input A: Input Current Input B: Output Current, 875 Watts Non-Linear,

SP1250PD, -44R3.99

THANK YOU

Dr. Joseph G. Palsa P.E.

Director Sales & Marketing

CLARY CORPORATION

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Joint Service Power Expo

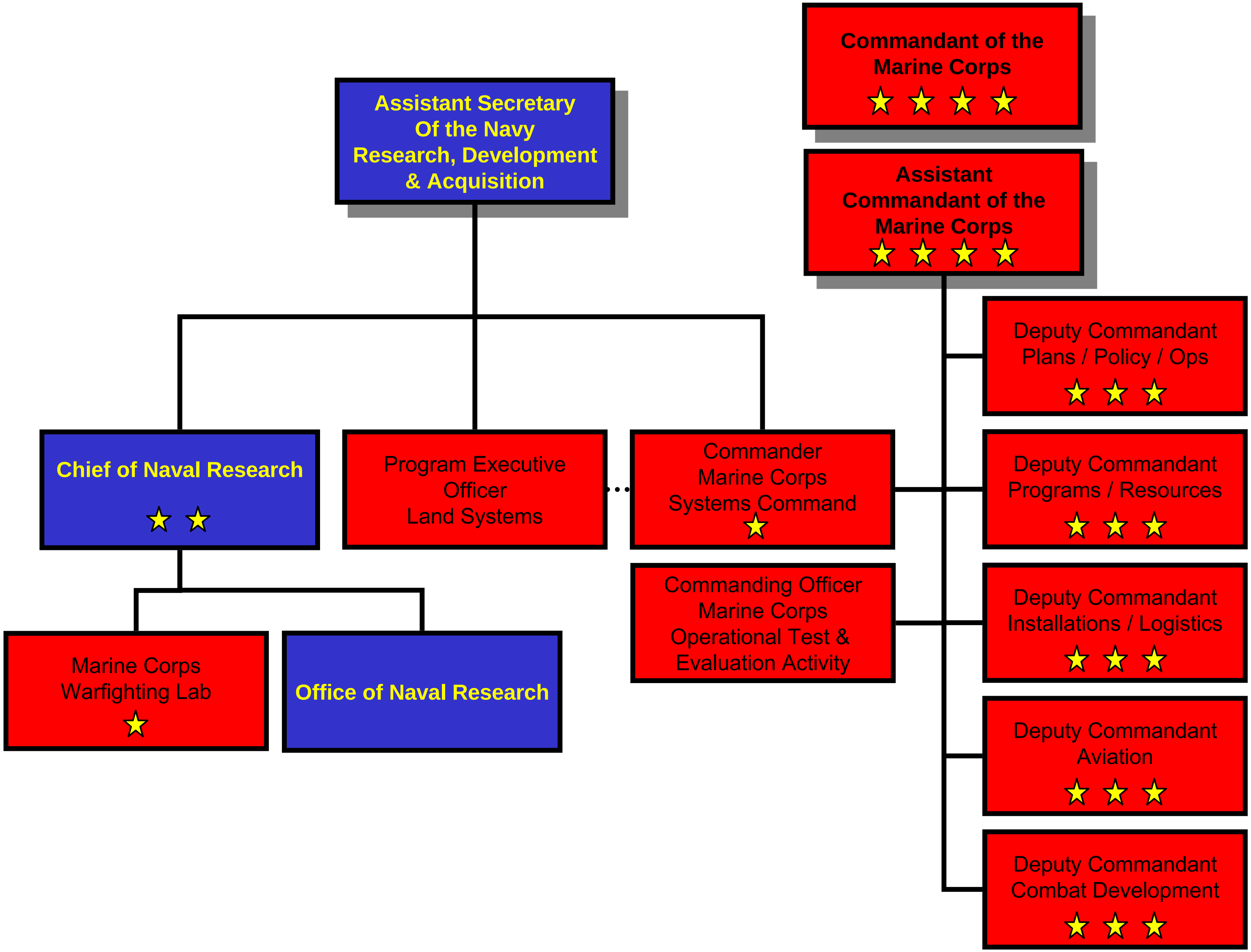
USMC Expeditionary Power Systems

Michael Gallagher
Program Manager – Expeditionary Power Systems
Marine Corps Systems Command
May 2009

Briefing Topics

- Who we are
- Where we've been
- Where we're going
- What we know
- Some things to think about

USMC Organizations involved in Research and Acquisition



Marine Corps Systems Command

- **COMMANDER**
- **DEPUTY COMMANDER**
  - **PGD 09 Operational Forces Support**
  - **PGD 10 Info Systems and Infrastructure**
    - PMM 101 Global Combat Support System
    - PMM 102 Navy Marine Corps Intranet / ITI
    - PMM 103 Enterprise Business and Systems Support
    - PMM 104 Logistics Information Systems
  - **PGD 11 MAGTF C2 Integrations**
    - PMM 111 MC2I Coordination Team
    - PMM 112 MAGTF C2 Systems
    - PMM 113 Radar Systems
    - PMM 114 Air Defense Weapons Systems
    - PMM 115 Unmanned Systems
  - **PGD 12 Comm / Intel / Networking**
    - PMM 121 Counter RCIED EW Systems
    - PMM 122 Communications & Networking Systems
    - PMM 123 Intelligence Systems
  - **PGD 13 Infantry Weapons Systems**
    - PMM 131 Reconnaissance and Amphibious Raids
    - PMM 132 Infantry Weapons
    - PMM 133 Anti-Armor Systems
    - PMM 134 Marine Expeditionary Rifle Squad
    - PMM 135 Optics & Non-Lethal
  - **PGD 14 Armor and Fire Support Systems**
    - PMM 141 Fire Support Systems
    - PMM 142 Tank Systems
    - PMM 143 Assault Amphibious Vehicle Systems
    - PMM 144 High Mobility Artillery Rocket System
  - **PGD 15 Ground Trans and Engineer Systems**
    - PMM 151 Motor Transportation
    - PMM 152 Engineer Systems
    - PMM 153 Expeditionary Power Systems
  - **PGD 16 Combat Equipment and Support Systems**
    - PMM 161 Test, Measurement and Diagnostic Equip
    - PMM 162 Infantry Combat Equipment
    - PMM 163 NBC Defense Systems

Marine Corps Systems Command

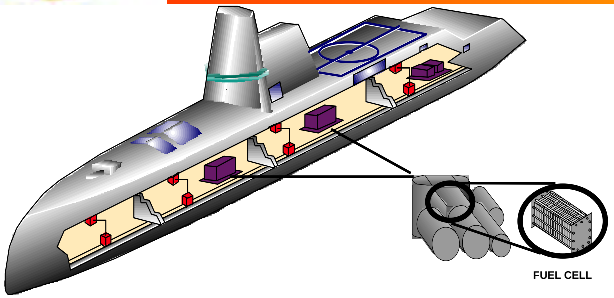
COMMANDER

DEPUTY COMMANDER

PGD 09 Operational Forces Support	PGD 10 Info Systems and Infrastructure	PGD 11 MAGTF C2 Integrations	PGD 12 Comm / Intel / Networking	PGD 13 Infantry Weapons Systems	PGD 14 Armor and Fire Support Systems	PGD 15 Ground Trans and Engineer Systems	PGD 16 Combat Equipment and Support Systems
	PMM 101 Global Combat Support System	PMM 111 MC2I Coordination Team	PMM 121 Counter RCIED EW Systems	PMM 131 Reconnaissance and Amphibious Raids	PMM 141 Fire Support Systems	PMM 151 Motor Transportation	PMM 161 Test, Measurement and Diagnostic Equip
	PMM 102 Navy Marine Corps Intranet / ITI	PMM 112 MAGTF C2 Systems	PMM 122 Communications & Networking Systems	PMM 132 Infantry Weapons	PMM 142 Tank Systems	PMM 152 Engineer Systems	PMM 162 Infantry Combat Equipment
	PMM 103 Enterprise Business and Systems Support	PMM 113 Radar Systems	PMM 123 Intelligence Systems	PMM 133 Anti-Armor Systems	PMM 143 Assault Amphibious Vehicle Systems	PMM 153 Expeditionary Power Systems	PMM 163 NBC Defense Systems
	PMM 104 Logistics Information Systems	PMM 114 Air Defense Weapons Systems		PMM 134 Marine Expeditionary Rifle Squad	PMM 144 High Mobility Artillery Rocket System		
		PMM 115 Unmanned Systems		PMM 135 Optics & Non-Lethal			

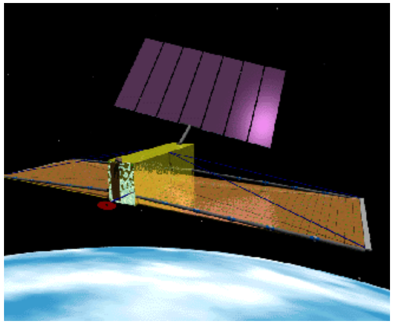
PEO Land Systems: EFV G/ATOR MTVR LVSR LW 155 CAC2S PM LAV

Power …*Pervasive & Enabling*

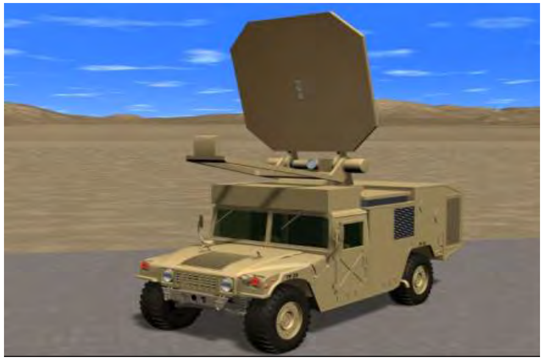


Electric Warship

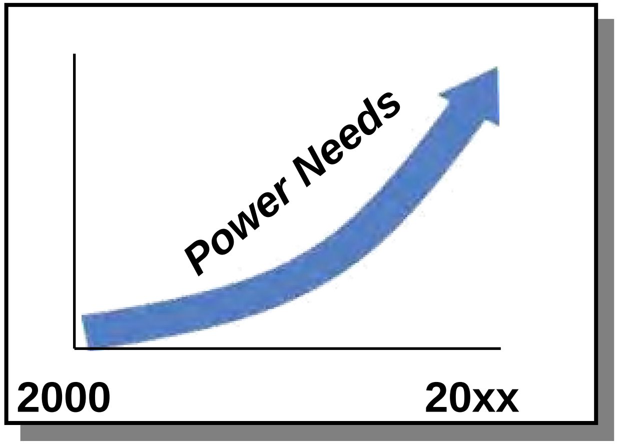
More Electric Aircraft



Space Systems



Less-than-Lethal Systems

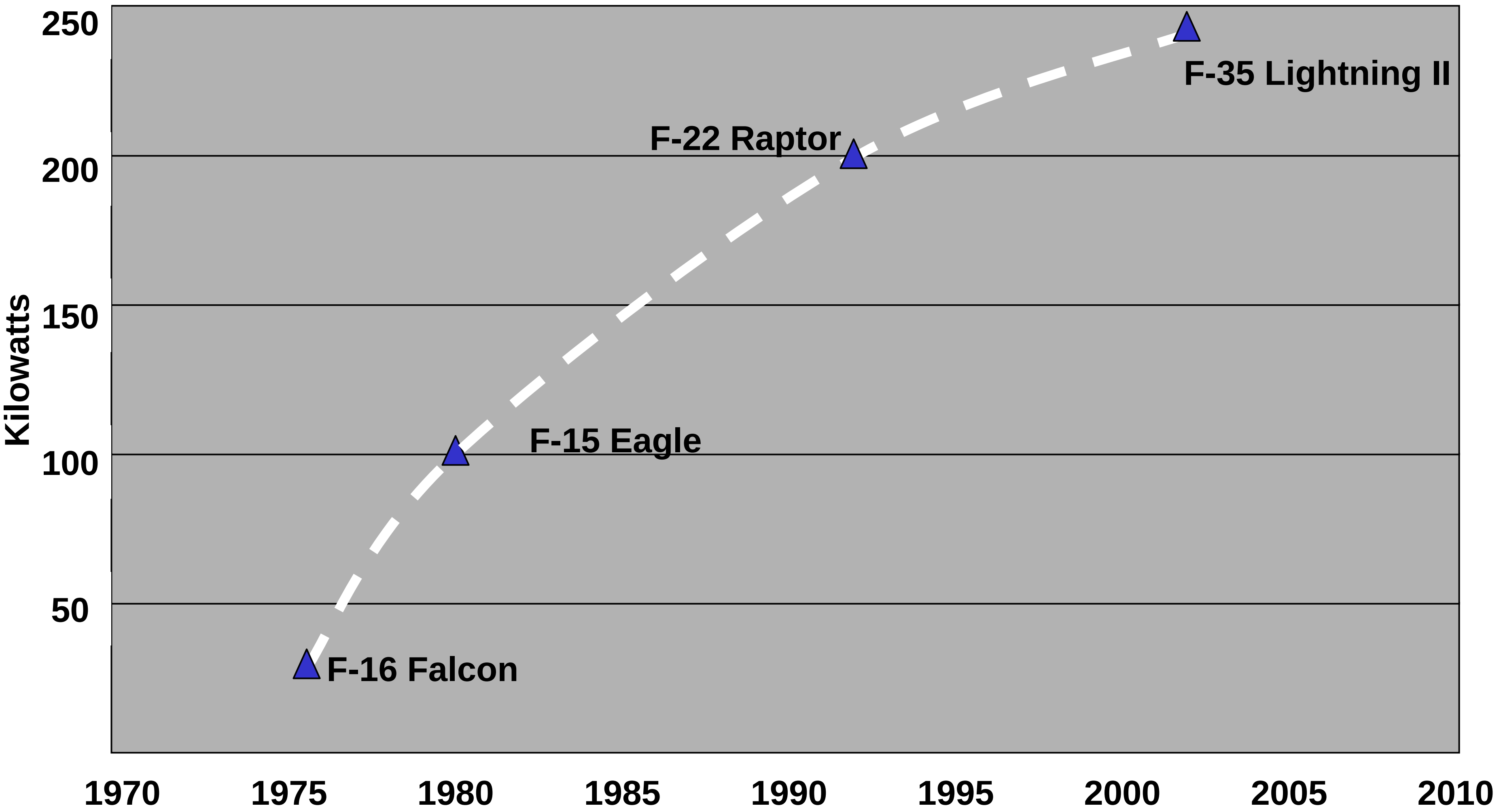


Warfighter

Combat Vehicles & Weapons

Tactical Vehicles & Support Systems

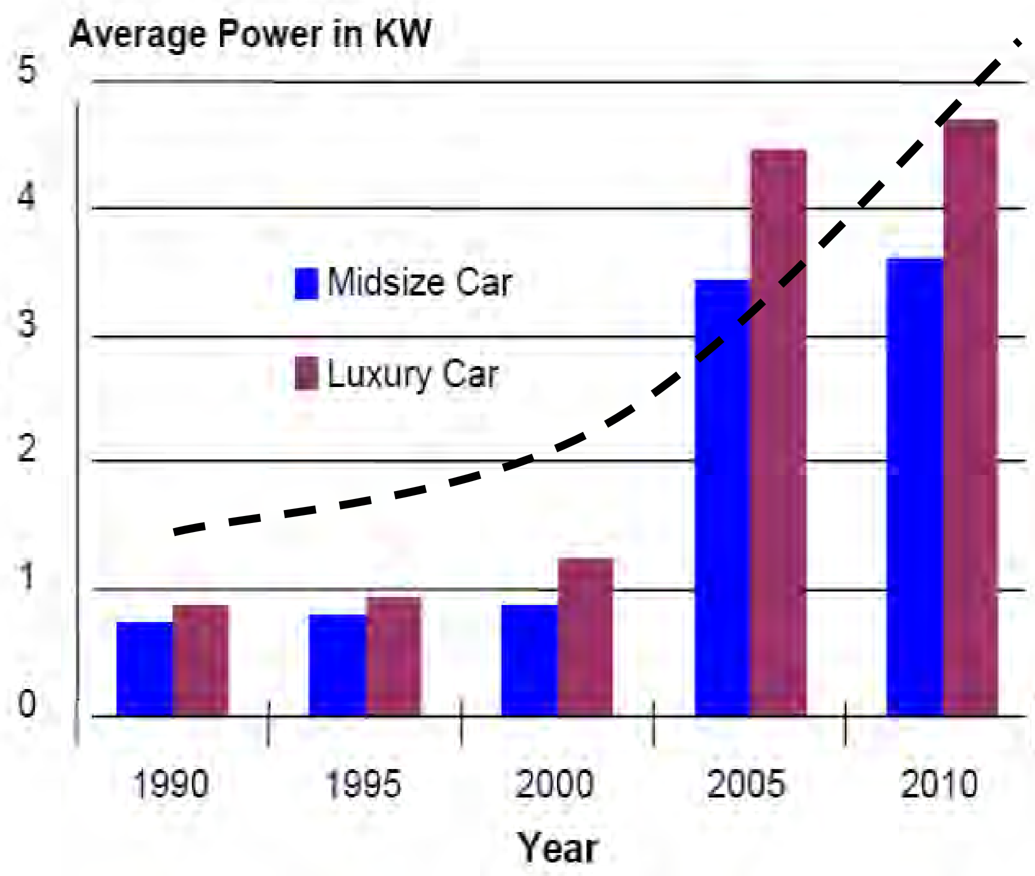
Alternator Rating on USAF Fighter Aircraft



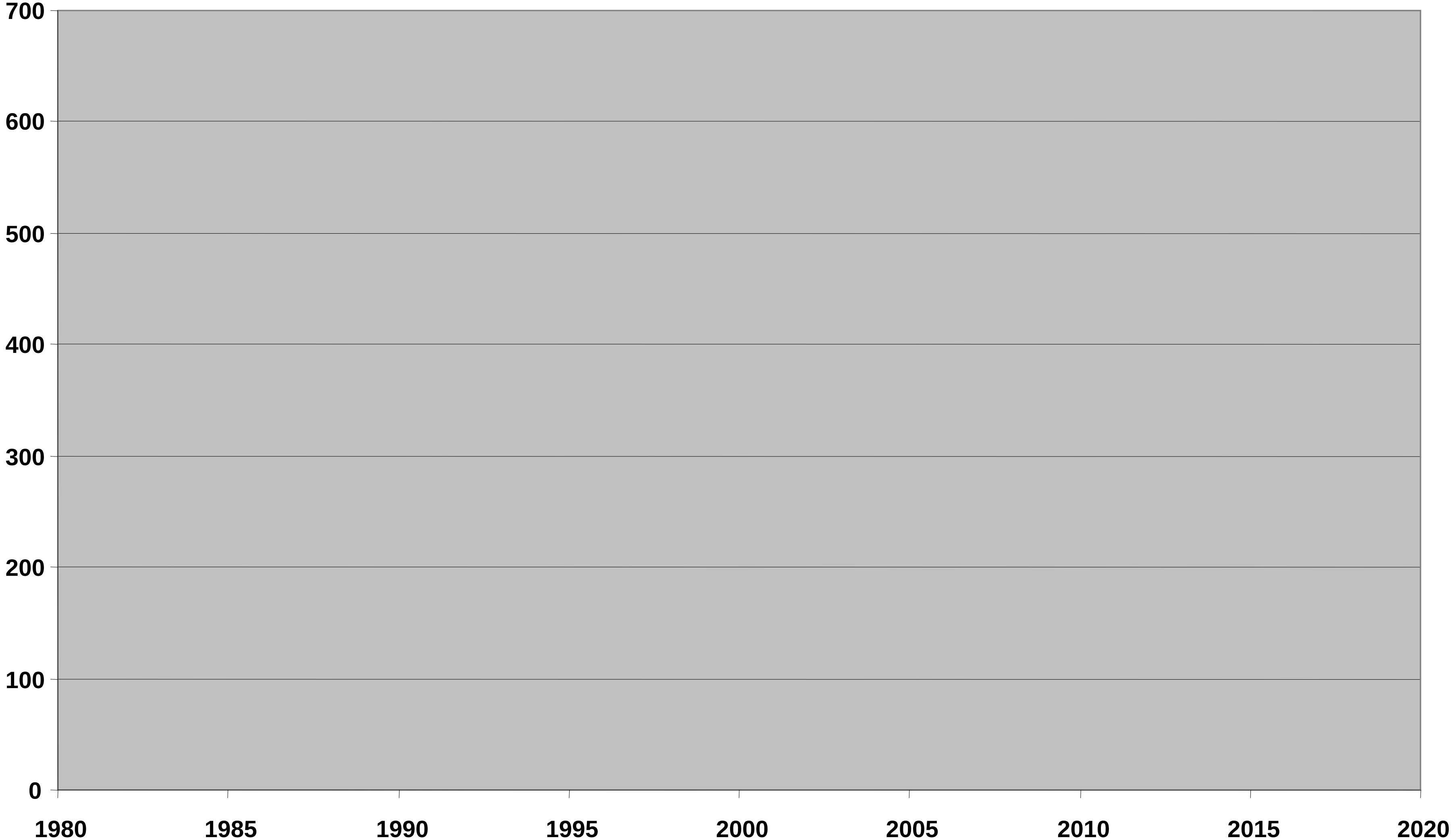
U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Increasing Electrical Power Requirements for Vehicles

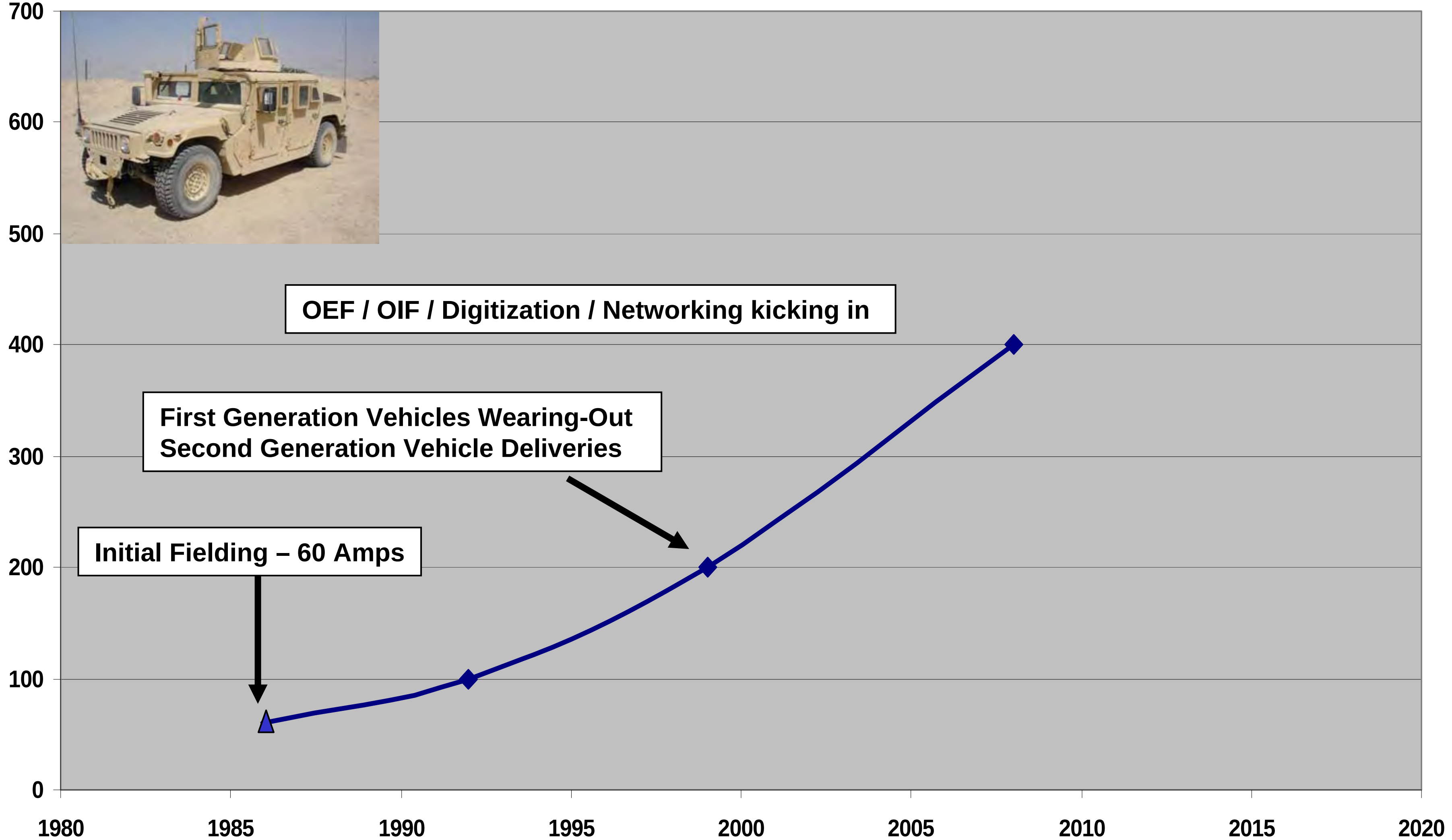
- Stability controls
- Telematics
- Collision avoidance systems
- Onstar Communication systems
- Navigation systems
- Steer by-wire
- Electronic braking
- Powertrain/body controllers & Sensors



Alternator Amperage Rating on HMMWV / MRAP at 28 VDC



Alternator Amperage Rating on HMMWV / MRAP at 28 VDC



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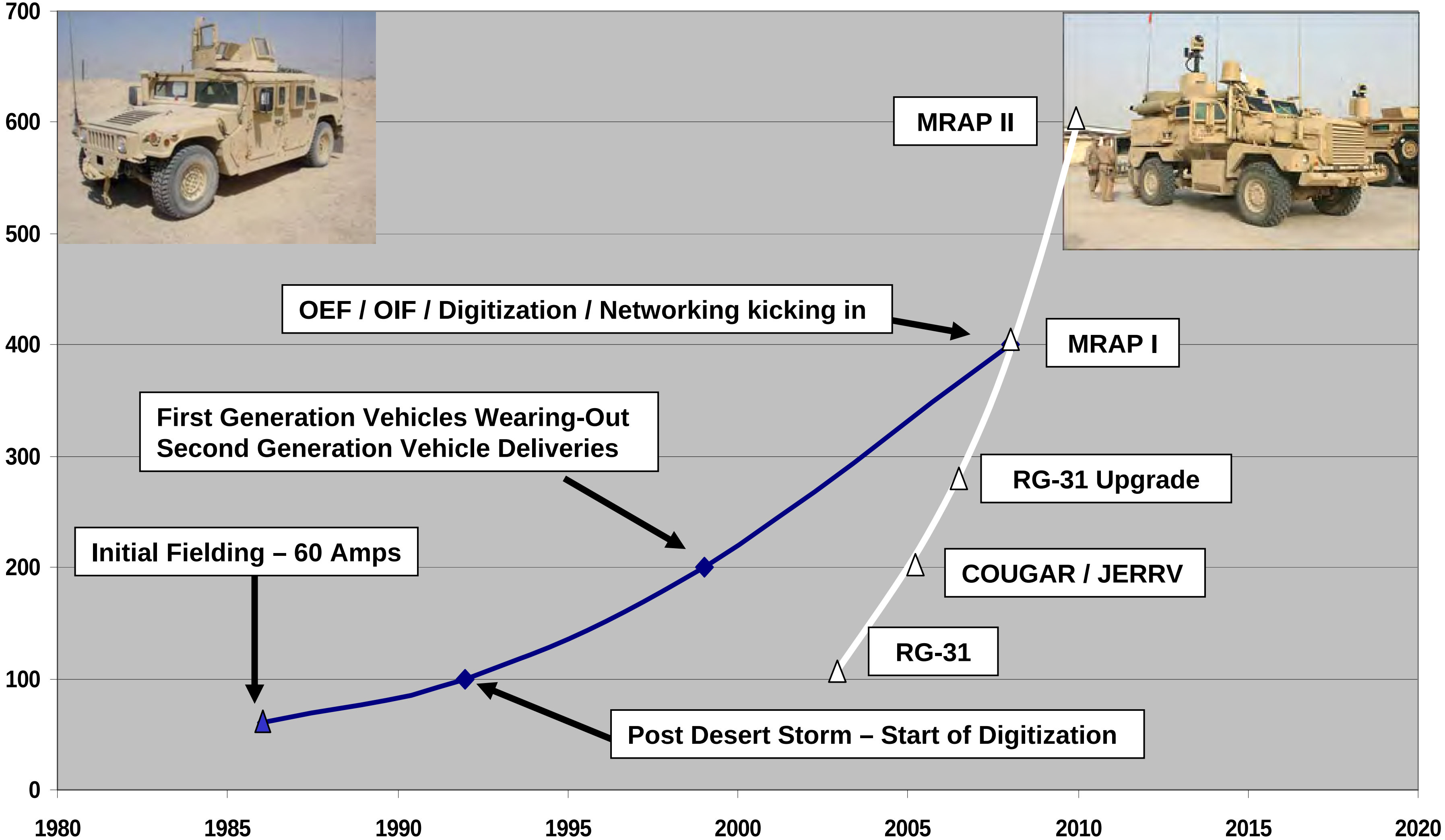

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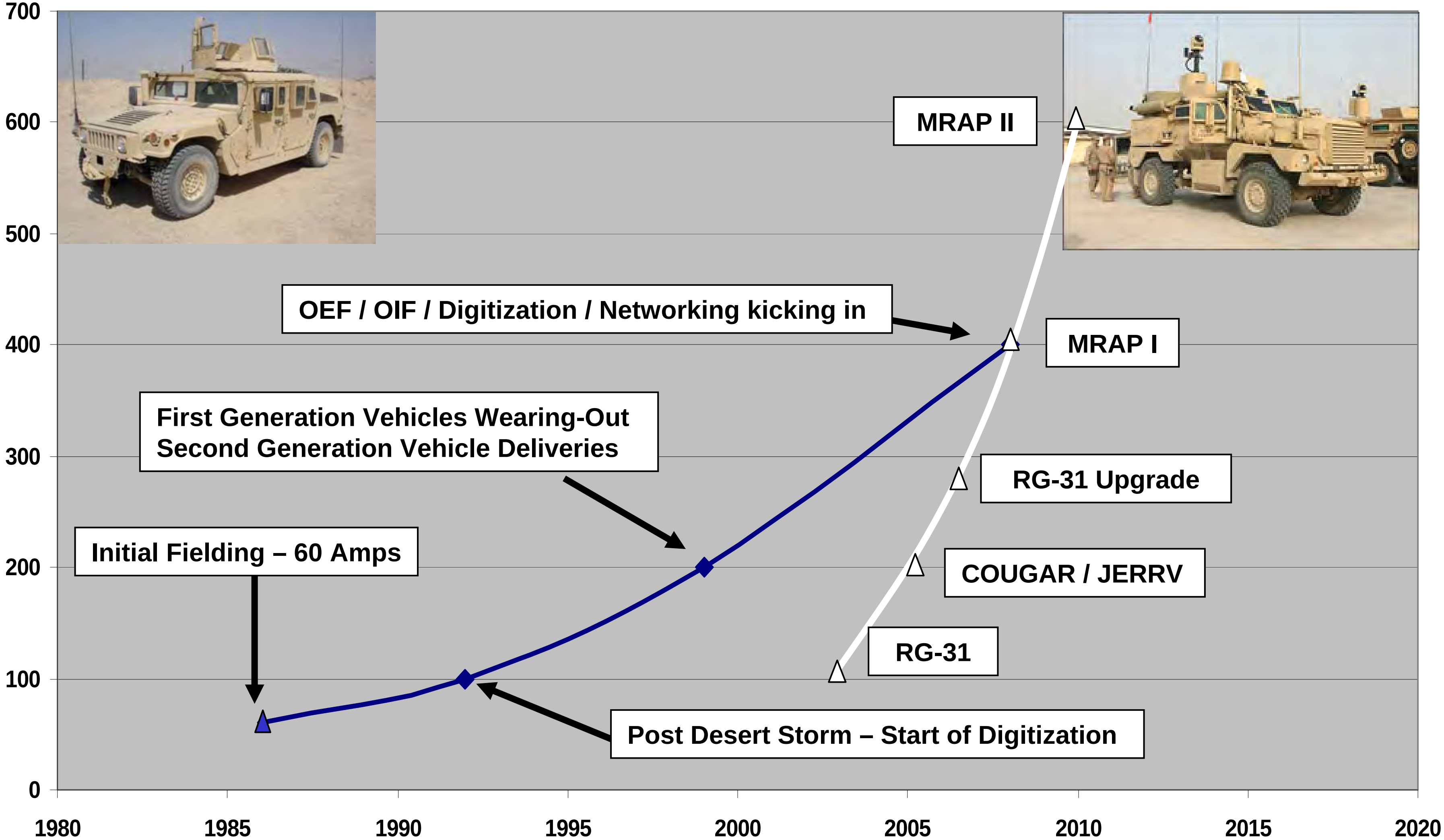
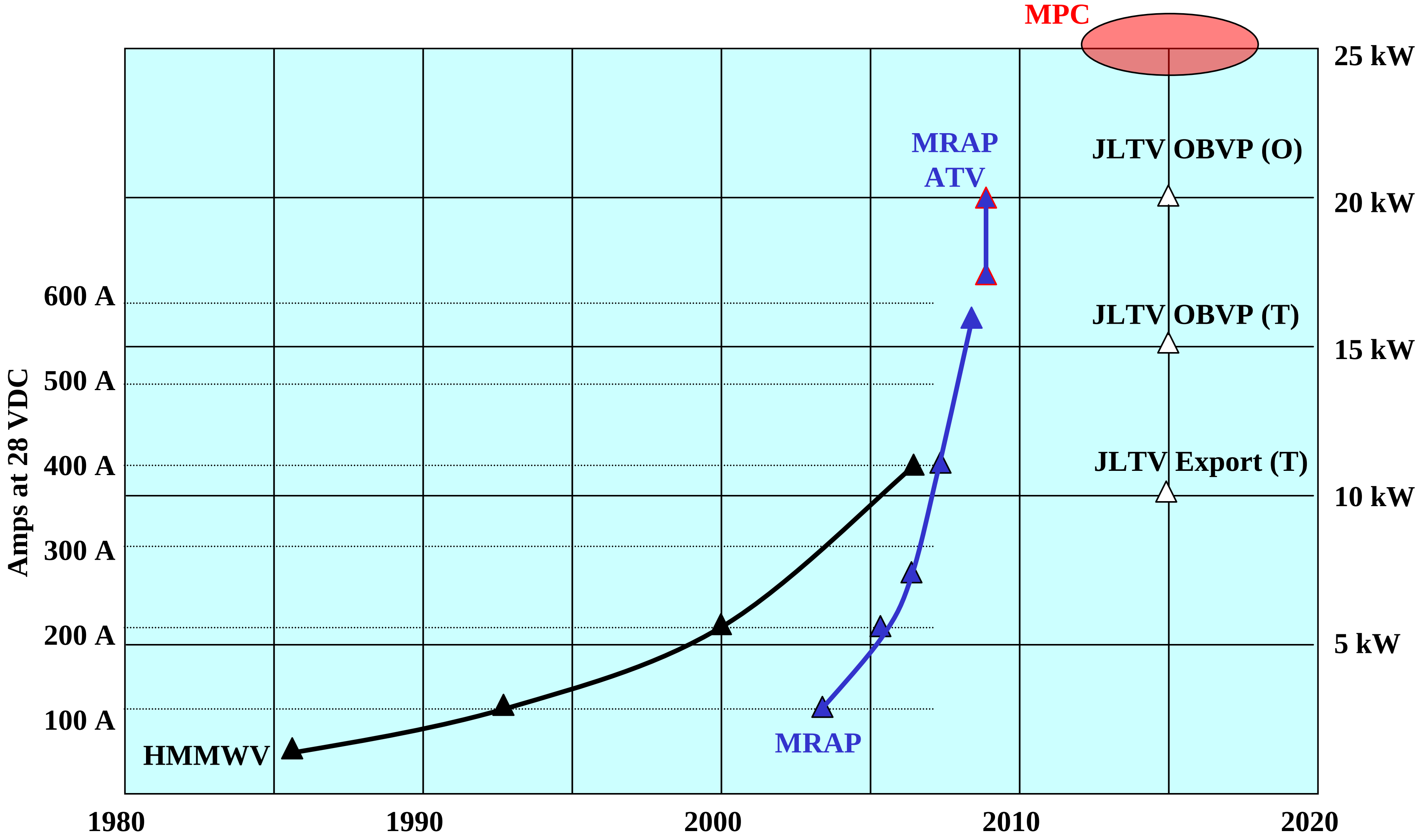
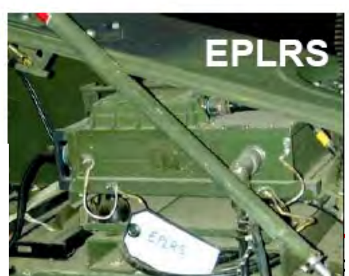


Tactical Vehicle Electric Power

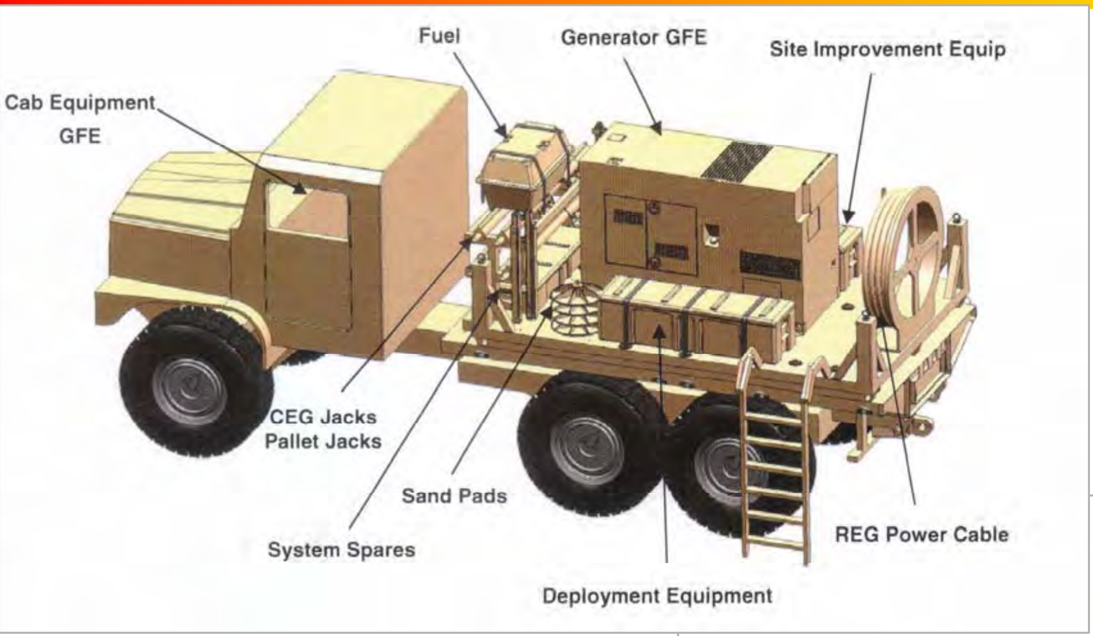


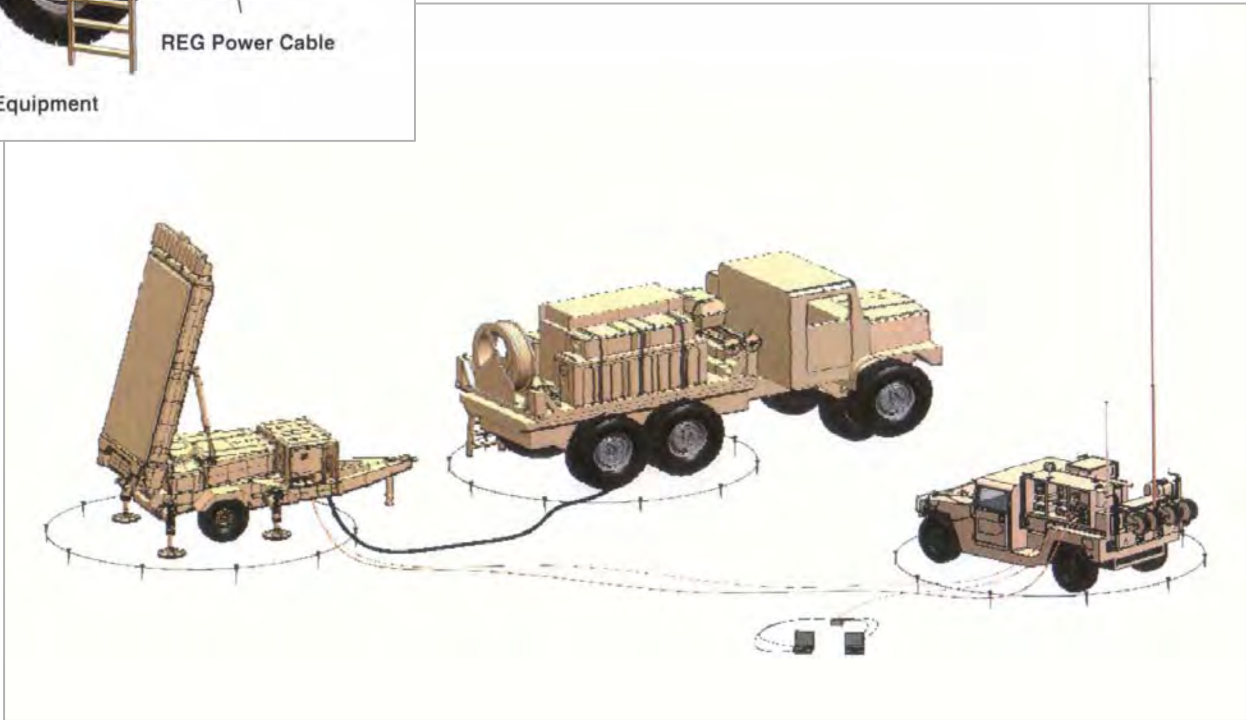
What's Consuming Power?



USMC JOLLER C-IED Experiment

Current power plan for USMC MTVR and G/ATOR Radar



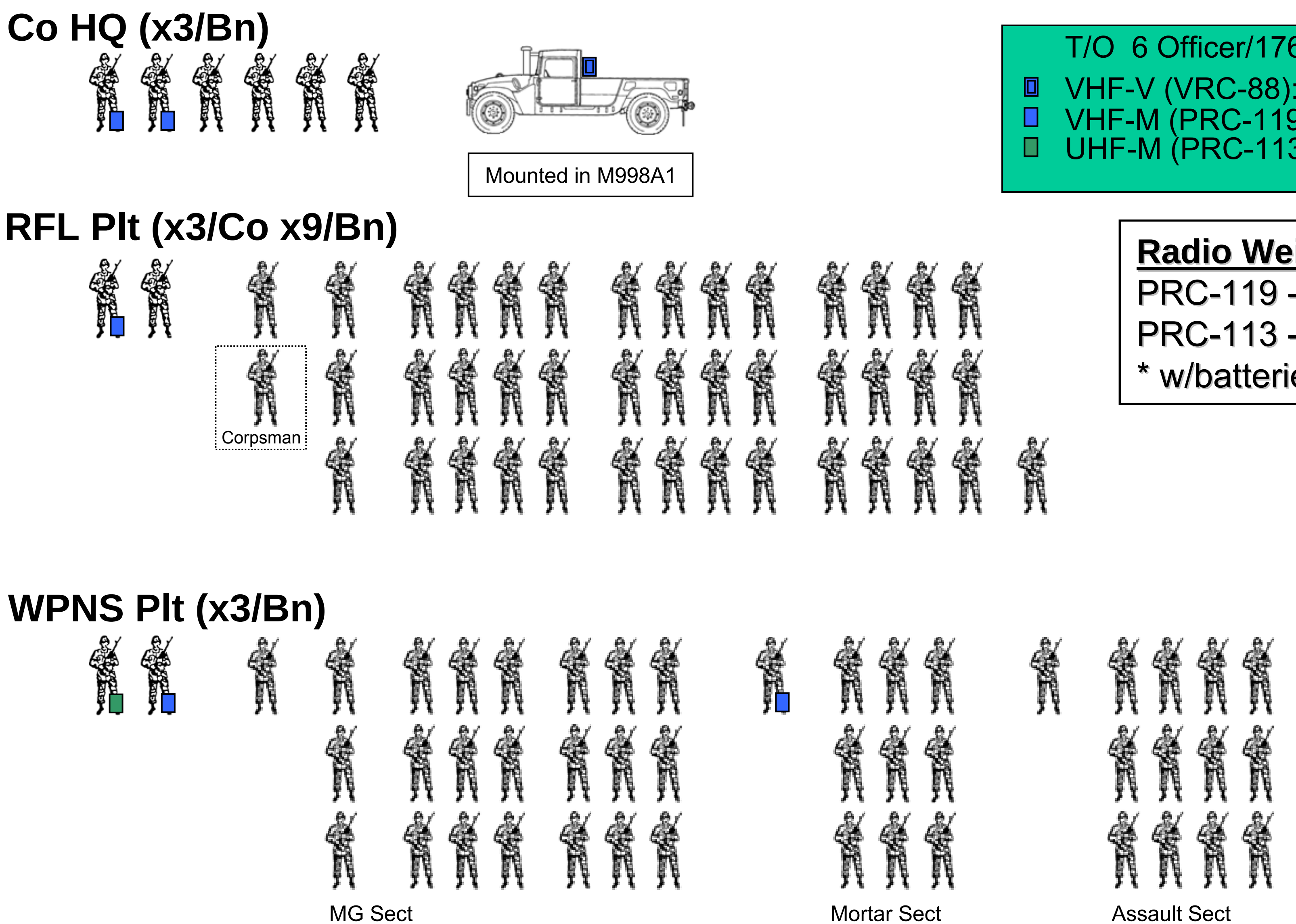


“Every Marine is a Rifleman”

“Every Marine is a Radio Operator”

Operations in Afghanistan, August 2008

Pre-OIF Rifle Company Radios



T/O 6 Officer/176 Enlisted

- VHF-V (VRC-88): 1
- VHF-M (PRC-119): 7
- UHF-M (PRC-113): 1

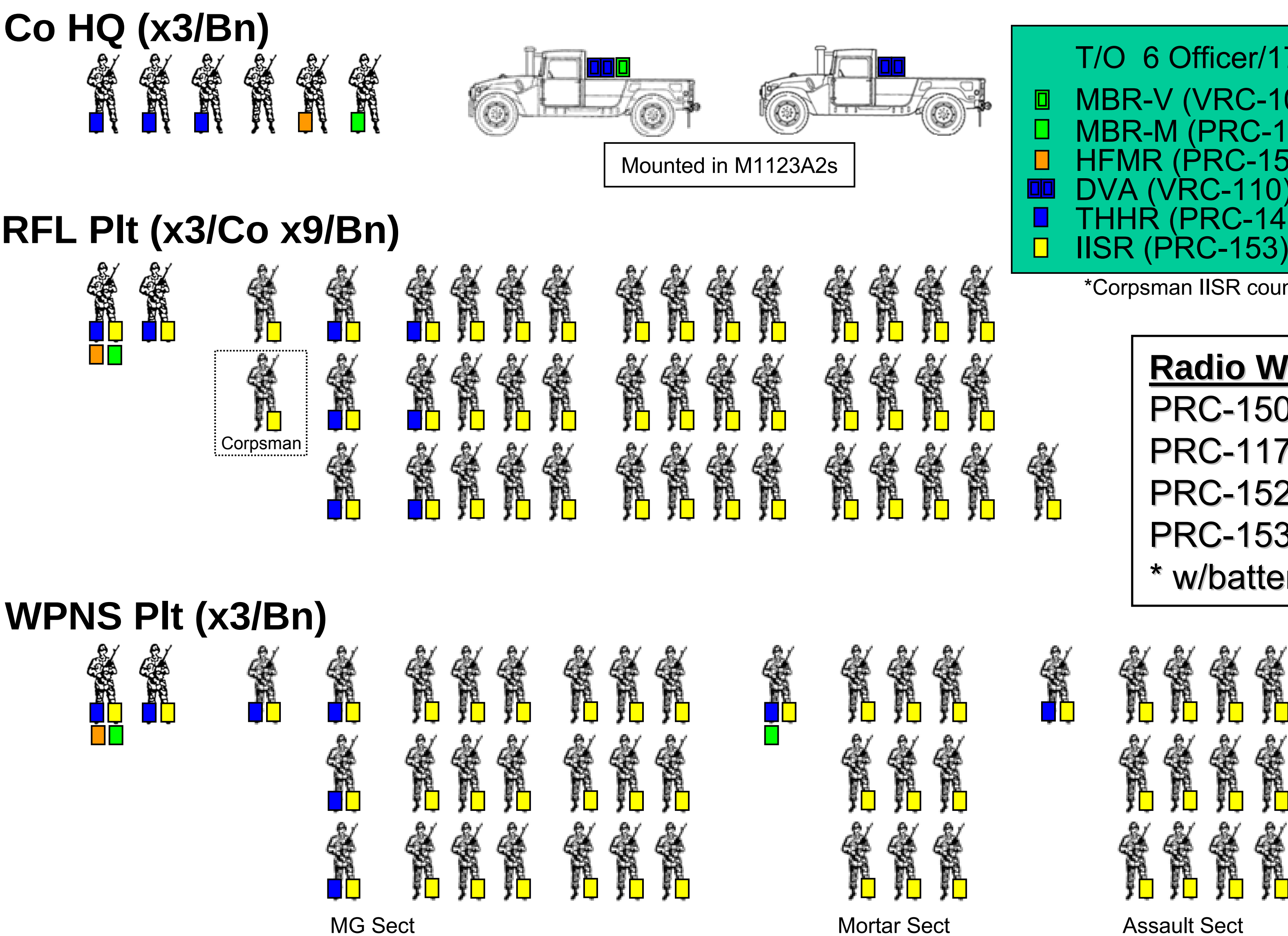
Radio Weights

PRC-119 - 22.5 lbs

PRC-113 - 16.7 lbs

* w/batteries

OEF-Era Rifle Company Radios



T/O 6 Officer/176 Enlisted

MBR-V (VRC-103):	1
MBR-M (PRC-117):	6
HFMR (PRC-150):	5
DVA (VRC-110):	2
THHR (PRC-148/152):	35
IISR (PRC-153):	176

*Corpsman IISR counted in H&S

Radio Weights

PRC-150 - 15.7 lbs
PRC-117 - 15.9 lbs
PRC-152 - 2.4 lbs
PRC-153 - 1 lbs
* w/batteries

What's Unique about USMC Acquisition

"DOESN'T THE USMC JUST BUY ARMY STUFF?"

1947 National Security Act

- **Provide Fleet Marine Forces with combined arms and supporting air components for service with the United States Fleet in the <u>seizures or defense of advanced naval bases</u> and for the <u>conduct of such land operations</u> as may be essential to the execution of a Naval campaign.**

- **Develop, in coordination with the Army, Navy and Air Force, the doctrine, tactics, techniques, and <u>equipment employed by landing forces in amphibious operations.</u>**

- **Develop in coordination with the Army, Navy and Air Force the doctrine , procedures and <u>equipment for airborne operations</u>.**

Bottom Line: USMC does procure unique equipment for its unique missions


OBJ
FBHL
FBHL
WHAT WE DO TODAY

WHAT WE WILL DO TOMORROW

Implications to Power & Energy

- **<u>Space</u> and <u>Weight</u> are at a premium due to lift restrictions**
  - Air
  - Sea
- **Efficiency and adaptability of energy use for deployed forces**
- **Unique transportation requirements**
  - All equipment must be capable of deploying via ship or air
  - Equipment must survive coming through surf
  - Electromagnetic interference from shipboard systems
  - Special restrictions for shipboard stowage / transport
  - Supply / resupply is from the mother-ship / Pre-Positioned Forces

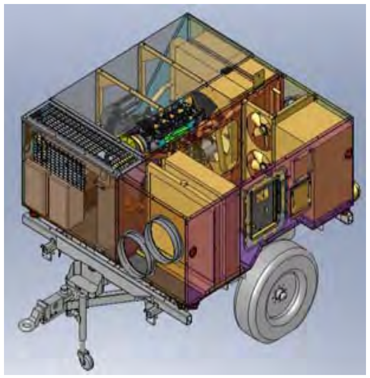
Mobile Electric Power

DOD Standard Generators

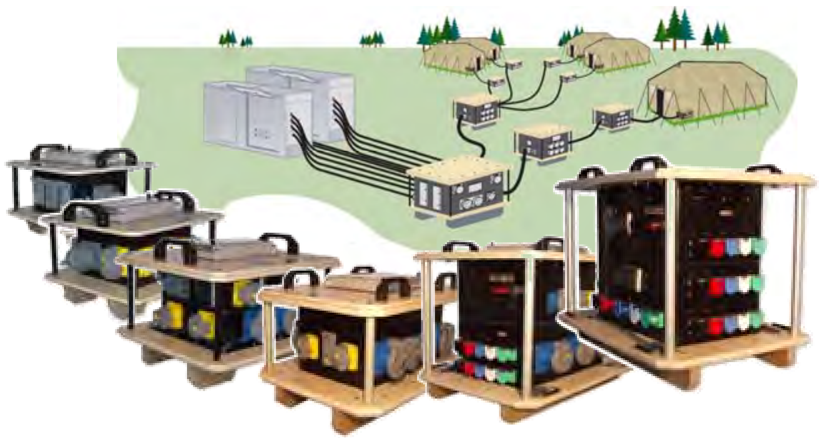
USMC Unique Generators

Tools / Customer Support

Integrated Trailer ECU - Generator



Power Distribution



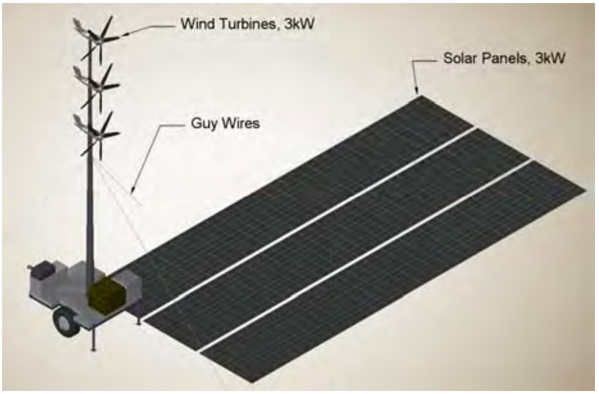
Floodlight Sets

Advanced Power Sources

Radio Power Adaptors

Power Supplies

Renewable Energy

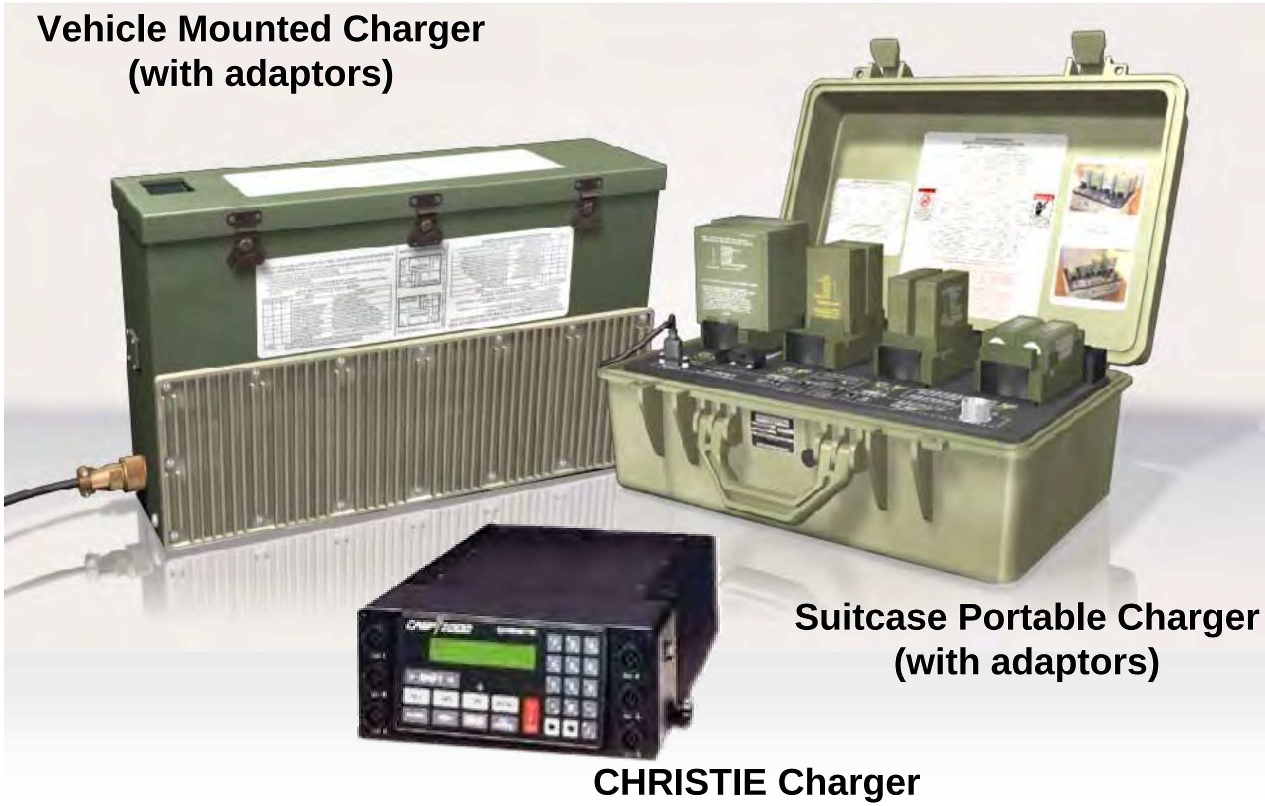


On-Board Power

Battery Management / Sustainment Systems

Battery Management & Sustainment

Battery Chargers (Comm-Elec)



Battery Chargers / Tools (Ground Equipment)

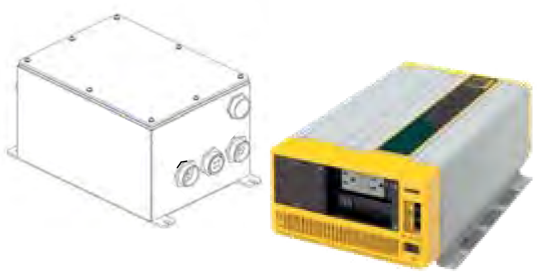
Computer Based Training

Military Batteries

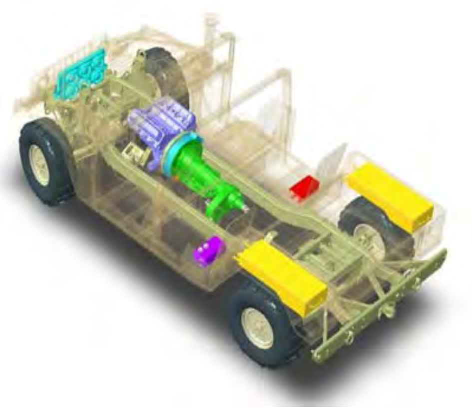
Naval Lithium Battery Safety Program

USMC On-Board Vehicle Power

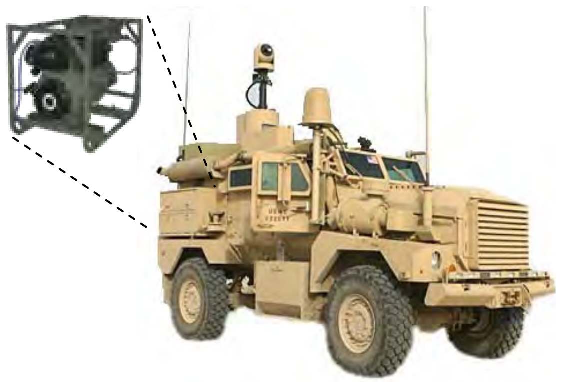
DC-AC Power Inverters
1.8 / 2.5 kW



OBVP - Medium
20-30 kW HMMWV

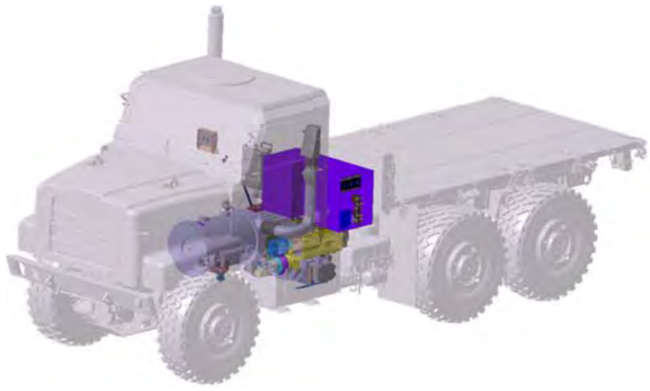


Auxiliary Power Units



OBVP - Small
400 Amps @ 28 VDC (HMMWV)

OBVP - Large
120 kW (MTVR)



Renewable Energy Systems

Internal
< 10 W

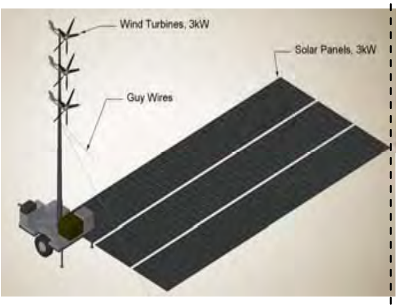
Carried
10 - 100 W

SPACES Project

Portable
100 - 1000 W

GREEN Project

Generator
1 – 10 kW



DREAM Project

Stationary
> 10 kW

Advanced Planning to Industry

Future Program Initiatives

- Renewable Energy Systems – Man-portable (2009)
- On-Board Vehicle Power (2009)
- Advanced Battery Technology (2010)
- Family of Battery Chargers (2011)
  - Vehicle Mounted Battery Charger (now)
- Family of Radio Power Adaptors Reset (2011)
- Family of Power Supplies (2012)
- Family of Environmental Control Units (2013)
- Field Refrigeration Systems (2013)
- Mobile Electric Power Distribution (2013)
- Floodlight Set Rebuy (2013)

USMC Power Considerations

- Acquisition in accordance with Department of Defense policies for requirements validation / acquisition management / DOD MEPGS

- USMC has unique requirements over and above other services

- Many of the power solutions are adapted from commercial sector, but ruggedized for the military environment

- Equipment requirements continue to grow, but manpower to support has not kept up.

- Troop rotation is perpetual. Training/retraining is paramount. Ease of equipment use vitally important.

Closing Comments USMC Acquisition

- We compete 99% of our programs
  - For programs that may go sole-source to a vendor, most likely they were competed in the initial phase
- Market research dictates whether programs are small business set aside, or Full and Open competition
  - Don't ignore Sources Sought Notices or Requests for Information
- If we see that an item is commercially available, we will request / require a loaned article as part of proposal submission to support our source selection
- Order of precedence when we procure:
  - Federally mandated suppliers (Lighthouse for the Blind, Federal Prisons)
  - Federal Supply Schedule
  - Small / disadvantaged businesses
  - Small business
  - Open sources
  - Limited sources
- For all solicitations and notices, keep an eye on FEDBIZOPPS

Questions









Revolutionary Research . . . Relevant Results

Future Naval Capability: Advanced Power Generation

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Power Systems Engineer
Marine Corps System Command
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Clint.govar@usmc.mil

Michele Anderson
Office of Naval Research

Michele.anderson@navy.mil

Distribution Statement A: Approved for public release; distribution is unlimited.

Agenda

- Future Naval Capabilities: Advanced Power Generation overview
- Marine Portable Generator (MPG)
  - Product overview
  - Current status
- Ground Renewable Expeditionary Energy System (GREENS)
  - Product overview
  - Current status
- Questions

Advanced Power Generation Overview

<u>Marine Portable Generator (MPG)</u>
- Lunchbox-sized, JP-8 fueled 500-1000W generator

<u>Ground Renewable Expeditionary Energy System (GREENS)</u>
- 300W expeditionary renewable energy system
- Renewable energy system tool box

R&D Program Funding Level:
FY06-FY11: ~$16.5M

Time Line: FY06 → FY11

TRL: Start 3 → Transition 7

<u>Planned Transitions</u>

1. Mid FY09: 300W expeditionary renewable energy system
2. End of FY11: single person portable generator and renewable energy system tool box

<u>Warfighting Payoff</u>:
- Power C4I equipment
- Reduce logistical burden
- Reduce life cycle cost
- Fills power source void:
  - Bigger than a battery
  - Smaller than a generator (< 2kW)

Marine Portable Generator (MPG)

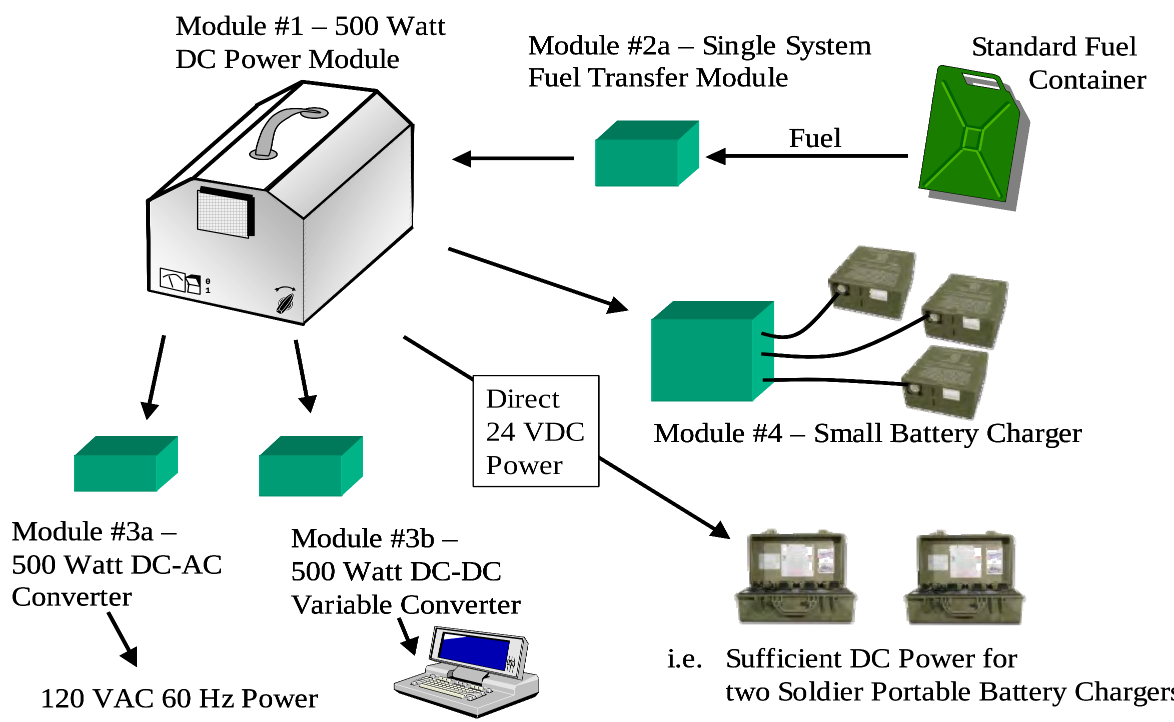
Revolutionary Research . . . Relevant Results

Objective

Develop & demonstrate a single-person portable power unit

Desired Capabilities

- TQG quality power
- Low cost of ownership
- Weight - <15 lbs
- Volume – lunch box size person portable
- <70 dB at 7 meters
- 500W - 1000W output power
- Field operational
- JP-8 fuel with > 1500 ppm of sulfur
- 1 hr internal fuel
- 600 hours before major maintenance
- Start-up in <10 minutes



MPG Project Plan

- BAA released in FY06
  - Phase 1 – detailed design – TRL 3-4
    - Teledyne, D-Star, Creare, L-3 & FEV, Tiax
  - Phase 2 – prototype development & demo – TRL 5-6
  - Phase 3 – product evaluation and field test
  - Phase 4 – production & delivery of field units – TLR 6-7
- SBIR Development Transition
  - Further develop existing fuel cell portable generator SBIR topic
    - Altex, InnovaTek
- Program plan
  - 1st prototype demo in FY10
  - Transition TLR 6-7 to MARCORSYSCOM in FY11

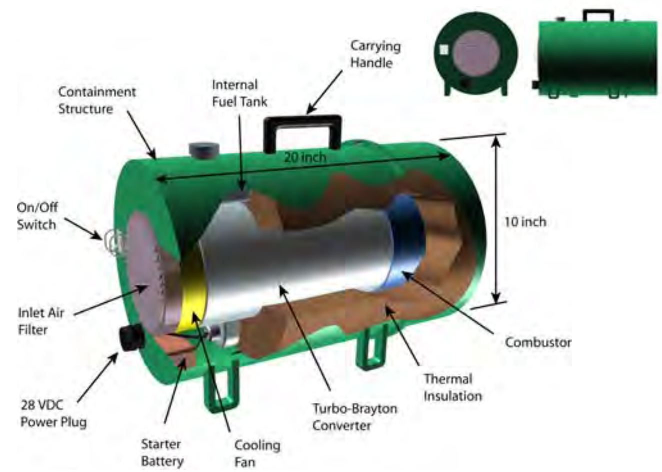
500-1000 W Single Person Portable Generator Product

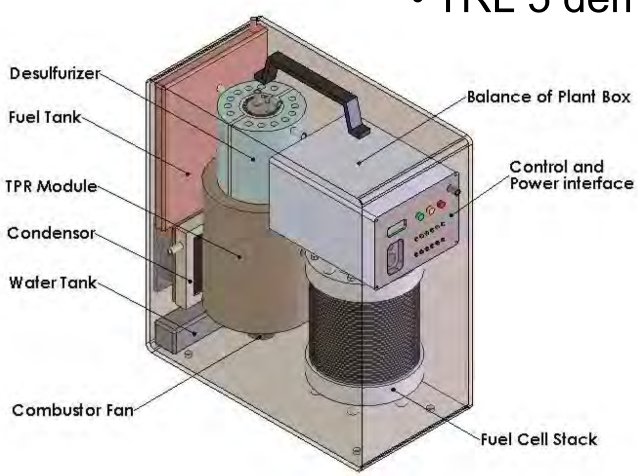
D-STAR – Modified COTS 4-Stroke Engine

- 19% efficiency
- 14lbs, 0.4ft^3, 1kW
- TRL 5 demo early FY10

Creare - Turbo-Brayton Power System

- 24.3% efficiency
- 21.5lbs, 0.5ft^3, 538W
- TRL 5 demo early FY10





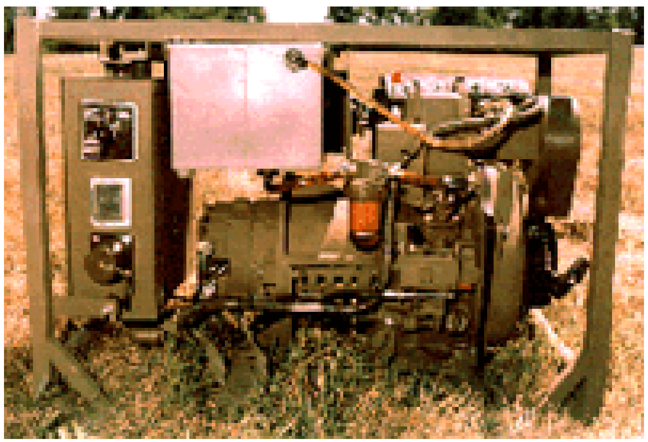
Altex – High Temperature PEM Fuel Cell/PJF-GEN unit

- >30% efficiency
- 17.6lbs, 0.5ft^3, 500W
- TRL 5 demo late FY09

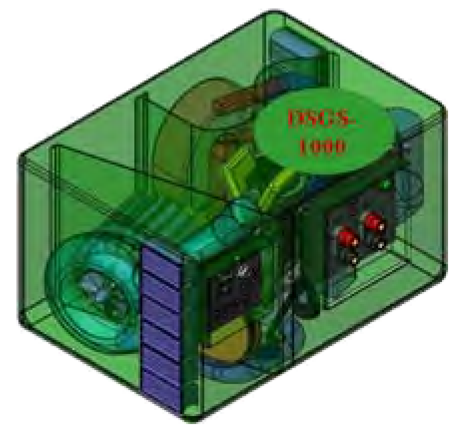
D-Star
(4-Stroke Diesel Engine)

Currently Fielded System

Future USMC MPG System



6x Pwr./Wt.
8x Pwr./Vol.
9 – 12 dB Quieter



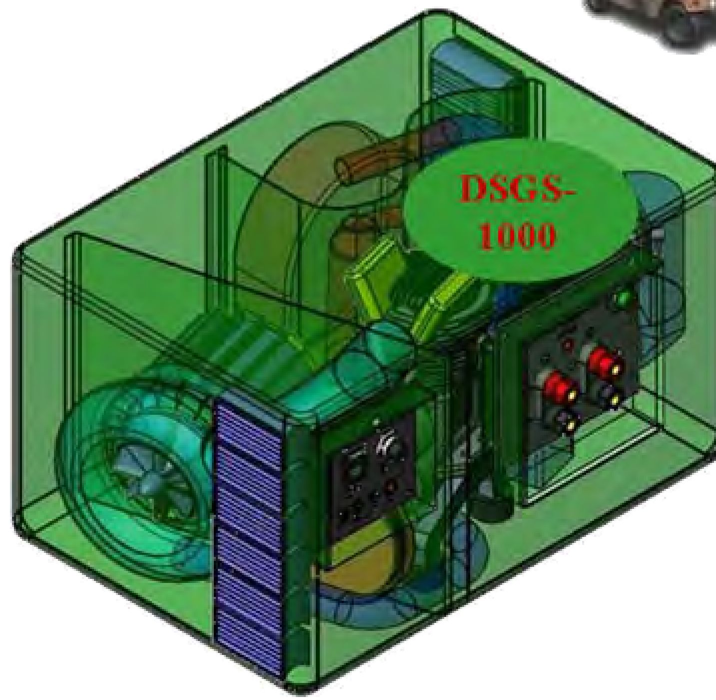
2 kW Generator Set
30” x 16” x 22”
> 6.0 cu. ft.
158 lbs
77 - 79 dB(A) @ 7m

1 kW Generator Set
12” x 8” x 6.5”
< 0.4 cu. ft.
14 lbs
65 - 68 dB(A) @ 7m

Benefits of
(4-stroke Engine Design)

Technical Highlights

- High-Speed (9,000 – 11,000 RPM) 4-stroke Heavy Fuel Engine
- Enhanced Heavy Fuel Atomization, Closed-Loop (Wet Sump) Lubrication
- Combustion Management, Material Substitutions
- Noise-Suppressing Casing

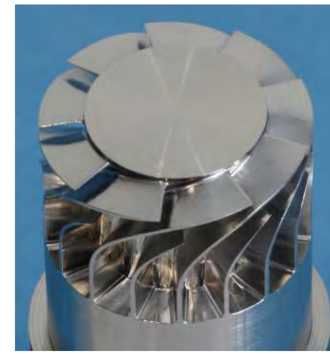


Benefits

- Low cost
- High power to weight and volume ratios
- Instantaneous power demand changes
- Reduced wet stacking issues

Creare
(Closed-loop Turbo-Brayton, Open-loop Combustion)

- Development Team
  - Creare Incorporated – *Lead integrator*
  - Cascade Designs Incorporated – *Combustion/Fuel systems*
  - M.S. Kennedy Corporation - *Electronics*
  - UTC Pratt & Whitney Rocketdyne – *Production cost*
- Status and Plans
  - PDR complete
  - CDR - June 2009
  - System testing - May 2010
  - Prototype delivery - September 2010



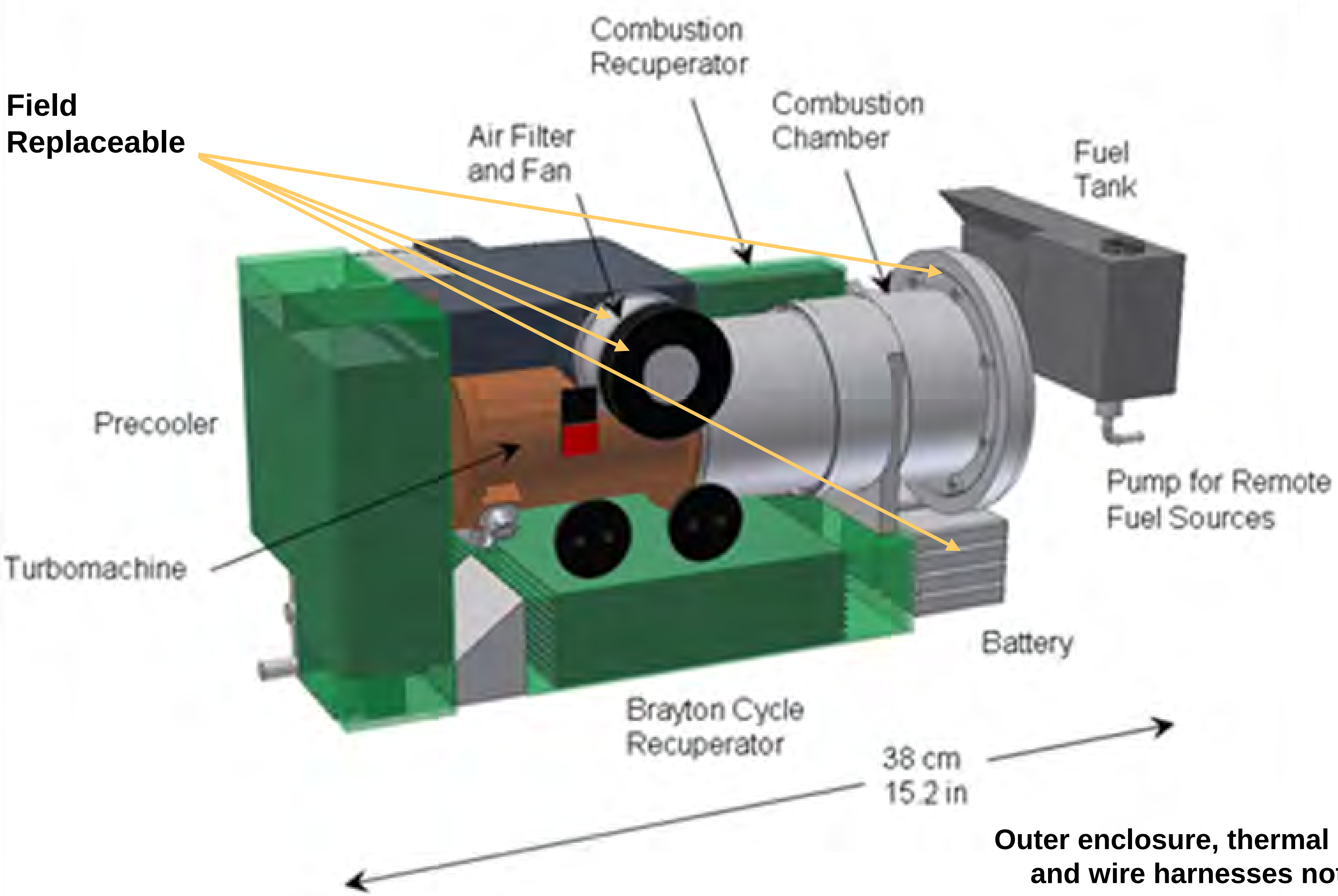
Turbine Rotor Fabrication Trial

Compressor Impeller Fabrication Trial

Benefits of
(Turbo-Brayton Design)

- High efficiency at reduced power levels
- High power to weight and size ratios
- Efficient – 24.3%
- Reliable with simple maintenance
- Long mean time between failures
- Quiet

Mechanical Layout

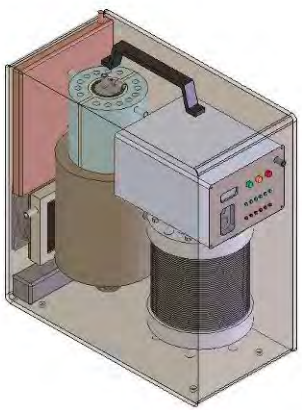


Outer enclosure, thermal insulation, and wire harnesses not shown

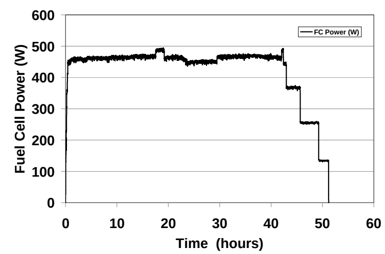
Altex

(High Temperature PEM JP-8 Fuel Cell)

Concept



TRL 4 – Lab Test



TRL 5 – Delivery

9 / 2006

TRL4

6 / 2008

TRL5

6 / 2009

Benefits of (High Temperature PEM JP-8 Fuel Cell)

- High efficiency at reduced power levels
- Efficient >30%
- High power to weight and size ratios
- Quiet
- No wet stacking issue

Ground Renewable Expeditionary Energy System (GREENS)

– 300W Renewable Expeditionary Energy System
  - Prototype currently being built
  - Initial Deployment of 10 -15 system late FY09 – Early FY10

– Renewable energy system tool box
  - Transition at the end of FY11
  - Toolbox of renewable components
    - (energy collectors, batteries, power managers, cabling) will be vetted against varying Marine Corps environments and usages (i.e., experimental data collected on COTS hardware) to enable system optimization for different deployment strategies and power usages

Ground Renewable Expeditionary Energy System (GREENS)

S&T OBJECTIVES

- Develop & demonstrate a 300W portable renewable power system
  - ➢300 W output power
  - ➢Field operational
  - ➢Breaks down to <80lbs cases
  - ➢1000W peak power
  - ➢HMMWV Transportable
  - ➢Stackable system

apply rapid prototyping toolbox to determine optimum renewable and storage component combination for required mission

↓

energy collection

power management

energy storage

cables & connectors

individual modules packaged for man transportability

↓

construct renewable 300 W power system

APPROACH

- Assemble highly qualified team
- Design, build and test 300W system (Q2 FY09)
- Transition 300W system (Q3 FY09)
- Evaluate available renewable tool box components
- Develop renewable energy tool box program
- Demonstrate renewable energy tool box
- Transition renewable energy tool box (FY11)

RESULTS/IMPACT/READINESS

- Results – System-level design trades underway
  System-level integration design underway
  Tool box population started
- Impact – Renewable energy can reduce logistic fuel burden and increase remote power capability
  - Addresses urgent needs request from troops in Iraq
- Readiness – Fundamental component technologies being evaluated, System-level build and testing next step

(300W, 24h System)

- Need 7200Wh
- Need 1.6kW rated solar capability
  - Solid panels
  - at near optimal angel, one angle set point
  - Winter/spring rating
  - Moderate solar climate
  - Sun 8 hours a day = 7.2kWh
    - 4.8kWh of energy storage (minimum)
    - 2.4kWh during light hours
- DC/DC converter, DC/AC inverter, safety and control electronics
- Transport and ruggedization

300W System

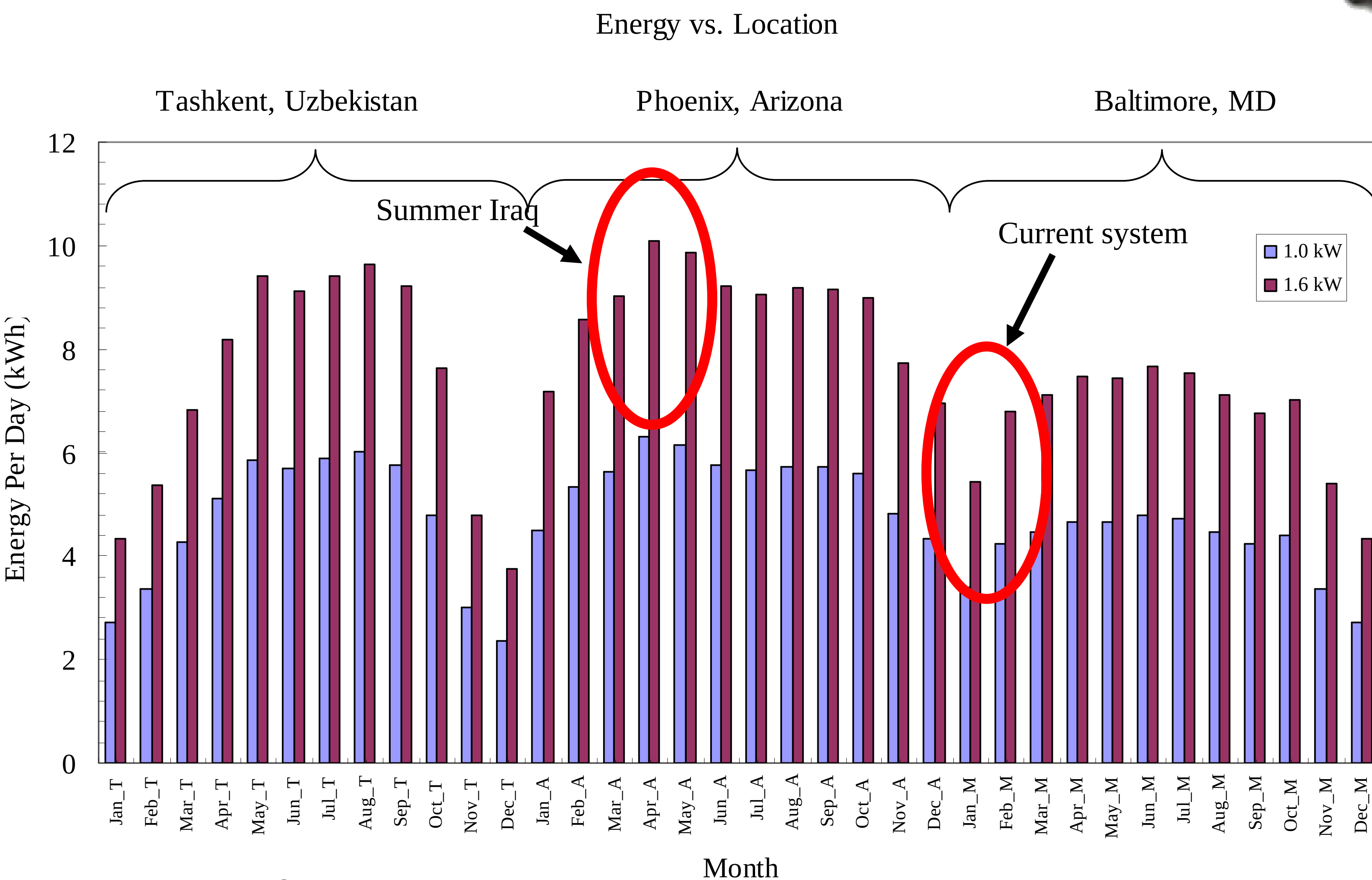
- 900 lbs → Ruggedized for expeditionary use
  - Breaks into 80 lbs single man portable cases
- 1.6kW rated solar
  - 7200Wh solar/day in Washington DC in January
- 300W continuous (600 max power)
- Output – 120VAC, 24VDC
- Cost <$35K

Weight vs. Power

Mission	Total Energy (Whr)	2590 Batteries (lbs)	Solar Weight (lbs)	Converter Weight (lbs)	Total Weight (lbs)
100W const (8hrs/day)	800	(1)3	23	5	31
100W const (16hrs/day)	1600	(5)15	46	5	66
100W const (24hrs/day)	2400	(10)30	69	5	104
200W const (8hrs/day)	1600	(2)6	46	5	57
200W const (16hrs/day)	3200	(10)30	92	5	127
200W const (24hrs/day)	4800	(20)60	138	5	203
300W const (8hrs/day)	2400	(3)9	69	10	88
300W const (16hrs/day)	4800	(15)45	138	10	198
300W const (24hrs/day)	7200	(30)90	207	10	317
With Packaging and deployment					1000 lbs
400W const (8hrs/day)	3200	(4)12	92	10	124
400W const (16hrs/day)	5400	(20)60	155	10	225
400W const (24hrs/day)	9600	(40)120	276	10	406
500W const (8hrs/day)	4000	(5)15	115	15	145
500W const (16hrs/day)	8000	(25)75	230	15	310
500W const (24hrs/day)	12000	(50)150	345	15	510

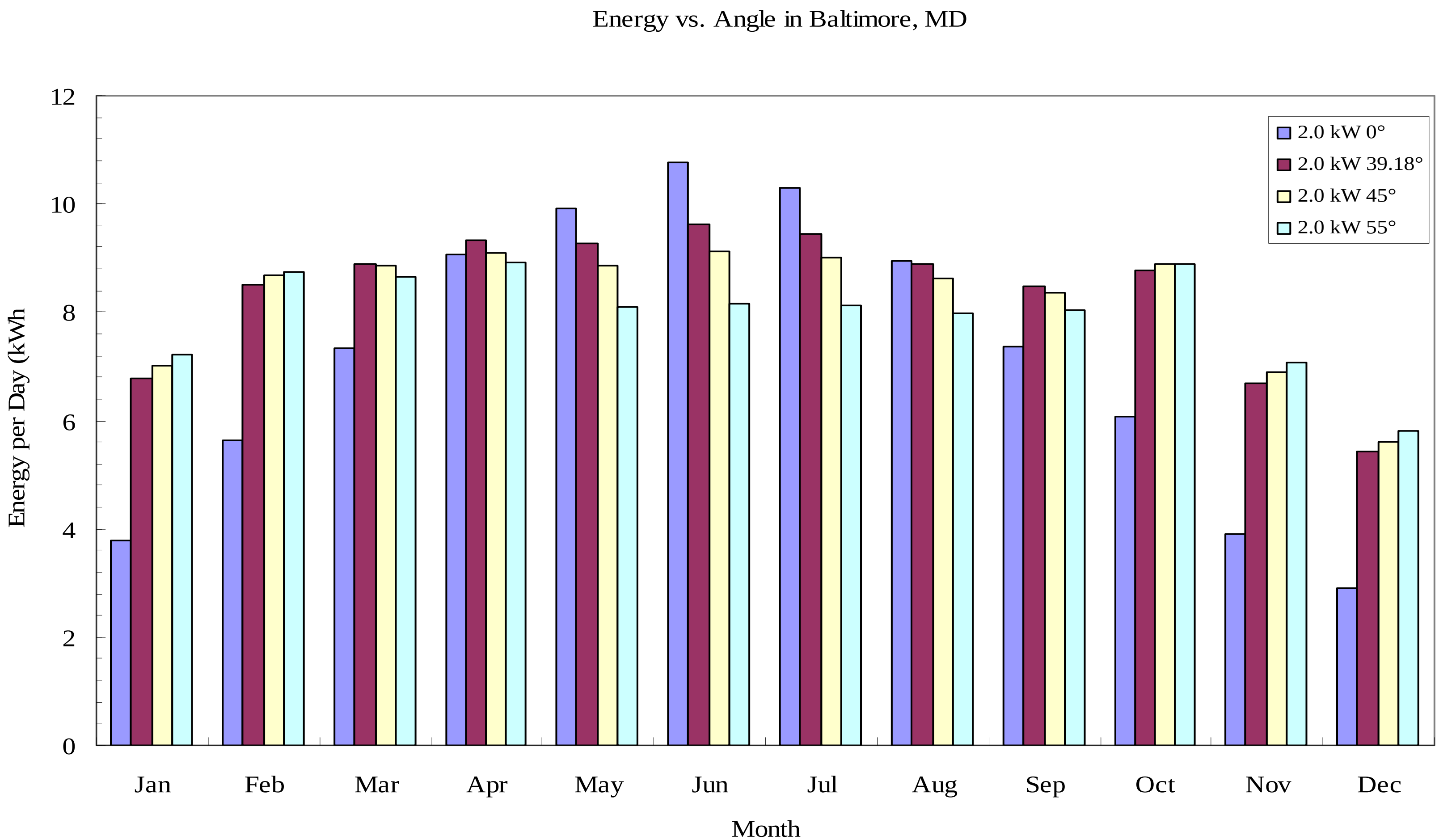
Solid panels are derated 50%; BB2590's are used as battery baseline

Solar Data (Various locations)



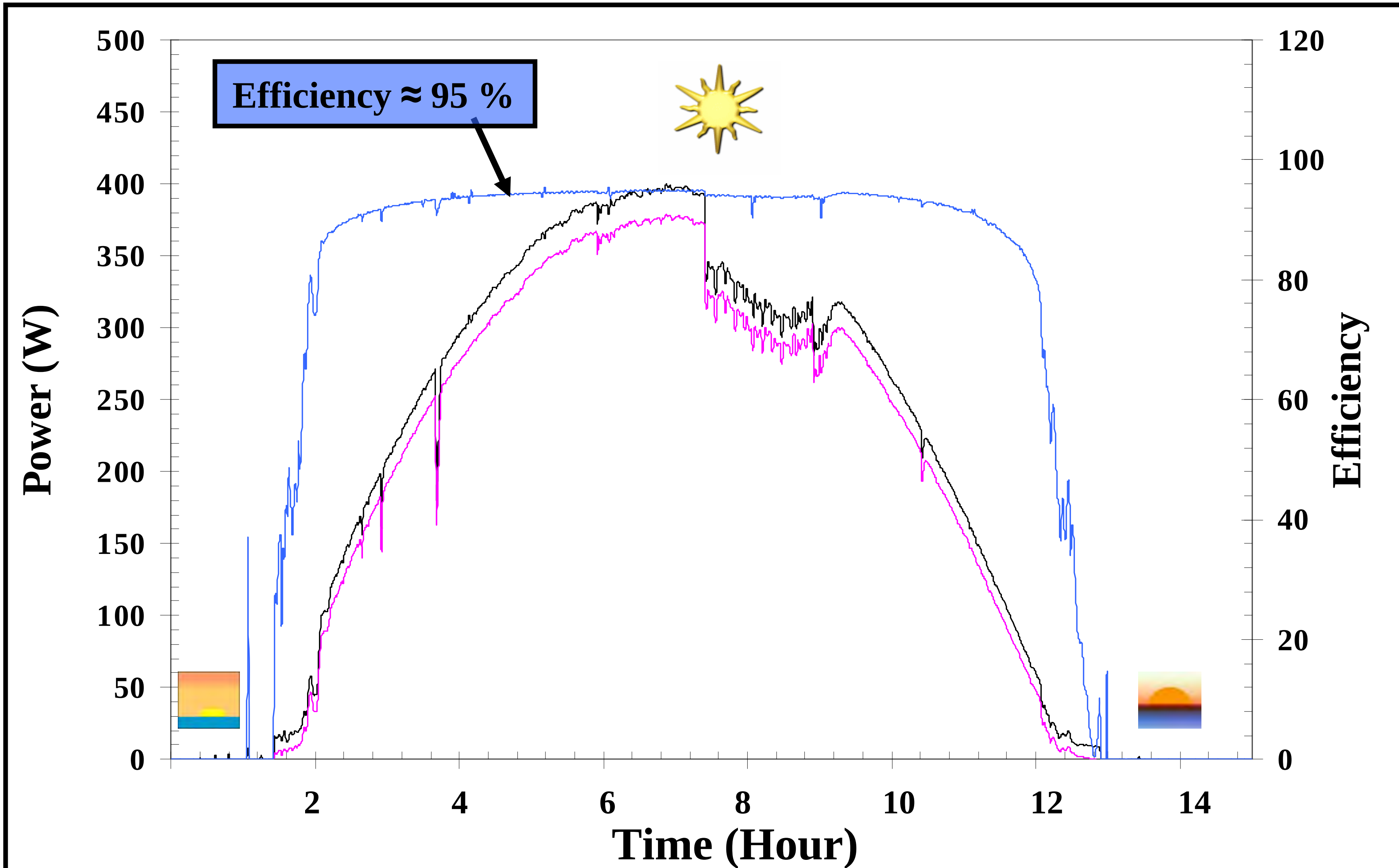
* Data complied form NREL Website

Angle vs. Months

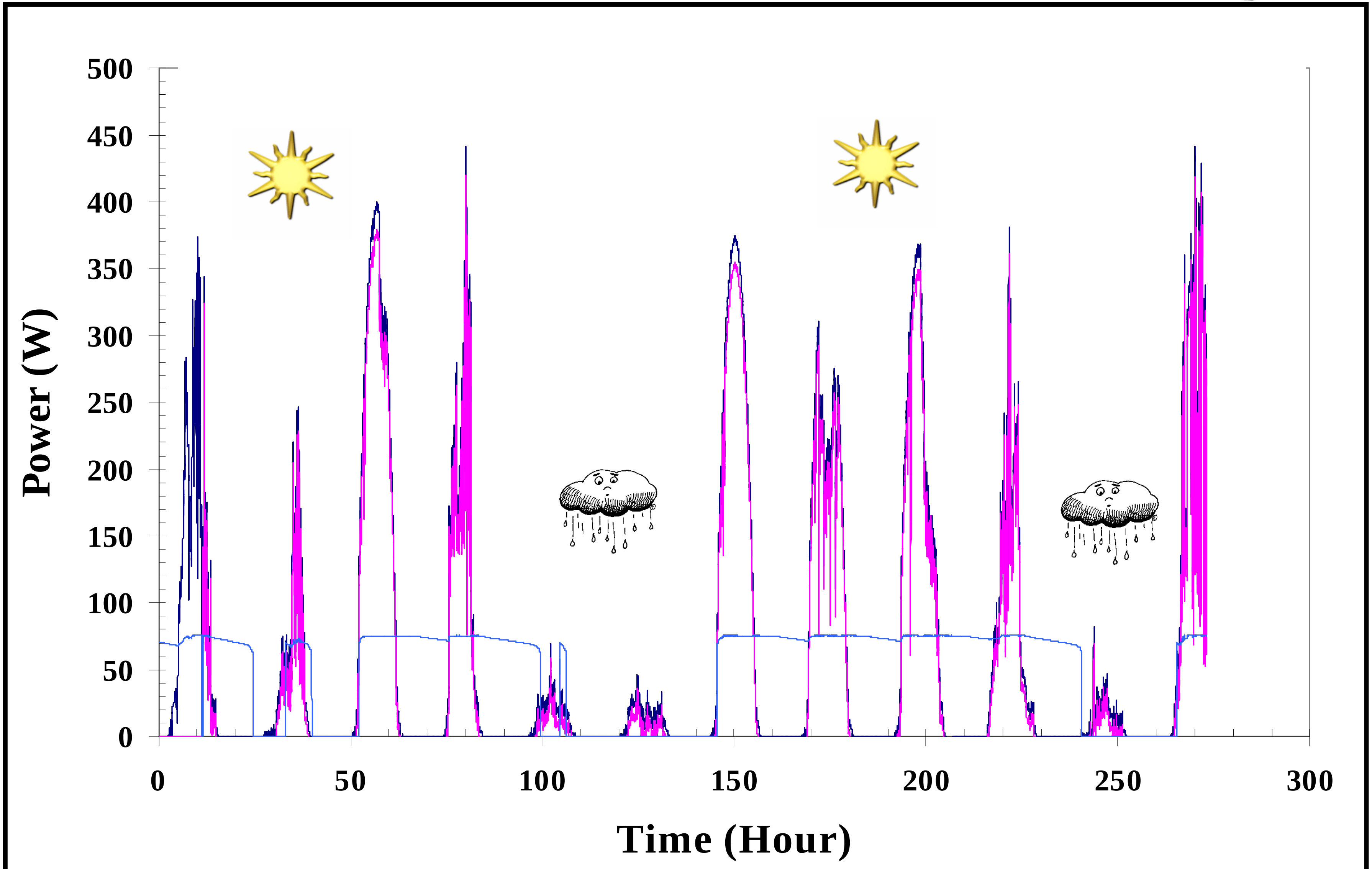


* Data complied form NREL Website

Solar Battery Charging



Power Reliability



GREENS Tool Box

- Tool to rapidly design a tailored renewable energy system, from a list of tested components, for specific deployment scenarios
  - Program
    - Interactive data base
    - Mission Requirements in → Renewable system design out
  - Tested components will include:
    - Energy collectors, batteries, power managers, cabling, packaging
    - Will be vetted against varying Marine Corps environments and usage requirements

Wrap-up

- Any companies that have components they would like to submit for evaluation for inclusion in the GREENS toolbox please contact NSWC Carderock or MARCORSYSCOM.

Acknowledgments

- S. Paul Dev, DStar Engineering
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- Jeff Breedlove, Creare
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- Mehdi Namazian, Altex Tech
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- Eric Shields, NSWC Carderock Team
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Joint Service Power Expo

May 5-7 2009

US Marine Corps Portable Power R&D Efforts

C. Justin Govar
Power Systems Engineer
Marine Corps Systems Command
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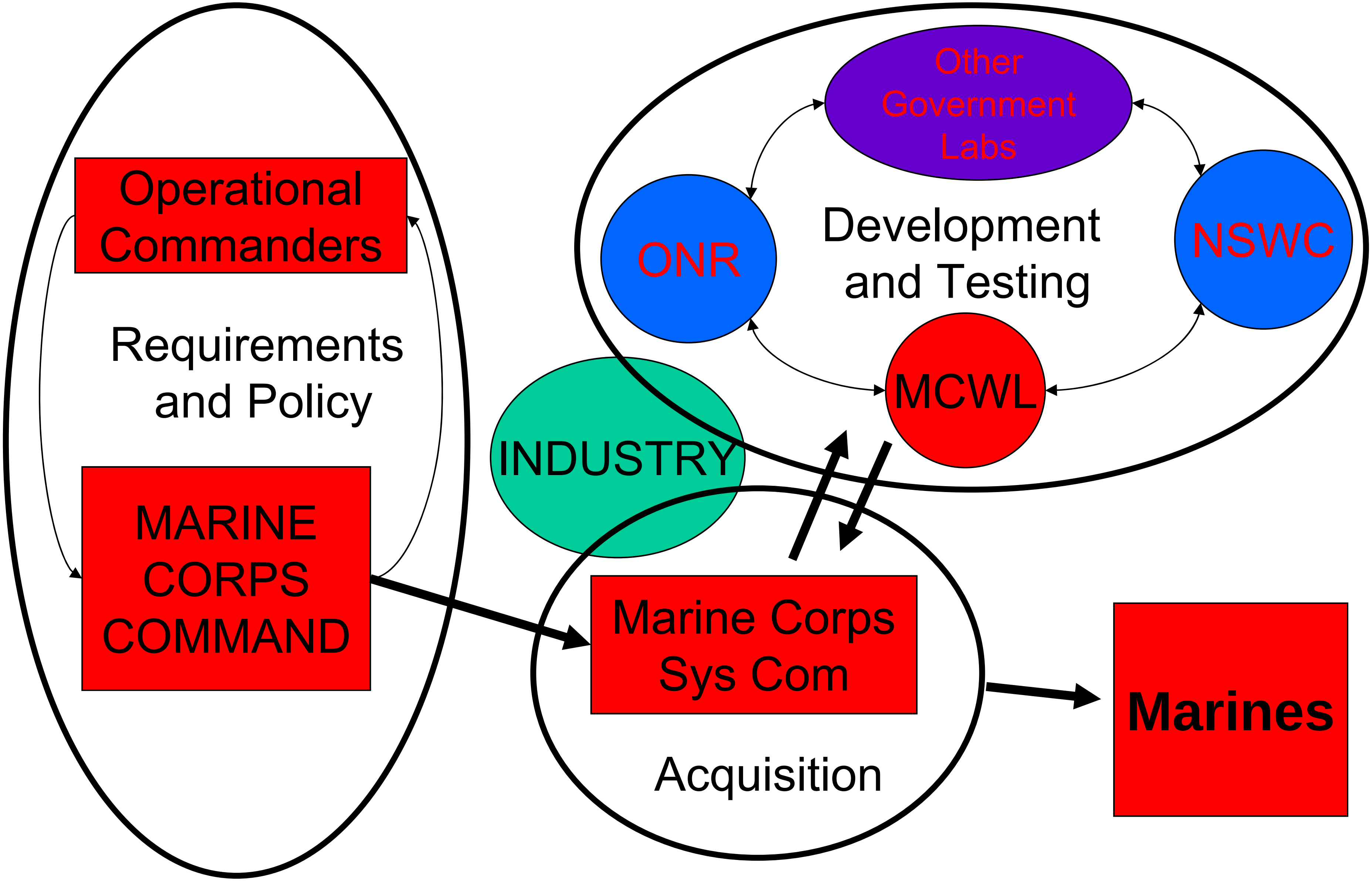
Briefing Topics

- How MARCORSYSCOM works with other organizations
  - Roles and responsibilities
- Current Development Programs
  - Portable Generators
  - Renewable Energy – (SPACES, GREENS, DREAMS)
  - Radio Power Adaptors – (24V RPA Towers, single RPA)
  - SBIR Efforts
  - Tactical Vehicle Battery Replacement
  - Vehicle Mounted Battery Charger Light (VMCB-Light)
  - Rugged Inverters
- Conclusions

The Marine Acquisition Universe



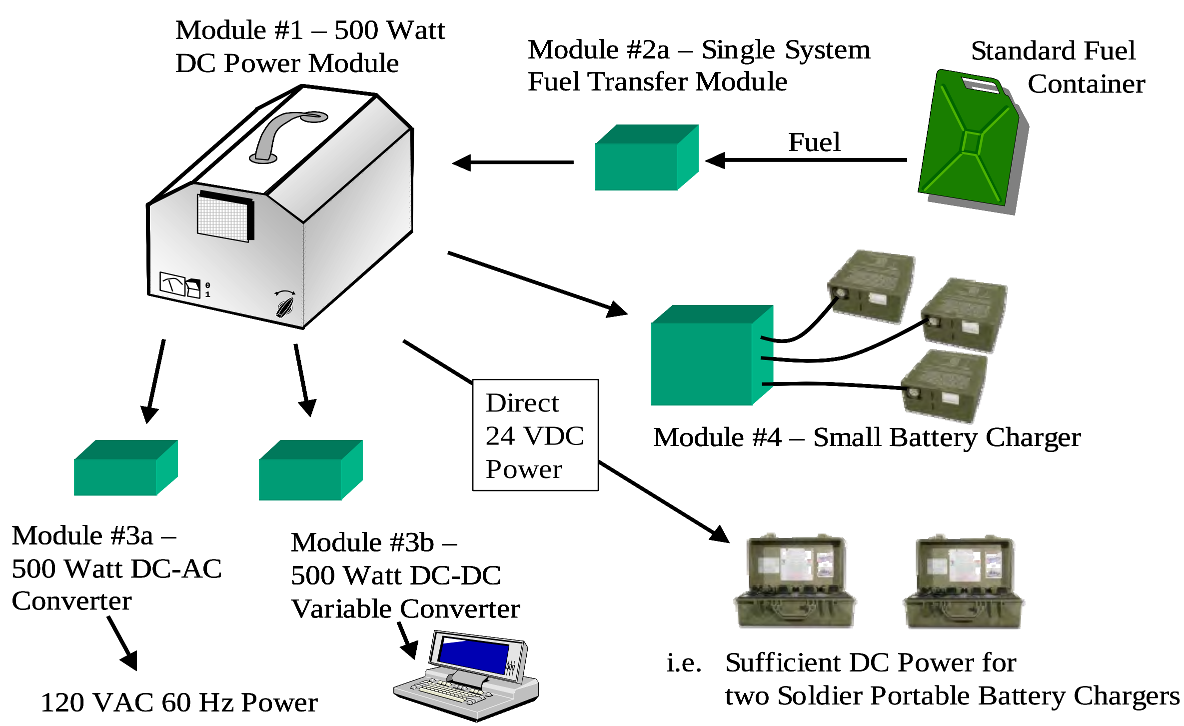
Marine Portable Generator (MPG)

Objective

Develop & demonstrate a single-person portable power unit

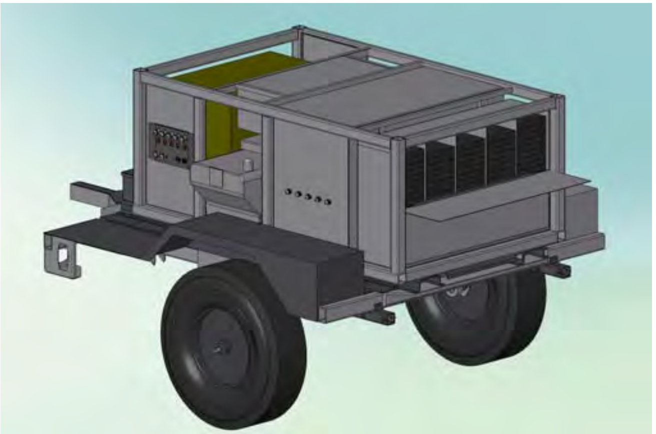
Desired Capabilities

- TQG quality power
- Low cost of ownership
- Weight - <15 lbs
- Volume – lunch box size person portable
- <70 dB at 7 meters
- 500W - 1000W output power
- Field operational
- JP-8 fuel with > 1500 ppm of sulfur
- 1 hr internal fuel
- 600 hours before major maintenance
- Start-up in <10 minutes



Renewable Power System

- DREAMS – Trailer Size
  - 3kW constant, 5kW peak, HMMWV towable hybrid renewable energy systems
    - Solar – panels, batteries, generator



- GREENS – Mid Size
  - 300W renewable energy system
  - Renewable energy tool box
    - Rapid design and deployment of mission specific renewable energy solutions

- SPACES – Man Portable
  - 100W solar battery charger
  - Power radio directly
  - Procurement and testing underway

Multi-Radio Power Adaptors

Current
12V Multi-SINCGARS Power Adapter (MSPA)

- Powers 6 SINCGARS radios
- UPS capable when connected to both AC and DC power
- Power Input: 110VAC or 12VDC, 40-70 Hz
- Weight – 110 lbs with case

New Start
24V Radio Power Adapter Tower

- 24V system with at least 4 radio bays
- Power Input: 110-280VAC or 24VDC, 40 – 400Hz
- < 80 lbs without case
- Currently in Source Selection
- Anticipated fielding start FY10

Individual Radio Power Adaptors

- **RPA for AN/PRC-148 / 152 / 153**
- **Power radios with BB2590/BA5590/BA5390 or 12/24VDC input**
- **Goals**
  - **Reduce overall battery weight**
  - **Increase power flexibility**
  - **Reduce logistical charging burden**
- **Received bid samples**
- **Testing is underway**

6T Battery Replacement

- Looking for new replacement for vehicular batteries
- Goals
  - Lighter weight
  - Longer run time
  - Same form factor
  - Cost competitive over life cycle
- RFI currently on Fed Biz Ops

If you have a technology that would work we are interested in hearing from you!!!

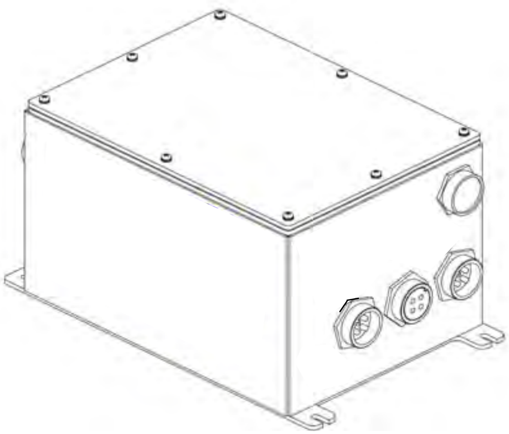
Vehicle Mounted Battery Charger – Light (VMBC-Light)

- Smaller and lighter VMBC
  - 60% Volume Reduction over existing VMCB
- Similar functionality of existing VMCB
- Currently open on Fed Biz Ops
- Multi battery universal adapter
- Bulk charging capability for AA rechargeable batteries
- Recent major changes to solicitation

OBVP - Inverters

- USMC currently fields / centrally manages **QP-1800** Inverter
  - Competitively selected 2006
  - Semi-ruggedized
  - 1800 watts output

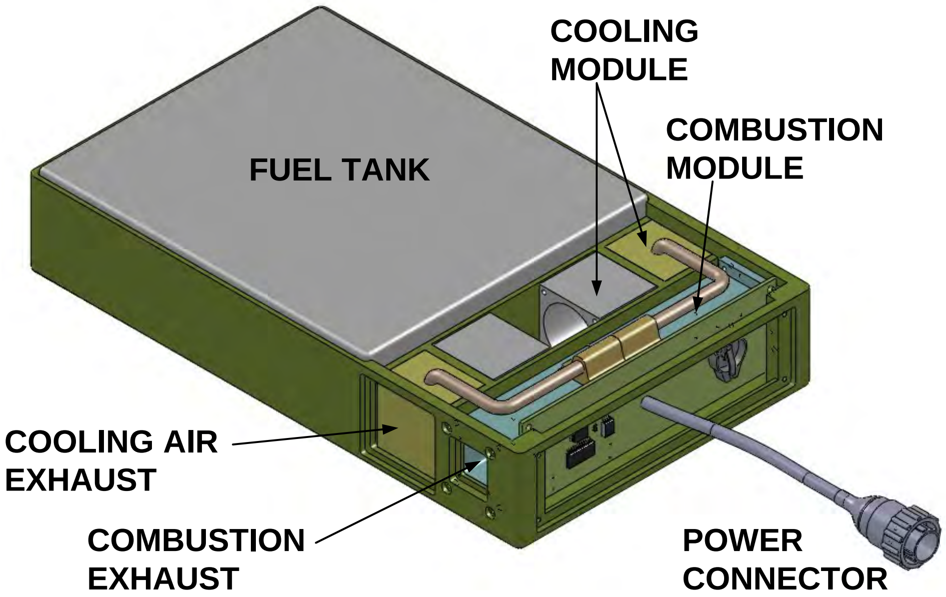
- Other USMC PMs have requested an **enhanced model**
  - Currently in Source Selection
  - Non-Developmental procurement
  - Critical Parameters:
    - 2000 - 2500 watts
    - Fully ruggedized (unprotected environments)
    - AC / DC input and output / battery charging



SBIR's

- Micro Fuel Power Source
- Universal Battery Adaptor
- Electronic Equipment Power Reduction
- Adaptive Power Profiling Suite (APPS)
- State of Charge Indicator for Zn/Air and CFx Batteries
- Wireless Battery Charging
- Man Portable Power System (MPPU) UPS

Micro Fueled Power Source (SBIR)



Key Features:

- Powered by liquid fuel (Butane, Propane)
- High energy density (500 W-hr/Kg)
- Microcombustion technology
- Thermoelectric power conversion
- Refillable power source
- JP-8 fuel in the future

Program Status:

- Phase I completed – 1st Qrt FY09

Micro Fueled Power Source

Size: 12.2 x 7.3cm x 2.4 in^3

(Same form factor as BA8180)

IRVINE SENSORS CORPORATION

Projected Performance:

Power Output:	20W
System Energy:	1220 W-hr
Gravimetric Energy Density:	500 W-hr/Kg
Volumetric Energy Density:	360 W-h/L
Fuel Mass/System Mass:	54%
System Mass:	2.42 Kg
System Volume:	3.44 liter

Universal Battery Adaptor (SBIR)

- Goal – Replace all the adaptors to the right with one universal adaptor
  - Account for connectors of different shapes, sizes and locations
  - Program driven for different charge profiles
  - Uses SMBus protocols
- Phase I Complete

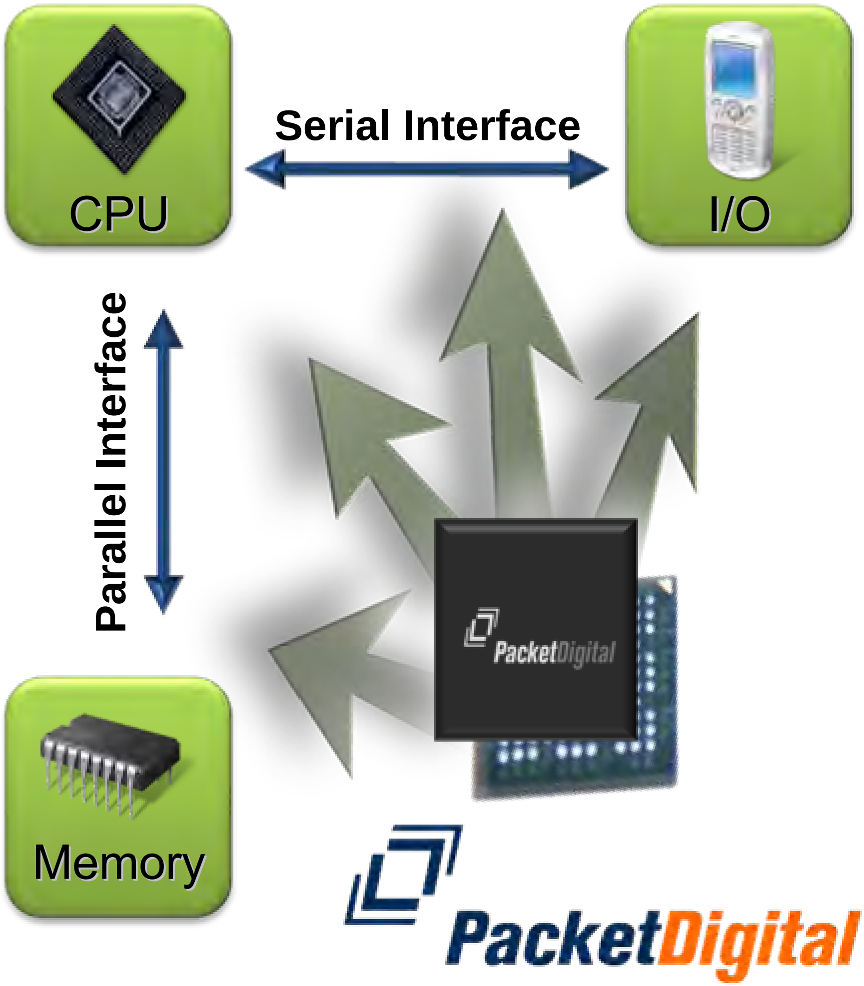
Solutions Through Advanced Technology™
MAINSTREAM
Engineering Corporation

Phase I: Prototype

Electronic Equipment Power Reduction (SBIR)

- Goal
  - Reduce end item power consumption without affecting functionality
- Company: Packet Digital
  - Patented On-Demand Power
  - Patented PowerSage PMICs
- Phase I Accomplishments:
  - 25% energy reduction in hard drives and DVD drives for Panasonic Toughbook
- Planned Phase II Goals:
  - Integrate PowerSage into PRC-117A, PRC-148, and PRC-150.
- Benefits:
  - Extends battery life
  - Improves signal-to-noise ratios
  - Reduces generated heat in electronics

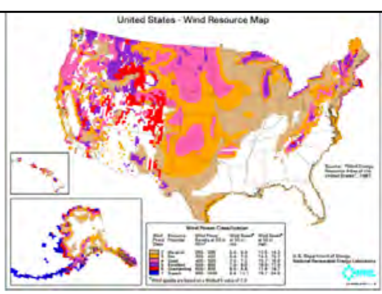
Scans Memory, CPU, I/O and Communication Links To Adjust Supply Voltages and Clocks



Adaptive Power Profiling Suite (APPS)

- Phase I - Develop a reconfigurable kit of power options to optimize energy usage for the Marine Core Distributed Operations squad and their electronic devices
- Phase II – Focus the Phase I develop on renewable energy systems
- Proposed Outcome
  - Tool to identify applicable renewable technologies for a given mission scenario and operating location
  - Provide an easily updated system that allows the input of new technologies

Wind Effectiveness



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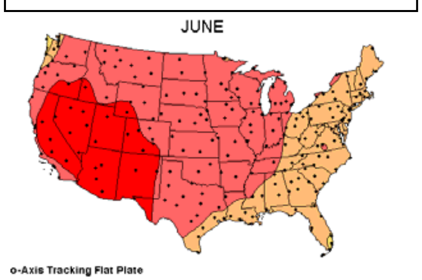
Solar Effectiveness



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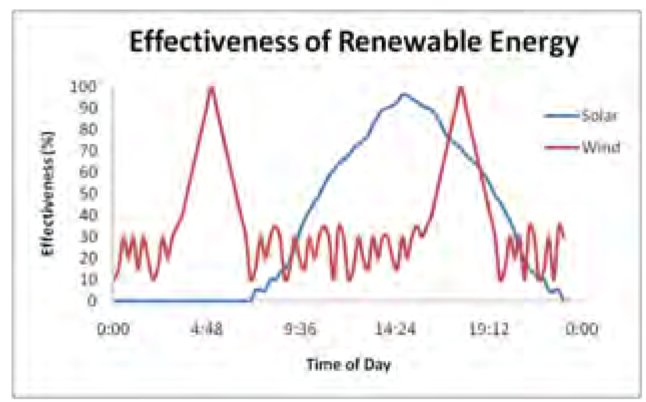


State of Charge Indication (SBIR)

- Objective
  - Develop a State of Charge indicator for battery technology that is highly modifiable
    - Focus on Zn/Air technology and CFx technology
    - Uses common micro-controller based SOC architecture
    - Uses fuzzy neural network based SOC algorithm
  - Phase I demonstrated capability to accurately detect SOC of Zn/Air technology
    - Further modeling needed to account for wide environmental and operational variations
  - Phase II – focused on developing models and adapting SOC technology for CFx batteries.
- Team: Global Technologies, University of Idaho, Rayovac
- Phase II completion end of FY10

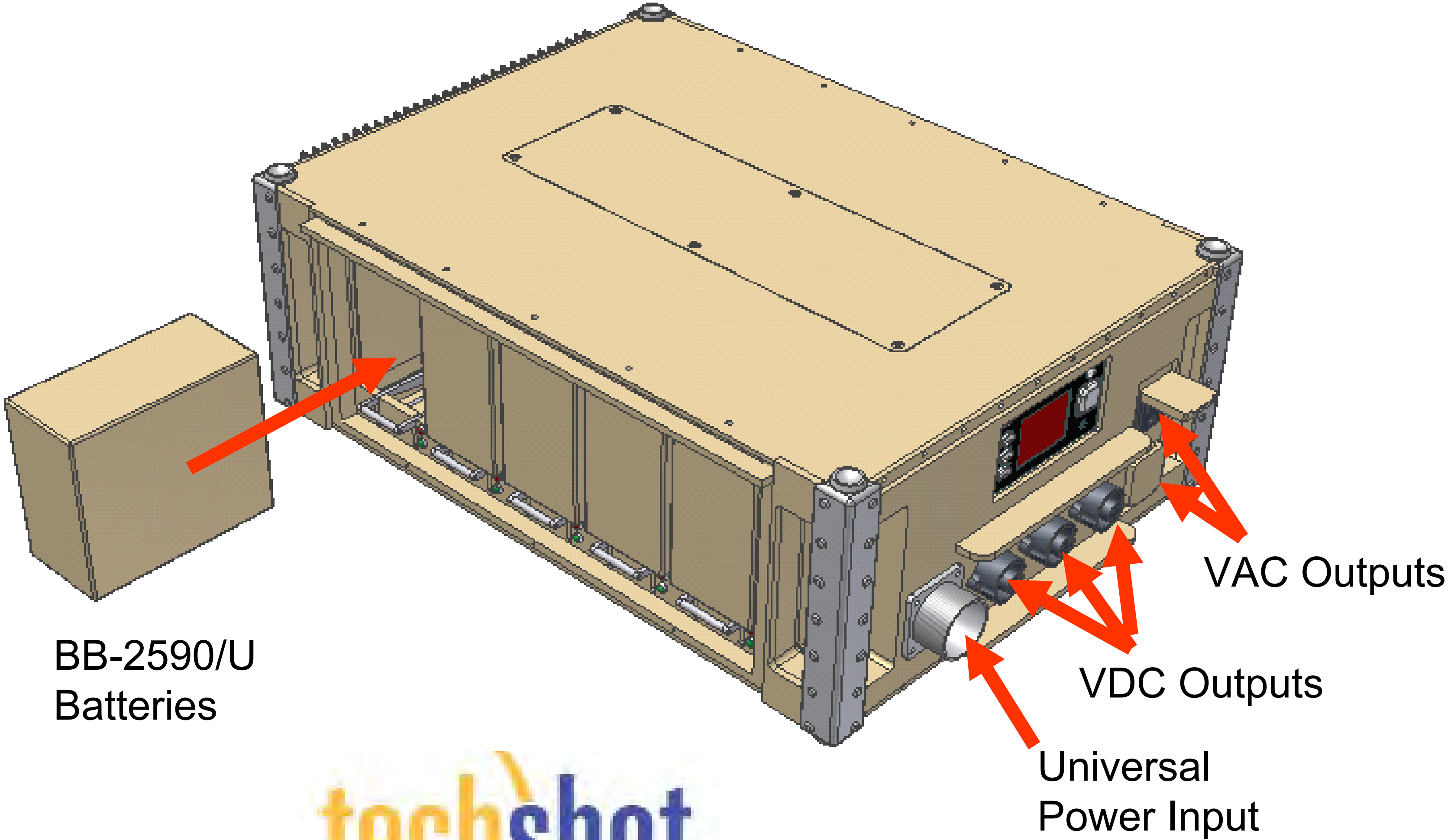
Marine Portable Power Unit (MPPU) SBIR

- Objective - Develop a UPS/Battery charger that:
  - Utilizes BB2590 for 1000Whr of energy storage
  - Batteries are hot-swappable
  - Inputs: 120- 240VAC at 40-440Hz, 24VDC
  - Outputs: 120VAC at 60Hz, 12VDC, 24VDC (regulated)
  - Weight ~ 50 lbs
  - SMBus capable
  - Rugged
- Mid to late FY10 deliverables

Acumentrics

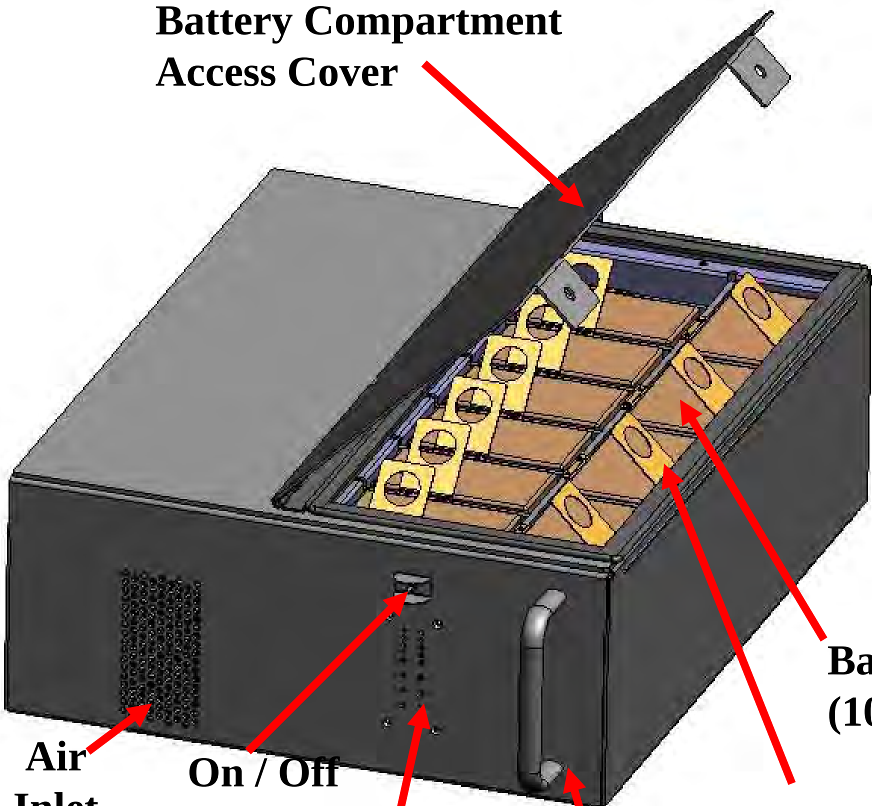
techshot

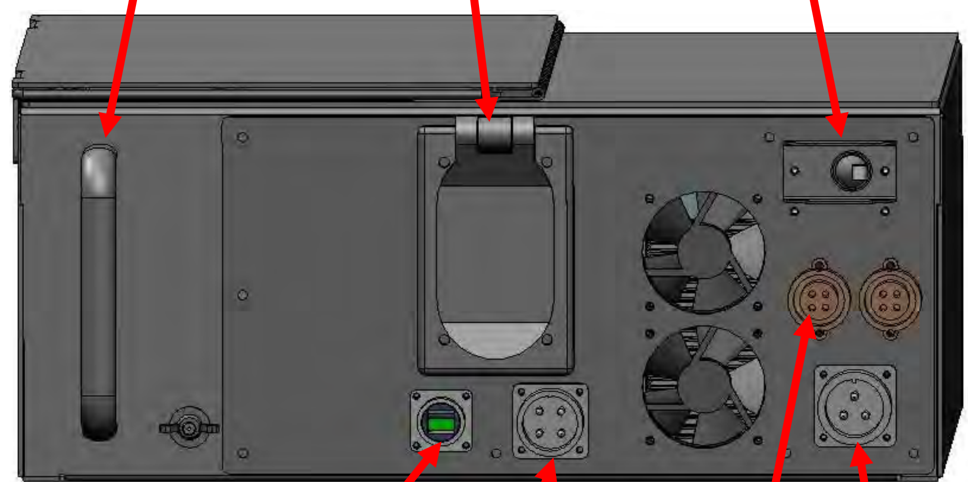
Marine Portable Power Unit (MPPU)



techshot

CHARGER-1250-Li





Acumentrics

SBIRs

- Wireless battery charging
  - Currently in Phase I, 4 companies
    - Physical Optics
    - PowerPad
    - Infoscitex
    - Eltron
- Battery maintenance and monitoring during storage
- Ruggedized power supply with world wide operations

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- Freeman Rufus, Global Technologies,
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Power Conversion Technologies for Improved System Performance

Kaz Furmanczyk
Crane Aerospace & Electronics

2009 Join Service Power Expo

May 4-7, 2009 – New Orleans, Louisiana

Introduction

- Background
- New Challenges for Power Conversion Equipment on Airplanes
- Review of Technology Options for Powering Motors that Meet Aerospace Requirements
- Implementing Modeling and Simulations for Design Optimization - Example
- Conclusions
- Summary of Hardware Performance

Background

- Traditional constant frequency power sources (400 Hz) on airplanes are being replaced by variable frequency generators (typically 360-800 Hz)
- Pneumatic and hydraulic systems are being replaced with electrical devices – most of which are using electric motors
- More electrical equipment is being added to airplanes – power quality becoming an issue

Challenges

This creates new challenges, which need to be resolved:

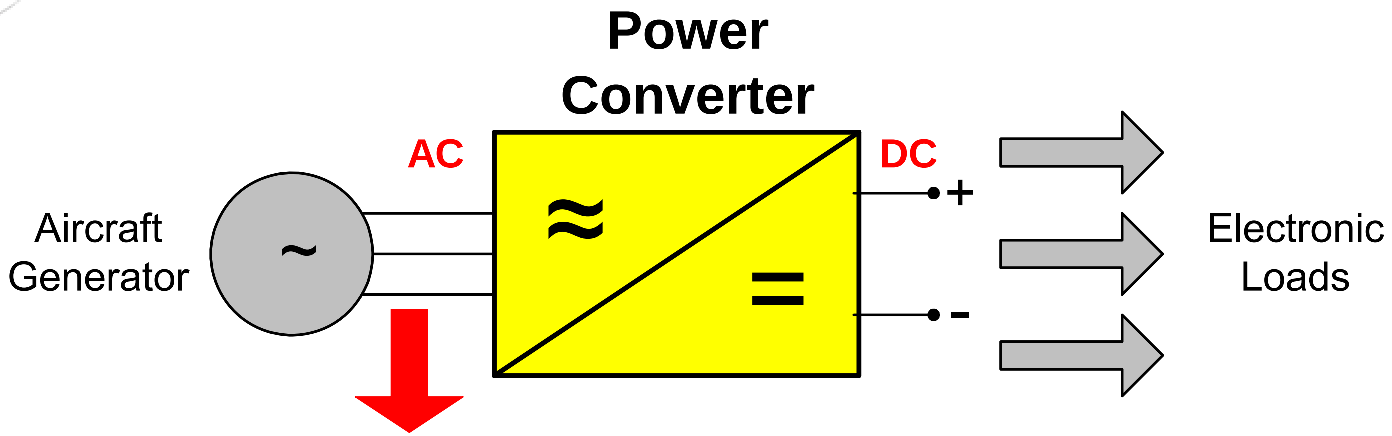
- Challenge #1 – Speed of inductive motors varies with frequency

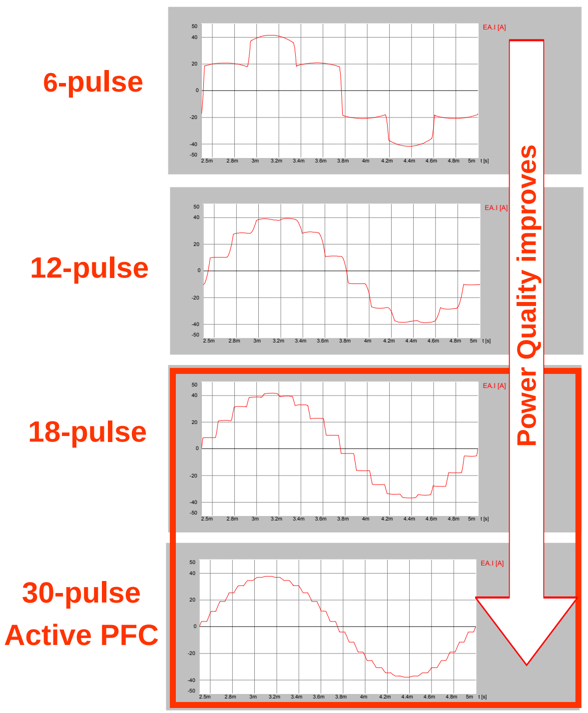
  → solution: replace inductive motors with DC brushless motors

  - However, direct rectification of AC into DC generates high current distortion – exceeding acceptable power quality limits

- Challenge #2 – Find effective solution for converting AC into DC with good power quality

Power Quality





- Effect of power conversion is reflected back onto the aircraft AC bus
- The smoother the current waveform ---> the better the “Power Quality”
- 18-pulse, 30-pulse and active PFC approaches represent good power quality

Power Quality

- Power quality requirements from leading OEMs (examples):
  - Boeing: 787B3-0147
  - Airbus: AMD-24
- Recent, DO-160, Rev. F Document imposed power quality requirements for aerospace products powered from an aircraft AC power system
- The most significant requirement is on restriction of individual harmonics generated by user equipment rated 35 VA or more
- The harmonic limits requirement makes direct rectification obsolete
  - Practically, all motor drivers, which are using direct rectification need to be replaced or upgraded
  - Majority of traditional TRU units can not meet new current limit requirements – improved designs or larger filters are needed

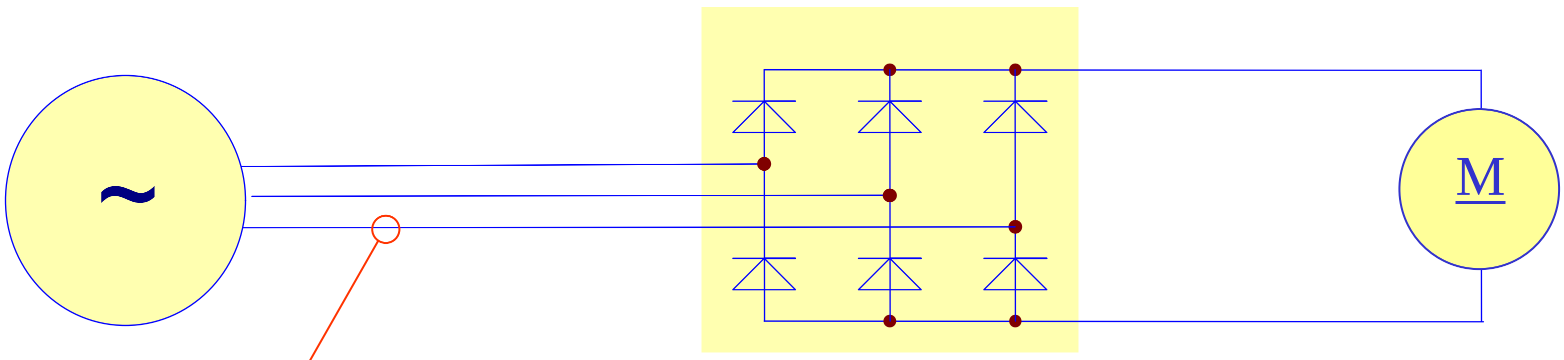
DO-160F Current Harmonics Limit

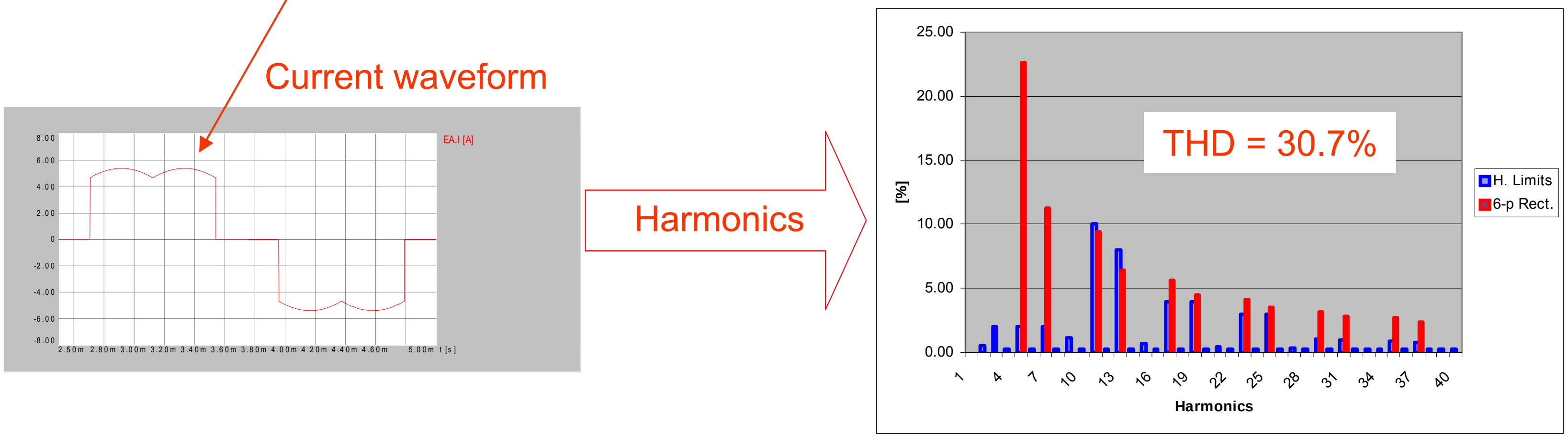
Each current harmonic, up to 40th harmonic has specified limit

Harmonic Order	Limits
3rd, 5th, 7th	$0.02\ I_1$
Odd Triplen Harmonics (h = 9, 15, 21, ..., 39)	$I_h = 0.1\ I_1 / h$
11th	$0.1\ I_1$
13th	$0.08\ I_1$
Odd Non Triplen Harmonics 17, 19	$0.04\ I_1$
Odd Non Triplen Harmonics 23, 25	$0.03\ I_1$
Odd Non Triplen Harmonics 29, 31, 35, 37	$I_h = 0.3\ I_1 / h$
Even Harmonics 2 and 4	$I_h = 0.01\ I_1 / h$
Even Harmonics > 4 (h = 6, 8, 10, ..., 40)	$I_h = 0.0025\ I_1$

Existing Approach

- Traditionally, 6-pulse rectification provides DC power for motors
- However, input current harmonics exceeded DO-160F limits
- New - more advanced technology - is required to convert AC into DC

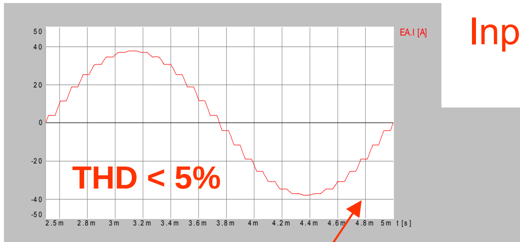




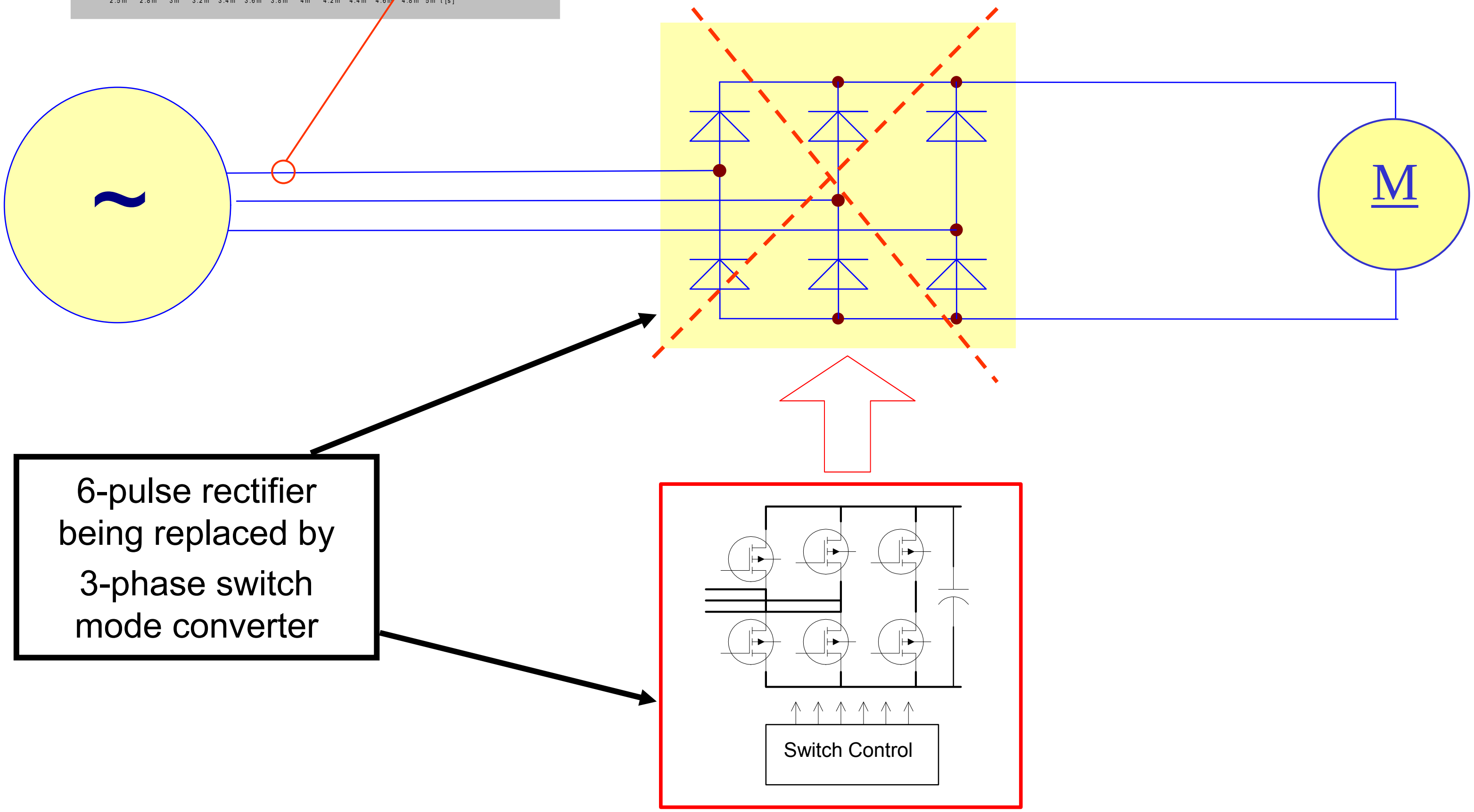
Technology Options

- The following power conversion technologies are capable of meeting the new power quality requirements:
  - High frequency switch mode conversion (active conversion)
  - Multiphase power conversion (passive conversion)
  - Other harmonic correction techniques, based on:
    - Harmonic injection
    - Active filter implementation

High Frequency Switch Mode Conversion



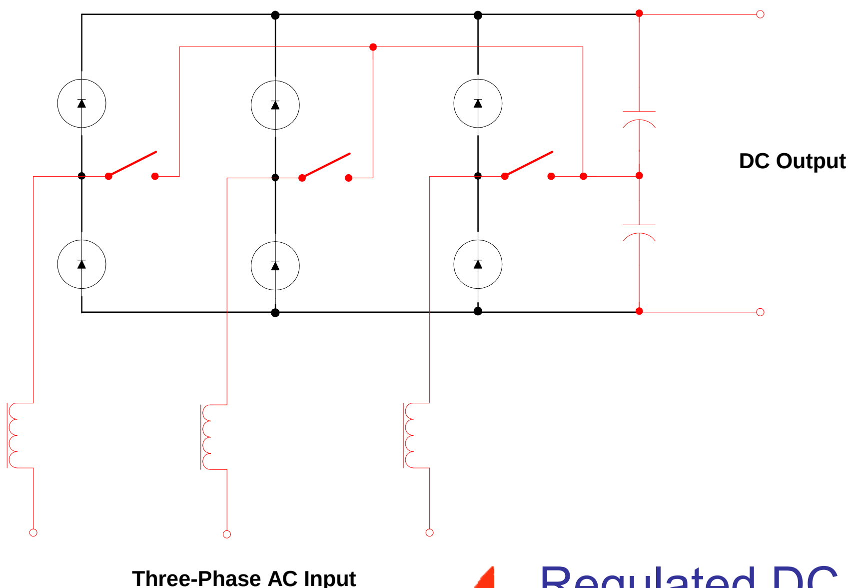
Input Current meets power quality



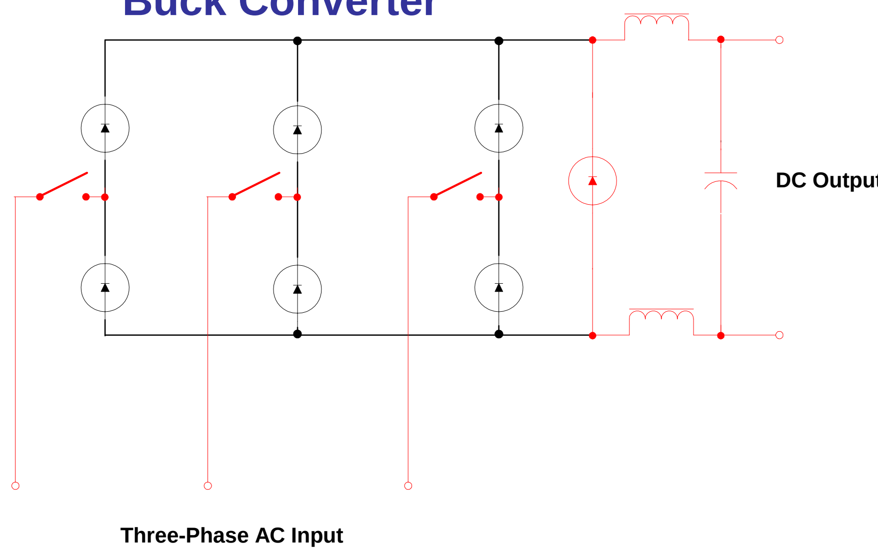
High Frequency Switch Mode Conversion

Two practical solutions, based on:

Boost Converter

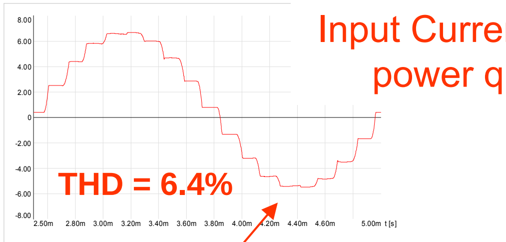


Buck Converter

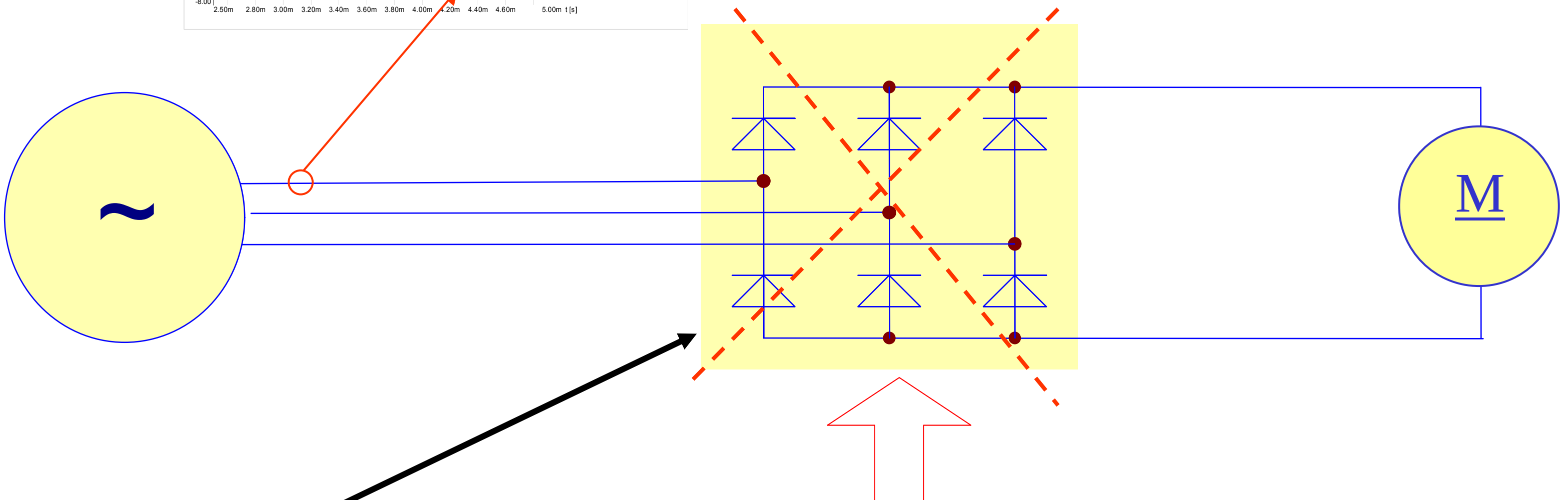


- Regulated DC Output Voltage:
  - 320 Vdc minimum (with 115 Vac input) - for boost converter
  - 230 Vdc maximum (with 115 Vac input) - for buck converter
- Meets Input Current Harmonic Limits
- Soft Start Ability
- Power Factor: 0.994–0.998
- Efficiency: 95–97 %

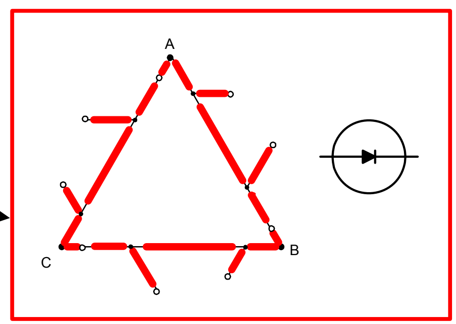
Multiphase Power Conversion



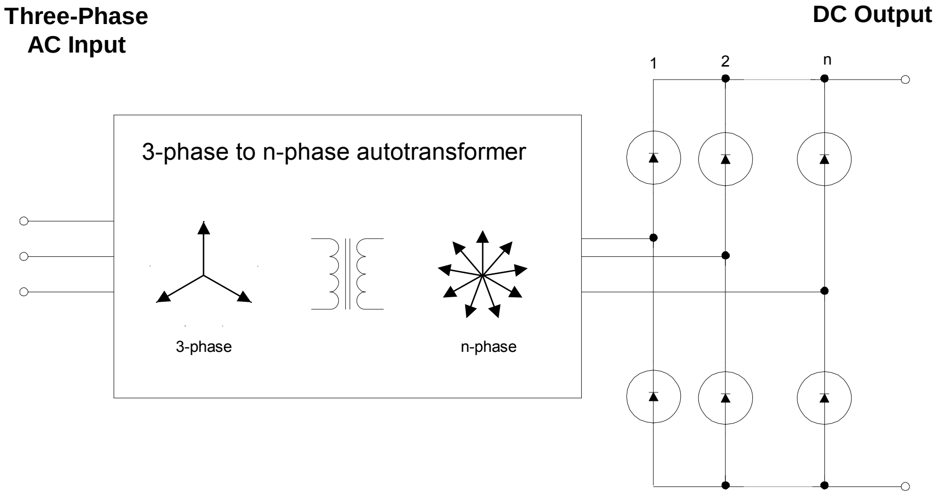
Input Current meets power quality



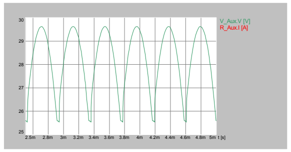
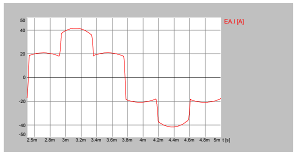
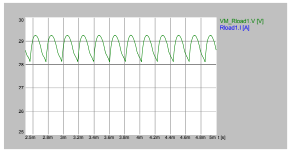
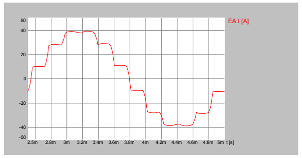
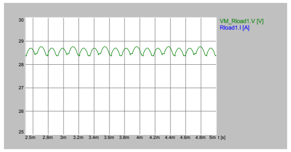
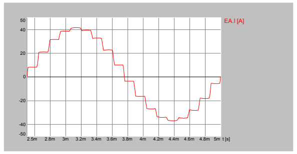
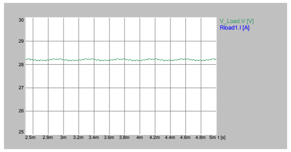
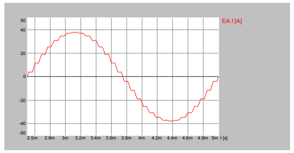
6-pulse rectifier being replaced by ATRU (18-pulse)



Multiphase Power Conversion

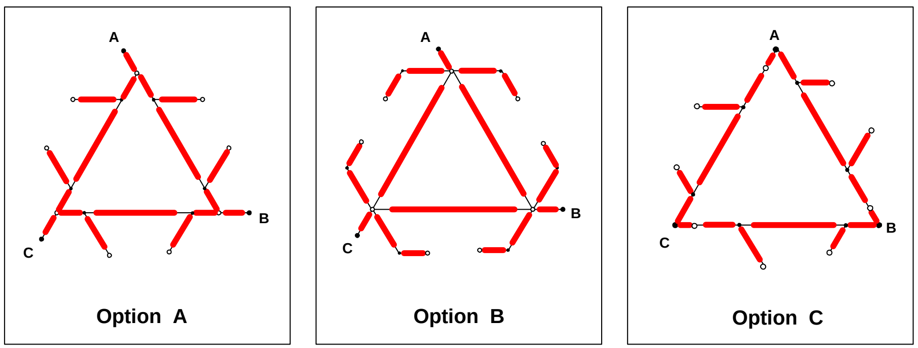


- Output Voltage: 270 Vdc nominal (with 115 Vac input); passive regulation
- Meets Input Current Harmonic Limits
- Power Factor: 0.980-0.990
- Efficiency: 96-98%
- Simplicity: low parts count; no need for energy storage components (C or L)

Design Approach	Output Voltage Ripple [%p-p]	Input Current THD [%]
6-pulse	14 	28-33 
12-pulse	3.4 	9-14 
18-pulse	1.52 	6-9 
30-pulse	0.55 	2.5-3.5 

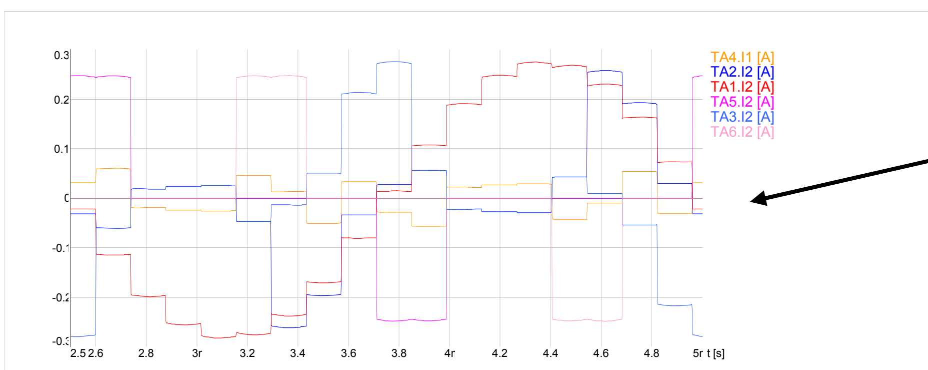
Design Example - Multiphase Power Converter

- 18-pulse autotransformer topology meets new harmonic limits – if designed correctly
- Some of available 18-pulse autotransformer options:



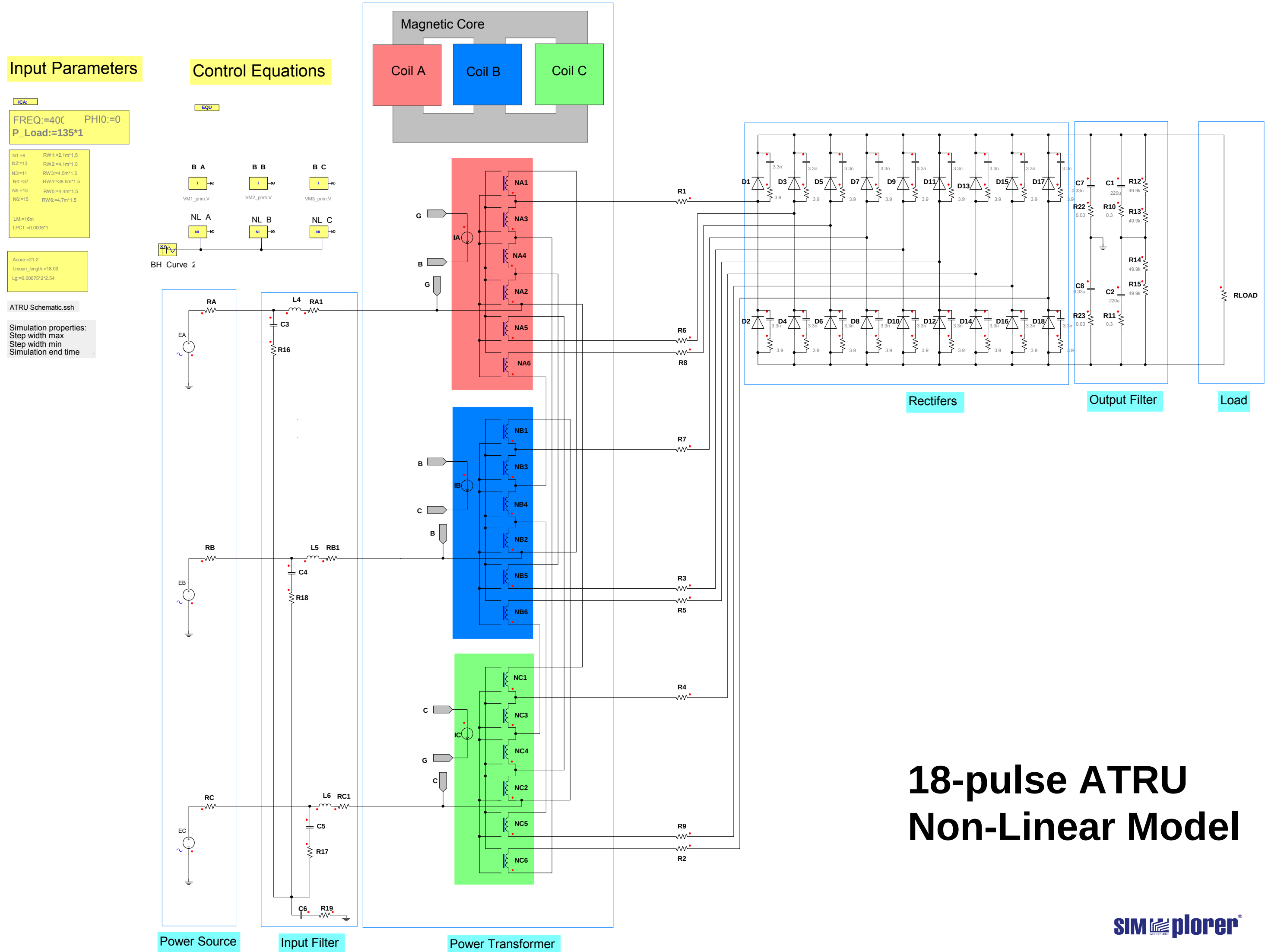
Autotransformer converts 3-phase input voltage into 9-phase output voltages (spaced 40 degrees from each other)

- It is almost impossible to analyze topology and optimize design without converter modeling and running simulations



Current waveforms in transformer windings become very complex

Design Example - Multiphase Power Converter



18-pulse ATRU Non-Linear Model

SIMplorer

Design Example - Multiphase Power Converter

Transformer construction challenges:

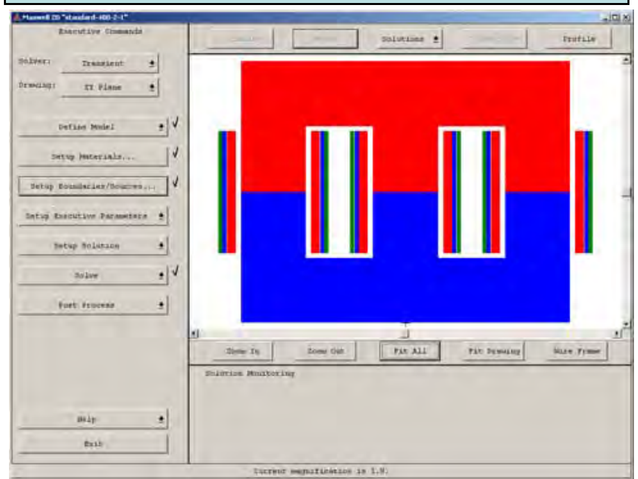
- Choosing winding material (copper, aluminum)
- Selecting conductor shape (round wire, square wire, foil)
- Defining and optimizing core geometry and aspect ratio
- Optimizing interactions between windings (leakage inductance, proximity effects)

- It is not practical to build and test each considered option
- Therefore, design iterations and optimizations need to be performed on computers

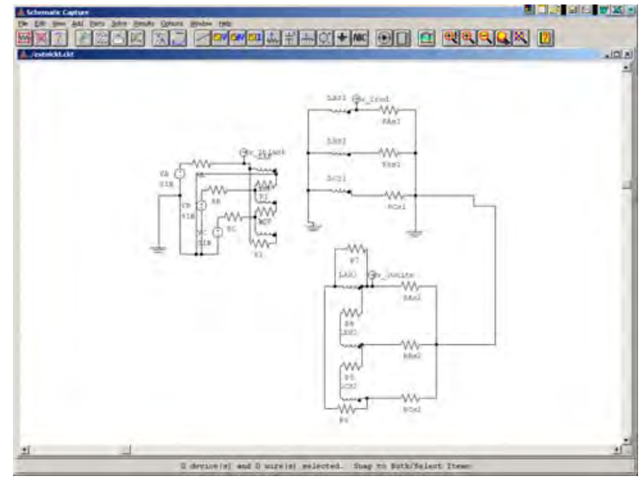
Design Example - Multiphase Power Converter

Transformer Construction Optimization:

Define core geometry and winding configuration



Convert geometry and materials into electrical parameters



Simulate performance

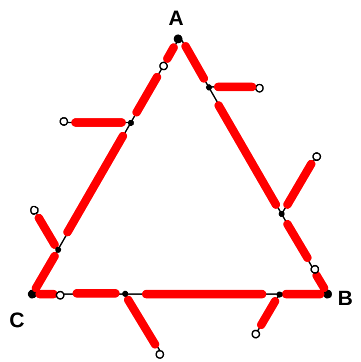
Core Losses
Winding Losses
Leakage Inductance
Regulation

Adjust and optimize

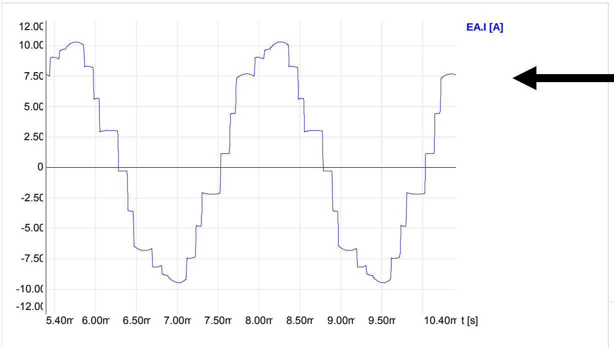
Design Example - Multiphase Power Converter

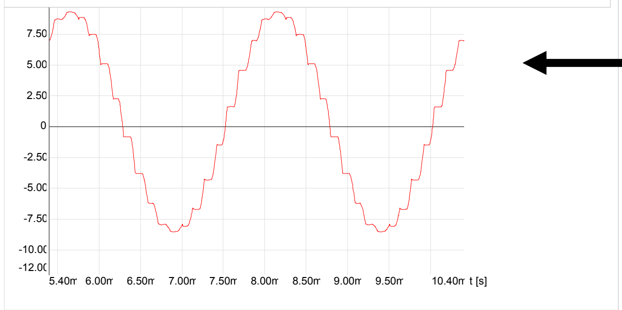
- Simulate converter performance and verify power quality

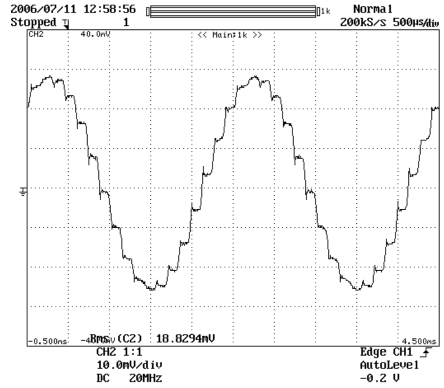
Autotransformer Configuration



Input Current Waveforms







Design

First Completed Design

Power Quality not met; several current harmonics exceed limits

Interactive Optimization

Optimized Design

All current harmonics within specification plus margin

Fabrication

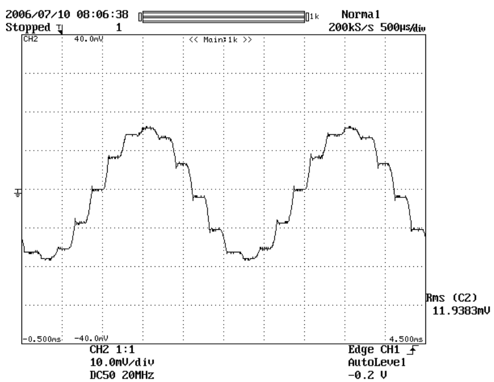
Completed Hardware

Performance correlates very closely with optimized design

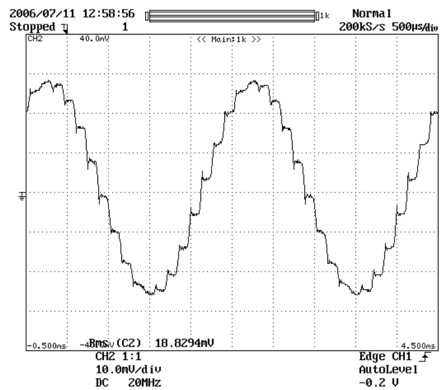
Performance Summary of Existing Hardware

Parameter	**Design A** Passive (12-pulse)	**Design B** Passive (18-pulse)	**Design C** Passive (30-pulse)	**Design D** Active (Boost)	**Design E** Active (Buck)
Output Power	4.5 kW	1.6 kW	8.6 kW	15 kW	5 kW
Input Voltage (nominal)	230 Vac	115 Vac	115 Vac	115 Vac	460 Vac
Output Voltage (nominal)	270 Vdc	270 Vdc	320 Vdc	400 Vdc	460 Vdc
Power Quality Meeting DO-160E ….Current THD Current Waveform	 Yes 11% Picture A	 Yes 6.4% Picture B	 Yes 3.3% Picture C	 Yes 3% Picture D	 Yes 3% Picture E
Power Factor	0.986	0.992	0.998	.990	.990
Output Ripple	15 Vp-p	12 Vp-p	7 Vp-p	3 Vp-p	10 Vp-p
Efficiency	95%	96%	97%	97.5 %	96 %
EMI Filter	No	Yes	No	Yes	Yes
Size	6” x 4.6” x 3”	7” x 2.6” x 2”	9” x 6” x 3.4”	11” x 15” x 3”	13.7” x 3.6” x 4”
Weight	5.5 lb	3.1 lb	10.2 lb	20.8 lb	6.7 lb

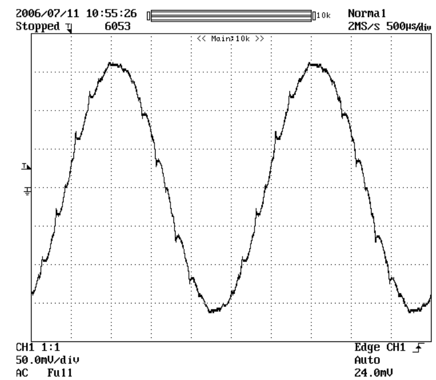
Input Current Waveforms of AC/DC Converters



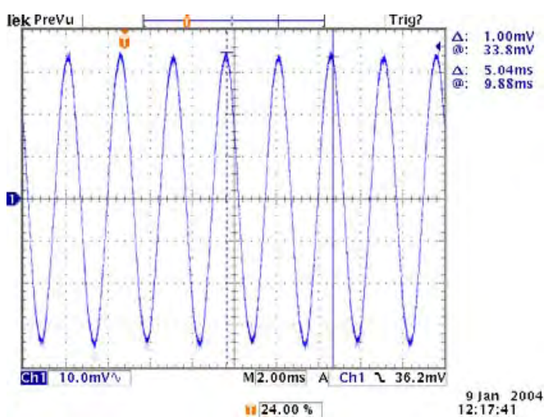
A) Passive, 12-pulse



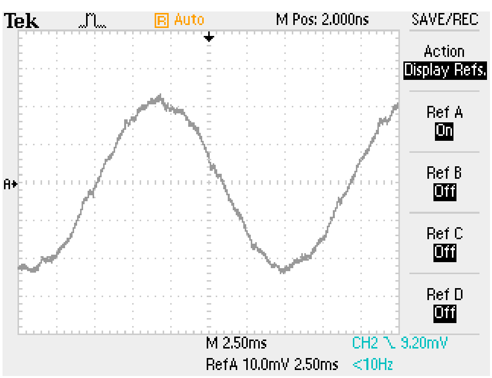
B) Passive, 18-pulse



C) Passive, 30-pulse



D) Active, Boost



E) Active, Buck

Comparison between Active and Passive Approaches

	Active Harmonic Reduction (Switch Mode)	Passive Harmonic Reduction (Multi-Phase)
Input Voltages	115 or 230 Vac	115 or 230 Vac
Output Voltages	150 - 230, 320 – 600 Vdc (without use of additional DC/DC converter) Is regulated over variations in line and load	150 – 600 Vdc (set by adjusting transformer turns ratio) Varies with line voltage and load
Harmonics	THD 3 – 7%	THD 3 – 12% (dependent on topology)
Power Factor	0.980- 0.998	0.980 – 0.998
Output Ripple	Dependent on output filter	Dependent on output filter
Efficiency	95 – 97%	96 – 98%
Soft Start	Available with existing design	Needs to be added on
Over-current Protection	Available with existing design	Needs to be added on
Cooling Method	Conduction, liquid or air	Conduction, liquid or air
Advantages	Precise output voltage regulation Output voltage can be adjusted Built in soft-start Built in over-current protection/current limiting The same unit can operate at 400Hz or 60Hz Significantly lower weight at 60 Hz	Simplicity No need for energy storage devices or control High reliability Typical MTBF - 250,000 hours Robust – accepts high overloads Lower weight at 400 Hz applications Lower cost
Disadvantages	Lower reliability High energy storage capacitor needed (Aluminum electrolytic) No overload capabilities Higher cost Gap in output voltage setting - Additional DC/DC converter is needed to obtain Voltage between 230 Vdc and 320 Vdc	No output voltage regulation Input voltage variations are passed to the output, plus about 4% voltage drop from no load to full load Additional DC/DC converter is needed to obtain full voltage regulation Presence of inrush current - basic design Additional circuitry is needed to shape input current

Existing Hardware Examples

1 kW Converter - 115Vac/270Vdc

5 kW Converter - 230Vac/540Vdc

8 kW Converter - 115Vac/300Vdc
(Fan cooled)

15 kW Converter -115Vac/270Vdc

135 kW Converter - 230Vac/540Vdc
(Liquid cooled)

CRANE AEROSPACE & ELECTRONICS

Conclusions

- Demands for electrical power on today's airplane are increasing
- Traditional, constant frequency power systems are being replaced by variable frequency
- DC brushless motor becoming the motor of choice on new airplanes – it requires DC power to operate
- New power conversion technologies are needed to fully meet recent power quality requirements – creating new challenges
- Effective simulation and optimization tools are critical in successful development of new generation aerospace power converters
- Two groups of technologies, capable of meeting new power quality requirements, are emerging: passive and active approach
- When unregulated DC voltage can be tolerated, multiphase conversion has a good fit in aerospace applications

More Information

- Crane Aerospace & Electronics, Power Solutions, designs, manufactures and supports products and capabilities via our brands: ELDEC, Interpoint and Keltec. We provide both Standard Power Products and Custom Power Products.
  - Standard Power Products consist primarily of our DC-DC converter and filter modules sold under the Interpoint brand.
  - Custom Power Products consists of our custom and semi-custom low voltage and high voltage power products and subsystems.
  - Our Power solutions meet the current and future needs of our customer's applications:
    - **Power for Electronic Systems** – Our full range of standard and custom products delivers compliant product performance, low cost of ownership and ease of integration thereby providing the lowest risk comprehensive solutions (Ex. Embedded low voltage power supplies)
    - **Power Distribution** – Low weight, high power quality and high efficiency platform power conversion, management and distribution. We can provide significant weight and volume savings through integrated power conversion, bus control and power control. (Ex. TRUs, ATRUs, etc.)
    - **Electronic Warfare & Radar** – Solid-State or traveling wave tube (TWT) based low/high voltage, high power products and subsystems for mission critical defense platform and payload applications (Ex. TWT amplifiers, high power / high voltage power supplies, etc)
    - **Energy Storage** – Delivering safe integration of energy storage devices into electrical systems while providing the longest maintenance interval and service life at the lowest weight. (Ex. Battery systems, battery charger/controller, batteries, etc.)
    - **Motor Power Conversion and Control** – High power quality ac-dc converters as standalone solutions or as part of an integrated electric drive motor package (Ex. ATRUs, active PFC converters, etc.)
- Information: www.craneae.com
- Technical assistance: Kaz Furmanczyk, Principal Engineer
  - Tel. 425-743-8106; e-mail: Kaz.Furmanczyk@crane-eg.com

Crane Power Solutions

Questions?

- Conversion, protection, monitoring
  - Milliwatts to megawatts
    - Custom and off-the-shelf
      - Module, SRU, LRU, integrated sub-system

USN Maritime Surveillance Power requirements for Future Distributed Netted Systems

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SPAWAR Systems Center – Pacific

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Distributed Netted Systems (DNS)

- **What is a Distributed Netted System?**

Outline

- USN & Renewable Energy Sources (RES)
- How RES Change the Game
- Constraints of DNS
- Types of Ocean Energy and associated pitfalls
- Past and Ongoing Industry/Academic Efforts
- Ongoing Search for New Power Solutions

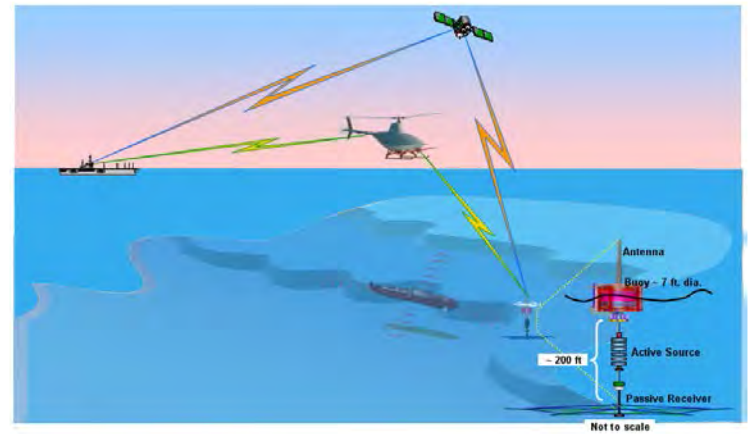
USN & Renewable Energy Sources (RES) It Makes Sense

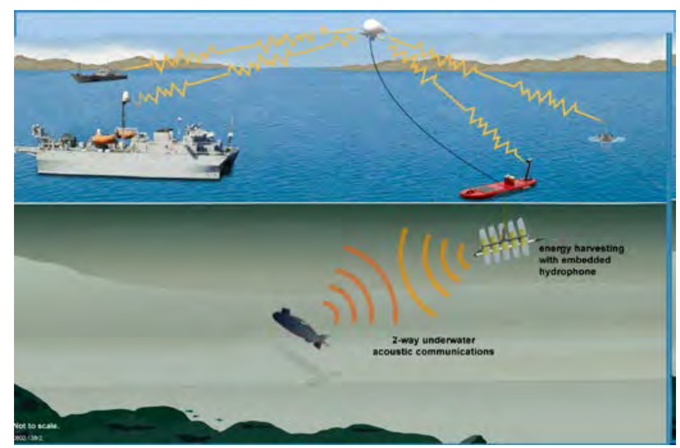
- **Navy Pushing for Renewable Power Sources – Multiple Directives**
  - The Department of the Navy Objectives for FY2008 and Beyond
  - Energy Policy Act of 2005
  - National Defense Authorization Act for Fiscal Year 2007
  - Presidential Executive Order 13423
  - Energy Independence and Security Act of 2007
- **Ocean Energy is a Current Thrust for Consideration**
  - Legislative Definition of Renewable Energy

Renewable Energy sources can be GAME CHANGING for Distributed Netted Systems

How RES Change the Game

- **DNS are Battery Centric**
- **Versus batteries, the hope is that RES yields:**
  - ↓ Cost
  - ↓ Size
  - ↓ Weight
  - ↓ Certification Cost
  - ↓ Disposal Costs
  - ↑ Life
  - ↑ Safety





Power is the limiting factor in DNS lifespans

Constraints of DNS

- **Power needed at the Distributed Sensor Node**

<table>
<tr><td>Passive</td><td>5 Watts</td><td rowspan="2">Continuous Power</td><td>Seafloor Node</td><td rowspan="2">Months - 1 Year+</td></tr>
<tr><td>Active</td><td>20 Kilowatts</td><td>Surface Node</td></tr>
</table>

- **Inherently, DNS are driven to be:**
  - Disposable
  - Inexpensive
  - Rapidly installed
    - **Compact** for ease of transport/overboarding
  - Resistant to harsh ocean environments/fouling
  - Resistant to Tampering
  - Long Shelf-Life

Types of Ocean Energy

- Wave
- Thermal
- Tidal/Ocean Current
- Wind
- Solar Energy
- Fuel Cells
- New Power Solutions

Ocean Energy - Wave Energy

- **Issues to be addressed - Wave Energy Converters**
  - Narrow frequency response
    - optimal power generation only in specific wave conditions
  - Size of systems
    - grow significantly with amount of power demanded
    - potential hybrid configuration to reduce size
  - Significant surface/water-column presence and moving parts that are highly susceptible to fouling/tampering.

Wave Energy Converters show promise

Ocean Energy - Other

- **Thermal/Tidal/Ocean Current**
  - Require more permanent installations
  - To date: size, weight, deployment issues don't make a good fit for DNS
- **Wind/Solar Energy**
  - Good if there is surface presence
  - Hybrid only
  - Presents a challenge with respect to fouling/tampering
  - Drag Considerations for station keeping

Past and Ongoing Industry/Academic Efforts

- High Energy Density Batteries
- Ocean Power Technologies (OPT) wave energy buoy
- Teledyne Wave Energy Harvester
  - **DARPA / Teledyne**
- Renewable At-Sea Power Program
  - **DARPA / MBARI**
- Microbial Fuel Cells
- Liquid Robotics
  - **Wave Energy to Motion**
- Lithium Sea Water Batteries – Higher energy density, increased safety

New Power Solutions

- **SPAWAR needs industry assistance**
  - Searching for innovative power approaches

- **Variety of Applications**
  - Sensors
  - Unmanned Underwater Vehicles
  - Unmanned Surface Vehicles
  - Station Keeping Buoys

- **Questions?**

Energy & National Security: An Exploration of Threats, Solutions, and Alternative Futures

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Approved for Public Release October 9, 2008

***Abstract* – Findings of multiple Department of Defense (DoD) studies and other sources indicate that the United States faces a cluster of significant security threats caused by how the country obtains, distributes, and uses energy. This paper explores the nature and magnitude of the security threats as related to energy—some potential solutions, which include technical, political, and programmatic options; and some alternative futures the nation may face depending upon various choices of actions and assumptions. Specific emerging options addressed include Polywell fusion, renewable fuel from waste and algae cultivation, all-electric vehicle fleets, highly-efficient heat engines, and special military energy considerations.**

FOREWORD

This paper presents the professional opinions of the author. While some may disagree over the implications of energy to national security, the fact remains that the Department of the Navy (DoN), the DoD, and the nation face what may be the most significant challenge of this time: how to ensure the security of our energy sources within the limits of technology, policy, budgets, and national will. This paper encompasses a review of the various energy issues and potential technological solutions. Inherent in this essay are policy implications. It is not the intention of the author, DoN, or DoD to propose these solutions as "the right" solution. Rather it is the intention to discuss them in light of the technological challenges facing their implementation.

The Naval Surface Warfare Center, Dahlgren Division is currently initiating the Asymmetric Energy Solutions (AES) project directly designed to assist the DoN and DoD in addressing these complex energy issues. The Asymmetric Defense Systems Department will be addressing these issues through AES by exploiting the current capabilities of that department, the Dahlgren laboratory complex, other Navy laboratories, and other public and private entities, including academia. AES will identify energy security technology options relevant to the DoN and DoD, including naval global platform support options and naval infrastructure support options.

The author intends to provide insight into the national and international energy challenges, and address them from a DoD perspective. In today's interconnected world, energy source, generation, and application technologies cannot be addressed in the single light of DoN and DoD requirements. However, by combining the international, national, and defense issues in this paper, the author hopes to highlight in the mind of the reader their interdependency, which must inform the holistic energy solution. Advances in DoN and DoD technologies and acquisition strategies can directly and indirectly affect the national and international markets. DoD fiscal investment in research and development, and technology purchasing is extensive and can be determinative in promoting timely deployment of technology. As in the past, DoD's technological advances will find their way into the commercial market in some fashion.

OVERVIEW

The Energy Security Challenges

The United States faces a cluster of significant security threats caused by how the country obtains, distributes and uses energy. The issues that directly confront DoD threaten the U.S. military strategically, fiscally, and operationally. However, in the larger context of national security, the United States faces potential economic hardship, with combined recession and inflation, and a growing drain of wealth needed to acquire imported petroleum, consequences of human-and/or-nature-made power disruptions to wide areas, and environmental consequences of energy production and use. The combined threat equals any the nation has ever faced. However, currently available solutions could within years, not decades, substantially mitigate the threat.

These solutions can improve military capability with reduced cost, thwart terrorism, contribute to world stability, mitigate climate change ramifications, and create a new economic prosperity both in this country and internationally. The future of the United States and the world depend on the nature and tempo of the solutions selected by the country—its institutions and its leadership, both public and private. The United States consumes a quarter of the world's oil produced daily. The U.S. actions related to energy dominate the course of the world. The military is the single biggest consumer and purchaser of energy in the United States and can have a significant impact on solutions picked and tempo of implementation.

This paper is intended to provide insight for both the military and national discussions on energy alternatives. To accomplish this objective, it explores the nature and magnitude of the security threats, as well as some potential solutions that are representative but cannot be exhaustive given the breadth of subject; and suggests a way ahead to a more secure future.

Surveying the Energy Security Landscape—
An Executive Summary

Energy issues loom large in national and global discussions on economics and national security. Multiple Defense Science Board (DSB) studies report that U.S. military forces are inefficiently designed, cost more than necessary, and are constrained in operational capability because energy requirements are not accurately and integrally incorporated into overall requirements generation and materiel acquisition analysis. The cost of military operations balloons as the price of oil rises. The effective loss in spending power in a year from the doubling of oil prices from last year equals about $8 billion for DoD. This 1-year fuel expense could buy eight Arleigh Burke destroyers or more than 20 F-22 Raptors.

The military and the broader national security community confront the economic drain of importing oil. Since 2007, the price of oil has doubled to a historic high; food prices soar, and the growth of food crops for fuel is blamed; inflation is ignited attributed (to some extent) to the rising price of fuel, which touches everything; while reflection on the Katrina hurricane disaster and gas price spikes from hurricane Ike's influence shows how little oil production and refinery-capacity margin exists in the world. The effect of rising energy cost negatively impacts the entire economy and further drains the resources the United States needs to maintain military capability.

National security hinges not just on military power projection, but protection of energy infrastructure at home and outside of the United States as well. The DoD contends with this responsibility. Incidents such as terrorist attacks and weather-related disasters point to vulnerabilities of the energy infrastructure.

Today, use of petroleum determines a nation's standard of living and level of military power. Some potential bottlenecks threaten access to this energy source. The United States relied on petroleum for about 40% of its total energy requirement of roughly 101 quadrillion Btu (British thermal unit) in 2007. Petroleum imports accounted for about 70% of U.S. total petroleum consumed. China and other emerging industrial nations will inevitably demand more energy, and the total quantity for the United States to consume will be eroded. A significant engineering debate exists over whether the relatively inexpensive oil, which civilization has come to rely on, can still be produced. Some experts project that the world has already or will soon pass "peak oil" production, after which, oil will become more and more expensive to produce and a rarer and rarer commodity.

Exploration of new reserves around the United States is expected to provide additional years of crude production. However, the Department of Energy (DOE) projections indicate a 7- to10-year lead time from exploration of a new reserve until product flows to the consumer. This fact suggests that near-term petroleum access to meet a growing demand means buying more imports. Even if availability of crude oil were assured, availability of processed petroleum product may be constrained because of a dearth of refining capacity, which emerges from the growing world demand for products and the failure of industry to invest in this low-profit-margin side of the business.

Add to the above one more wrinkle—the environmental effects of fossil fuel use. In June 2008, the U.S. intelligence community reported to Congress "wide-ranging implications" to national security due to climate change across the planet. The testimony responded to the most recent report published in 2007 of the Intergovernmental Panel on Climate Change (IPCC), which asserts that fossil fuel use is the principal cause of global warming. Although neither endorsing nor negating that position on causation, the testimony to Congress accepted that global warming and climate change is happening and must be addressed. According to the testimony, the United States can expect to suffer tens of billions of dollars in damages from severe weather, and loss of productivity and heavy tolls for fixing and replacing infrastructure. Intensified storms will threaten many nuclear facilities, oil refineries, and other energy infrastructure, especially along the Gulf Coast. Exteriorly, the United States will face a rising need for humanitarian and stability operations. The worldwide ramifications could cost in the range of 3% of annual global GDP as climate change continues through the century. These anticipated events directly challenge DoD's ability to defend the nation and supply international help when tasked by the President.

Energy security challenges abound. However, significant emerging technological opportunities can address and perhaps eliminate most of these problems and substantially mitigate others.

1. The military can use its consolidated purchasing power to encourage rapid development and deployment of alternative energy, and implementation of efficiency measures. The DoD can save money, enhance mission assurance of military facilities, reduce or more effectively reorient force structure, and provide greater operational capability by adapting its requirements-setting and acquisition processes to specifically and fully address its energy consumption. The DoD can, in effect, increase its force acquisition budget by decreasing its fuel budget. The federal government, as a whole, can likewise use its research development investment, its purchasing power, and its policing authority to foster rapid deployment of technology and processes to alleviate the security risks from current energy-use strategies.

2. The military gains greatly from increasing vehicle efficiency by increasing the operational range of vehicles, reducing demand for logistics investment, and reducing the force structure and mission requirement to defend logistics forces. By DoD's investing to do so, the entire nation gains. The amount of U.S. petroleum imports roughly equals the total U.S. fleet consumption of petroleum by cars and trucks. The United States imports about 70% of its petroleum product consumption. Car and truck engine fuel efficiency for most operation sits around 25%.

Among the many options available to DoD and the country, here are some possibilities:

a. Outfitting the U.S. vehicle fleet with emerging-technology engines, which achieve over 50% efficiency, would cut petroleum use and import requirements in half. Example engines are discussed in this paper.

b. Using hybrid-electric vehicles could raise the fuel efficiency even higher and provide a deeper reduction in oil imports.

c. An all-electric vehicle fleet, which could be recharged from non-petroleum-based electricity sources would completely eliminate the need for imported oil. Electrical storage solutions such as that offered by the company EEStor's new ultracapacitor are discussed. Current electricity power production infrastructure could accommodate the switch to electric vehicles and hybrids.

d. The DoD has the purchasing clout to influence rapid development and deployment of high-efficiency vehicles. The DoD action would enhance national security in multiple ways, from enabling greater operational capability for the military, to mitigating some infrastructure vulnerability, to national economic advantage in using domestic energy and potentially creating new domestic business and jobs.

3. Assured access to fuel is a must for the military and the nation. Fossil fuels are finite commodities, which do not regenerate in a time period meaningful to consider them as renewable fuels. However, a host of renewable alternative fuels are being produced today.

a. Alcohols, such as ethanol and butanol, are generated by bacteria or catalysis.

b. Diesel, gasoline, and others, such as 2.5-dimethyl furan, are generated by chemical processes, such as Fischer-Tropsch (FT), or biological processes.

c. Various technologies can turn waste into fuel, thus addressing two problems.

d. Algae, the original source of petroleum, can be grown to produce specific types of fuels, including diesel and gasoline, and can be used as a feedstock for other processes to produce artificial petroleum products. Algae produce prolifically and in dense concentration so that enough fuel product from algae could be produced in open ponds in an area of 25,000 square miles (which is the approximate combined size of San Bernadino and Los Angeles counties in California) to replace all U.S. petroleum needs. Other techniques that require building some industrial infrastructure can reduce that land-size requirement by a factor 10 or greater. Algae grow virtually anywhere. The United States could replace the entire world need for petroleum with algae products from an area four times the size of that just described. Various renewable and synthetic fuel options are discussed herein.

4. The DoD, and especially the DoN, could benefit greatly from the potential of nuclear power. But nuclear fission power is expensive and presents ongoing safety concerns. A spin-off from a form of nuclear fusion developed in the 1960s by Farnsworth and Hirsch has achieved groundbreaking success recently. This Polywell fusion device was pioneered and scientifically demonstrated in 2005 by Robert W. Bussard. This type of fusion can use boron-11 and hydrogen as the fuel. Fusion of these elements produces no neutrons and no radioactive waste. Estimated cost to build a Polywell electric plant is less than that for a similar power-producing, combined-cycle gas plant or coal plant. A gigawatt-sized reactor would be a sphere about 15 meters in diameter. If all power for the United States were generated with boron-11 and hydrogen Polywell fusion, the total yearly requirement for boron would be less than 5% of current U.S. boron production and would cost less than two trainloads of coal at current prices for both commodities. A single coal plant requires a trainload every day for full-scale operation. The U.S. Navy could adapt such devices to ship propulsion and free ships from the tether of petroleum use and logistics. The Polywell device could enable very inexpensive and reliable access to space for DoD and the nation as a whole.

5. Solar and wind power offer potential relief for DoD's and the nation's infrastructure security vulnerability. Emerging technical capability, and dropping prices in solar photovoltaics and wind-power generation may enable distributed-power production and reduce security vulnerability from monolithic production and distribution methods currently in place. The U.S. wind and sun resource is vastly greater than the required energy for the United States. Cost and industrial-base production capability drive the speed of implementation. However, with sun- and solar-power proliferation comes the need for efficient, cost-effective electricity storage. Many storage options exist, but they confront cost, size, reliability, and safety factors.

a. In 2008, wind power is still about 60% more costly than electricity from coal plants. Solar power is over twice as expensive as wind power. But the technologies are improving, and the costs to produce power are plummeting. The potential from such sources for distributed power—which removes customers and facilities from dependence on the grid—is, in itself, a huge security boon that could help alleviate issues associated with infrastructure vulnerability, while also decreasing energy demand on limited-quantity fossil fuels.

b. Photovoltaic power could be particularly valuable to the military. Especially as conversion efficiencies increase, the military could use high-energy lasers to deliver power to unmanned vehicles and other remote locations. All-electric or rechargeable hybrid vehicles with high-density storage could stay deployed or engaged in mission indefinitely as long as they could replenish from time to time by laser via their photovoltaic arrays. Emerging approaches to photovoltaic technology suggest the possibility of 80% conversion efficiency per cell. An interesting synergy might derive from using a new Massachusetts Institute of Technology (MIT) window-light-gathering unit combined with these highly efficient converters to provide a compact power array capable of double duty. Most of the area the window occupies on the surface of a vehicle possibly could be used as an aperture for sensors and communications arrays.

In summary, the energy security threats are diverse and potentially severe; potential solutions are diverse and very powerful. Different scenarios for the future unfold depending on what options for energy technology the nation (and world) exploits and how aggressively the options are pursued. These scenarios vary widely: from extinction of mankind; to the end of industrial civilization; to creating extreme hardship across the globe with a severe population crash; to a very unstable international peace, with resource wars, famine, and severe weather change rocking humanity. A feasible future could also be a new global prosperity based on abundant clean energy, which enables abundance of other resources.

EXAMINING THE NATURE OF THE THREATS

Military Energy Issues

The DoD Office of Force Transformation and Resources commissioned a 2007 report on the DoD energy strategy, which identified the Department's issues in terms of "disconnects" between DoD goals and practices as follows:

"*Strategic: DoD seeks to shape the future security environment in favor of the United States. But our dependence on foreign supplies of fuel limits our flexibility in dealing with producer nations who oppose or hinder our goals for greater prosperity and liberty.*

Operational: DoD's operational concepts seek greater mobility, persistence, and agility for our forces. But the energy logistics requirements of these forces limit our ability to realize these concepts.

Fiscal: DoD seeks to reduce operating costs of the current force to procure new capabilities for the future. But with increased energy consumption and increased price pressure due to growing global demand for energy, energy-associated operating costs are growing…

Environmental: In parallel with the increase in the global demand for energy is an increase in concern about global climate change and other environmental considerations. Therefore, when identifying technical solutions to its energy challenges, DoD should also consider a fourth disconnect—environmental ." [1]

The DSB commissioned two Task Forces which developed separate reports: one in 2001 [2] and one in 2007 [3], to examine DoD's energy strategy. According to the DSB 2007 Task Force report issued Feb 2008, current U.S. military's energy strategy risks both operational capability and mission performance. Additionally, in the 2008 final report, the Task Force warned of military installation vulnerabilities from potential commercial power disruption and inadequate backup power.

The 2008 DSB report indicates that the military suffers from unnecessarily high fuel consumption, which compromises and constrains its operational ability, its tooth-to-tail force structure. How the military operates with regard to fuel use and delivery creates opportunities for a threat to degrade or blunt U.S. force operations, provides the threat a large target in the energy-delivery logistics force, and demands a high financial cost over the life cycle of DoD's materiel. The Task Force also concluded that military installations worldwide "are almost completely dependent on a fragile and vulnerable power grid, placing critical military and Homeland Defense missions at unacceptable risk of extended outage."

Further, the report indicates that DoD does not have the modeling tools, strategy, policies, metrics or governance structure to effectively manage its energy risks. It noted that DoD has not heeded the 2001 Task Force's findings, nor implemented the 2001 recommendations. Specifically, the 2001 Task Force reported that DoD's requirements and acquisition processes do not value or reward energy efficiency, nor reduce logistics. According to the study, DoD does not attempt to use efficiency in energy or other aspects of logistics to guide development of solutions to provide military capability. As a result, DoD sacrifices potential military capability, which the services could have bought had they not needed to invest in force structure and infrastructure to make up for the lack of energy efficiencies. Efficiency does not necessarily equate to less capability, but rather can equate to increased military power at reduced cost and risk. The 2001 Task Force recommended that ACAT I programs, the largest defense acquisitions, establish energy efficiency in the key performance parameters and that trade-off analysis use "Fully Burdened Cost of Fuel."

Currently, in DoD's systems acquisition trade-off studies, the acquisition community uses the current "cost at the pump" that the Defense Energy Support Center (DESC) would charge for on-site purchase for a gallon of fuel, rather than the Fully Burdened Cost of Fuel, which includes delivery of fuel to the operational platform or unit. This practice means that cost for fuel would be considered perhaps $4.00 per gallon of jet propulsion (JP) fuel rather than the delivered cost of perhaps 10–20 times that much, plus the force-structure cost for the logistics units, the security force to protect the logistics units, and the potential casualties to those forces that may occur as they bring fuel to the tactical units. Using the notional "price at the pump" produces vastly distorted acquisition decisions.

The Task Force found further systemic behaviors in DoD that stem from this energy indifference. DoD under-invests in

Science and Technology that could yield reduction in logistics and increased efficiency. DoD has not implemented procedures that reduce needless energy consumption and reward efficiency achieved by operators. The services could buy off-the-shelf technology that would reduce energy consumption. Both long-term and near-term options exist. However, no organizational accountability exists to ensure energy efficiency, nor optimized logistics. The Task Force considers DoD energy problem so significant that it merits an immediate $500 million/year program to address the issues and appointment of a DoD senior coordinating official for energy.

The 2007 DSB study included many expert briefings and site visits, with many insights revealed. Not all of the information presented in these briefings and discussions could be distilled in the final report, and some information presented below may fit that category. The following data points from the study suggest the dimensions of the problem, but also point to remedies.

1. Eighty percent of all U.S. materiel shipped in and to the Iraq forces was fuel. Ninety percent of the fuel trucked to remotely deployed forces in Iraq and Afghanistan was used to air-condition uninsulated tents. Long caravans of fuel trucks required to deliver the subsequent heavy fuel loads become vulnerable to an improvised explosive device or other guerilla attack. If the tents were insulated to cut down on fuel use, heavy-lift helicopter delivery or parafoil air-drop of the remaining small fraction of the current shipments could conceivably replace the truck caravans otherwise needed. Using less fuel could save lives.

2. Most of the fuel consumed by DoD is JP fuel. Close to 50% of that JP is consumed by fuel transport planes to move fuel where it is needed. The 2001 DSB study indicated that if tactical aircraft, such as the B52, could extend their range by 30%, they would reduce air refueling requirements, and thereby eliminate the demand for part of the air refueling fleet. In addition to the fuel, the logistics aircraft investment could also be saved. The 2007 Task Force discovered that high-performance aircraft engines are being developed that could provide that 30% efficiency. With fuel efficiency, a key performance parameter in future aircraft design, unrefueled aircraft range could extend beyond—perhaps well beyond—an extra 30%.

3. The M1A2 main battle tank gets about 4 mpg (miles per gallon) as its 1500 horsepower turbine moves the 80-ton vehicle. However, much of its fuel is used by its crew to keep the environmental and other systems running when the tank is not rolling (i.e., 0 mpg). Turbines can be extremely efficient at a specific design load, but tend to be extremely inefficient otherwise. The DoD could replace the large, thirsty turbine with high-efficiency, off-the-shelf diesel engines to increase gas mileage. Auxiliary generators could reduce the fuel drain by the crew when the tank is parked.

The Task Force's yearlong investigation uncovered these and other illustrations of DoD's current lack of fuel policy and identified means to address the problems. Key findings state that DoD has "no unifying vision, strategy, metrics, or governance structure" to deal with energy issues, and current information gathered about energy is insufficient to make good decisions. The DoD has no current simulation mechanisms to wargame fuel issues or strategically plan fuel requirements. Therefore, DoD has no structural mechanism to systemically or systematically address the problems. However, the study concludes that many options exist to solve energy issues, including more efficient platforms and engines, conservation processes, and alternative fuels for assured fuel access. DoD problems mirror broader U.S. issues, and DoD actions could enable or promote solutions to national energy challenges.

The DoD problem is large but has largely been ignored. In worst-case scenarios, DoD expects to get priority access to U.S. energy resources. The DoD—the biggest single user of energy in the country—uses about 300,000 barrels of oil per day compared to the 21–22 million barrels of oil per day used by the United States as a whole. The United States produces about 30% of the oil it consumes from domestic sources. The military, in case of sudden disruption of all imports, could obtain enough fuel to operate with only a small portion of domestic production.

Assured access (or not), DoD pays a heavy price for fuel. Every $10.00 increase in a barrel of oil costs DoD over a billion dollars per year. Manpower, operational tempo, reconstitution, and acquisition are threatened by dependence on volatile international fuel prices. The "energy tether" to tactical forces is a military Achilles' heel and, in its own right, must be addressed. However, the military energy problem faces an additional problem of the potential disruption of critical military infrastructure.

Infrastructure Vulnerability

Largely, DoD has assumed that local power grids will provide needed power to support national security missions. Backup power plans consider only limited-duration (a few days at most) interruptions in service from the grid. Examples of large-scale power outages caused by natural calamity or systems overload suggest that DoD must develop a new approach. Further, the threat of coordinated terrorist disruption of power through physical or cyber attack and the potential for disruption of the flow of energy producing resources mandates that DoD reevaluate and redesign power access to mission-critical facilities.

Although DoD has analyzed installation vulnerabilities, it has not been able to consistently fund and implement mitigations. The 2007 Task Force strongly recommended that DoD get a firm understanding of risk management and power outage consequences. The report suggested various mechanisms to better ensure power access, including conservation; on-base, power-generation options; and grid islanding. One particularly notable point from the report is the possibility of natural or human-induced widespread power outages, which could endure for months or even years, and which could be very difficult to recover from if mechanisms for recovery were not well developed and implemented in advance. A classified annex to the 2008 Task Force report discusses this vulnerability subject in greater detail. This is not just a DoD problem. National security demands intelligent planning and action by national leadership to address the threats, which include acts of war, terrorism, or natural catastrophe—all of which could prevent oil production, distribution across the oceans, and potential infrastructure destruction or disruption in the United States [4].

Even with a larger U.S. domestic crude oil supply, a refinery bottleneck could continue to drive prices higher and create shortages of refined products. A 2005 report by ICF Consulting [5] predicted that to keep pace with growing demand for refined products, the already strained world refining capacity needed to grow at least 8 Mbbl/day (million barrels per day) (about 9%) by 2020. Refining is a low-profit-margin part of the oil business. It entails significant operation expenses, maintenance, and environmental issues. The United States has not built a new refinery since the 1970s. The shutdown of refineries as a result of hurricane Katrina and the subsequent product shortages demonstrate that the “Refinery Capacity Crunch” is upon us.

Infrastructure vulnerabilities must also be examined in the light of global climate change warnings. Severe storms, especially around the Gulf Coast; new patterns of drought in the west; and heavy rains in the east could reduce crop production; cause mass migrations; or threaten or actually destroy infrastructure such as oil refineries, nuclear power plants, and transportation means. The Intelligence Community’s 2008 testimony to Congress warns that the United States will need to plan for tens of billions of dollars of infrastructure repair, replacement, and upgrading. Tropical diseases previously not a threat to the homeland could invade and become pervasive as the climate warms. The financial cost would likely result in 3% annual decline in world GDP for years. A 10% total decline in GDP is defined as a depression [6].

However, both Task Forces indicate that DoD could substantially enhance its performance by acting with awareness of its reliance on energy. The 2008 Task Force made several specific technology recommendations in that regard—principally aimed at building aircraft that delivered longer range and better performance per fuel required. Overall, the studies concluded that DoD can improve its ability to provide national security and world stability at reduced cost by:

- Making energy performance part of the key performance parameters in acquisition programs,
- Using Fully Burdened Fuel Cost in analysis of alternatives,
- Incorporating full costs of logistics into military requirements development and acquisition processes,
- Incentivizing personnel to be energy efficient,
- Promoting immediate adoption of more energy-efficient processes and procedures in operations both at the tooth and the tail,
- Acquiring more fuel-efficient off-the-shelf systems,
- Investing in science and technology to provide better performance versus fuel use and logistics needs,
- Directly addressing grid-reliance vulnerabilities, and
- Requiring less fuel and logistics to achieve desired military performance

National Economics and Resource Availability

The United States’ dominant military power flows directly from the ability of the U.S. economy to resource national defense and international military engagement. The national security of the United States is based on its national economic viability and its economic competitive prowess and success. National economics is a crucial DoD interest and a determinative limitation on DoD capability. Assurance of energy resource availability to sustain national economic prosperity is a crucial DoD responsibility. A multifront war—both on the battlefields of Southwest Asia and potentially importable within our own borders—warns us of potential catastrophic energy-distribution disruptions. The U.S. need for foreign oil grows, but the leadership and/or cultures of nations that sell the United States large quantities of oil often do not share American ideals of pluralistic democracy, personal freedom, and equality of opportunity.

As reported to the DSB Task Force, petroleum experts indicate that although the world’s discovered oil reserves are enough only for the next 40 years, that situation has always been such for at least a century simply because it is not economic for the oil industry to find more than 40 years of oil. So the arguments are raised that the oil production-consumption imbalance is not a threat, but just an artifact of the free market and the flat world.

America has not produced enough oil for itself since the 1970s. Since that decline, members of OPEC discovered that they could manipulate international oil prices. A 25% reduction in Mideast oil production after the Yom Kippur War and an embargo against the United States caused prices at the pump in the United States to quadruple [7, 8]. In the late 1990s, the price of oil was under $20 per barrel. The price per barrel of oil in 2006 was around $65.00, in early 2007 in the low $70s. In 2008, oil passed $140 per barrel. At least one market analyst says that since oil is a commodity on which people speculate, double that price is totally conceivable. Another analyst, Henry Groppe, suggests that the current oil prices are just a bubble [9]. However, he believes that the new low for oil prices is going to be higher than $70 per barrel, and that natural gas prices will likely rise by a factor of two or three.

Some economists blame the current high oil prices on a monetary issue—the weak dollar. Whatever the impetus may be, rising oil prices are a direct threat to international economic stability. Further, as pointed out by Jason Henderson in *The Main Street Economist* [10] increased fuel price means increased food price, and growing fuel crops rather than growing food further creates food price inflation.

However, world oil production may have already peaked. Arguments and evidence in books—such as *The End of Oil* by Paul Roberts and *Twilight in the Desert* by Matt Simmons—strongly suggest that there are no new large oil reserves to be discovered and tapped [11]. The current mother lode of oil in the world is Saudi Arabia, and using the best technology available, the Saudi production has not increased much. Additional oil, such as Canadian tar sands and Venezuelan heavy crude, cannot be produced in quantity to make up for the decreasing production in other fields. Access to oil is not just a political or even technological issue, but a matter of the resource being a fundamentally limited commodity. The price of oil must therefore increase even if the United States could start producing all of its current oil needs. The Energy Information Agency (EIA) in a March 2004 report—*Analysis of Oil and Gas Production in the Arctic National Wildlife Refuge* [12], indicates that after exploratory drilling of a new reserve begins, significant oil production from that field does not come to market for 7–10 years. As an example, the expected oil reserve in the Arctic would provide approximately 1 year's worth of total U.S. consumption spread over a couple decades starting about 10 years after drilling begins. Of course, that amount of oil equates to over a trillion dollars in market value to the companies that get to sell the oil, but it really does not do much at all to sustain the U.S. economy or security. The Gulf of Mexico offers several times as much oil—again, not a long-term solution and too distant in time to help with the oil flow for over a decade. The world oil market will drive the price up and cause reduced use—eventually.

So, why not use our "vast" quantities of coal to provide both electrical power and via such technologies as FT convert coal to liquid fuel? More will be discussed later on FT, but problems hit from multiple directions—cost of FT facilities, cost to the environment or additional cost of fuel from sequestration, energy inefficiency of FT, and resource commodity constraints. There's only so much coal, and if you use it at a greater rate, it disappears rather quickly before the end of the century. With 263 billion short tons of reserves, the United States has about 225 years of domestic coal, but converting coal to fuel would more than double that consumption rate [13].

Given the over 13 Mbbl/day imported in 2007 by the United States [14], each $10.00 increase in price per barrel equates to about $50 billion from U.S. pockets given to other countries including Venezuela, Saudi Arabia, Russia, and Nigeria. And, of course, these funds can not be spent in this country for medical care, infrastructure improvement, education, or military reconstitution. As previously mentioned, the biggest single spender in the United States for energy is the Defense Department, which uses over 300,000 barrels a day. A $70-increase per barrel since last year, if sustained for 12 months, equals about $7 billion, which could buy two Sea Wolf submarines or half of an aircraft carrier.

The military challenge to assure national energy access must be met to ensure national economic security. The economic threat of potential oil-import interruption is so important that it must be reiterated and elaborated upon. Energy enables our cars to get us to work; our trucks and trains to transport goods; our farms and factories to produce our food and goods to live; our water systems to run; our home and industrial appliances to heat, to cool, to clean, to maintain, to build, and to light; our grocers to maintain food in refrigeration for distribution; our computers to provide information and automation; our air transports and air traffic control to function; modern universities to educate; industry, academia and government laboratories to create new knowledge and technological innovation; doctors and medical facilities to use modern medical procedures and equipment; the ability to develop and produce modern necessary materials, such as plastics, fertilizer, and pesticides; and our military to defend us and help secure world peace and economic opportunity for the world. Our society, our economy cannot function without a ready, affordable, and adequate supply of energy [15]. Oil use correlates directly with standard of living and military capability. Two nations with the largest economies in the world—China and the United States—already rationalize this into their international policies [16].

As of 2007, about 70% all petroleum products used in the United States went for transportation. The United States imported about 70% of its total petroleum consumption [14]. These numbers and their implications are discussed in detail in Appendix A. Diagrams 1 and 2 [14] in Appendix A illustrate this "big picture" on U.S. energy flow and petroleum consumption. The bottom line is that security and DoD mission are linked directly to this oil import reliance, and DoD can have a major impact on reducing or even eliminating this reliance.

As previously noted, the DoD Office of Force Transformation and Resources 2007 special report on energy strategy [1] specifically noted the environmental aspect of energy use as one of the four "disconnects" in current DoD energy use. The DSB 2008 report on energy strategy also mentions environmental implications in DoD's addressing its current energy challenges. Dr. Thomas Fingar, speaking for the U.S. intelligence community, reported to Congress in June 2008 the potential implications of climate change to national security [6]. The United Nations' IPCC 2007 report [17] documents scientific consensus, which accepts fossil-fuel-use-induced climate change. It is this climate change that the intelligence community's testimony to Congress addressed. Top military and intelligence advisors are announcing for the record that the consequences of climate change also threaten national security. Prudent planning suggests that DoD and, more broadly, the total U.S. command authority must consider as a key national security issue the effects of global climate change [18].

Many challenges could confront the United States in terms of stability operations and international humanitarian need, as well as potential internal homeland support in which DoD would likely have to engage [6, 17–19]. The United States could face multiple, simultaneous potential international crises around the world, which could range from rescuing natural disaster victims, to helping to keep peace within resource-challenged nations, to augmenting security in key resource nations, to peacekeeping among nations, and more. Even countries with nuclear weapons, such as India and China, could square off against each other in resource wars provoked by climate change. The shape and size of the U.S. military force structure could be profoundly affected by the size and quantity of direct military engagement needed and by the level of homeland defense requirements emerging from climate change.

Economic loss to the country directly impacts the nation's ability to provide self-defense, lead the international community, assist in stability operations, support human rights abroad, defend our allies, and provide international humanitarian assistance. The economic realities of energy access and consumption loom large over national security. For a comprehensive quantitative look at energy consumption and use challenges, see Appendix A, which contains statistics and implications of those statistics, as well as definitions for a number of energy-related unit measures.

Summary of Vulnerabilities and Threats

Responsible access to energy could be the single largest U.S. strategic security issue short of full-scale nuclear war. The threats of nuclear or biological weapons terrorism do not offer the same broad-scale impact to U.S. national security as the combined energy problems. The rise of a hostile military equal, if it should happen, is decades away. The energy-use challenges are pervasive and current.

The solutions to the total energy problem involve economics, technology, politics, industrial-base development, and, very likely, unintended consequences. Multiple solutions are being proposed and pursued. Some are perhaps ill-advised and even counterproductive. However, many good options exist to make the United States energy independent and more secure, as well as making DoD much less energy-tethered—and responsibly so within years, not decades. Changes in energy strategy for the nation and DoD can enhance military readiness and cost effectiveness, boost the national economy and general welfare, as well as drastically cut carbon emissions, which can help mitigate the impact of climate change [18].

EXAMINING POTENTIAL TECHNICAL SOLUTIONS

The Shell Oil Company recently published a "Dialogue with the Country" [20] in which it cites people's opinions about the energy crisis and gives a twelve-step program to address the problem. The publication says that as in any self-help program one must first admit that one has a problem. Given the current rise in fuel prices and concurrent political rhetoric, and actions of private citizens, perhaps the United States has accomplished step 1.

Alternatives to Foreign Oil & Methods to Mitigate Climate Change

What technological options then are available to relieve petroleum reliance? Some technologies are mature but need significant investment and nurturing to establish an industry. Some technology is at the level ready to prototype, but still needs substantial investment to prototype and then follow-on funds for years to develop the industrial base. Some technology is still in investigation but could be more rapidly developed with a focused financed effort. Some technical approaches are not ready or are simply the wrong path from a holistic perspective of providing national energy independence with financial and environmental responsibility. Some solutions are not so much technological as industrial, social, managerial, and political in nature. A broad front of solutions is definitely called for.

The advantages and disadvantages of several important solutions are examined below to demonstrate both readiness and appropriateness. This section addresses several major solution areas. Because of the breadth of these subjects the discussions are not exhaustive. Specific technologies—which can contribute to a given solution or perhaps broadly across solutions—are discussed in the "Technical Options" section.

More Efficient Fuel-Burning Engines for Vehicles

Less consumption is the best possible alternative if one can get equal performance. From looking at the fact that 80% of materiel supplied to Iraq and Afghanistan theaters was fuel, DoD can identify fuel savings as a focus for reducing logistics needs, the force that goes into providing those needs, and the forces required to protect the logistics forces. For the military, the true cost to provide a barrel of fuel to deployed forces, which includes the fuel required to deliver fuel, is as much as five times the "cost at the pump" [2]. If DoD can deploy vehicles that have much larger range for a given fuel requirement, it can achieve a new advantage in maneuver warfare. This can be accomplished by cutting recurring fuel expense and thus freeing assets to acquire additional advantage in operational performance. More efficient, tactical fuel use and, thus, significantly reducing fuel consumption, has a multiplicative positive effect.

A DoD investment in higher efficiency vehicles can have broad, positive effect in the homeland as well as on the battle field to reduce all aspects of the energy challenge. Virtually all U.S. vehicles run on petroleum products. The vast majority of this petroleum comes from outside the United States. Oil is rapidly and simultaneously becoming both a commodity in greater demand and greater scarcity [11]. Before the United States hit peak oil in 1970, a single barrel of oil from West Texas provided enough energy to produce 30 other barrels of oil, but oil used versus produced from the Gulf of Mexico is on a one-to-five ratio [21].

As previously noted, the U.S. transportation sector consumes roughly the equivalent of all imported petroleum products. Transportation is a great "target of opportunity" to introduce technology innovation; i.e., internal combustion engines (ICEs) and external combustion engines, including turbine-drive vehicles. But ICEs (mostly gasoline) drive most vehicles and they achieve only 20–25%, or less, energy efficiency [22]. As a thought experiment, imagine a row of ten 1-gallon cans of gasoline for your car, and then throw eight of those in the garbage. That's what our ICEs in effect do. We use 2 gallons out of 10 and throw the rest away. If current engines could be replaced with extremely high-efficiency engines, which are 2 or even 3 times higher in efficiency, the demand for imported oil could be cut at least by half. Vehicle engine inefficiency is determinative in petroleum demand.

Current ICEs, diesel or gasoline powered, are not even close to the theoretical maximum efficiency. Even current car fuel cells have only about 35% efficiency [23]. Immediate replacement of the U.S.-land-vehicle-fleet's ICEs with 50% efficient engines would cut petroleum consumption by over 6 Mbbl/day, eliminate the delivery costs and delivery security issues, mitigate/eliminate refinery processing shortfalls and bottlenecks, and save the U.S. economy over $260 billion a year in import costs (at $120 per barrel).

Because today's car engines run at about 20–25% engine efficiency, incrementally raising engine efficiency by 25 or 30% saves less than 10% of national petroleum use. The United States needs 200–300% efficiency improvements to make substantial progress toward energy independence and carbon emission reduction. Plug-in hybrids, fuel cells, radically improved-efficiency heat engines, and all-electric vehicles powered by batteries or ultracapacitors offer this level of magnum leap in conservation without having to sacrifice performance. Example heat engines, fuel cell, and electric vehicle technologies are discussed in under "Technology Options." The examples and options discussed are not intended to be exhaustive, but rather indicative that much can be done and done quickly.

The U.S. vehicle fleet is huge and replacement will not happen quickly. The United States has over 250 million vehicles on the road [24]. Yearly, the United States replaces around 8% of the fleet. Even if the country started a 2009 "crash" program allowing new purchases only of high-efficiency vehicles (if industry could affordably provide the product), fleet replacement takes until 2021. However, if complete replacement of vehicles—or at least their engines—with 50% efficiency engines were achieved, the United States could eliminate 6 Mbbl/day of oil from the current 20.7 Mbbl/day demand. The reduction could eliminate almost half of the U.S. daily petroleum imports. Apart from the other financial and potential climate benefits of this reduction, U.S. oil-refinery capacity would not have to increase. DoD could save force structure and fuel cost, and enable expanded operational performance if vehicle range could double with a doubling of energy efficiency and, consequently, halving the fuel-logistics requirement for such vehicles.

High-efficiency, affordable engine replacements can be achieved in the near future. Industrial base considerations could inhibit producing and fielding tens of millions of new, high-efficiency engines needed for the entire U.S. fleet, but DoD investment can drive expanded production and reduced cost. Raw material production and transport, production line development, safety qualification, public acceptance, and other factors play in determining how quickly the car and truck fleet could migrate to high-efficiency engines. Government support can boost their rapid production and deployment through mandatory fuel standards, carbon emission reduction mandates, and tax benefits to producers and consumers. DoD development and acquisition can accelerate how increasing oil prices will promote conservation-enabling technologies, such as the high-efficiency fuel burners.

All-Electric Vehicles—Beyond Burning Fuel in a Vehicle

DoD is already developing hybrid-electric vehicles, but also can promote and take advantage of all-electric vehicle technology, which could be an enabler in building unmanned vehicles that can stay on mission for greater duration. The all-electric tactical vehicle for DoD, with today's technology, may have limited application, but that may soon change [25–27]. However, in projecting possible future capability and in considering the broader security implications for the country, DoD could serve itself and the nation well by investing to promote such technology.

The best mechanism to reduce petroleum consumption in vehicles, and the cost and logistics that go with it, is to not use petroleum in vehicles. All-electric cars can run on stored electricity from any source, including hydroelectric, geothermal, nuclear, photovoltaic, wind, burning biomass, or whatever. Electric motors can typically achieve 90% efficiency [28]. Electric motors can drive cars, trucks and, potentially, even aircraft. An all-electric-motor fleet would use only about one quarter of the energy required by the current U.S. land vehicle fleet and would not need petroleum. Electric vehicles themselves do not emit greenhouse gases. Electric power plants needed to charge the vehicles could run on renewable or nuclear power from domestic and, perhaps, environmentally benign sources.

Even today, electricity storage technology for all-electric vehicles is sufficient to meet the commuter needs of most Americans. Cost of electricity storage today is comparatively high. However, considering only fuel use, using electricity to power vehicles costs less than burning petroleum-based fuels. Oil prices soared over $140 per barrel in 2008, and gas at the pump exceeded $4.00 per gallon. Electricity is still cheaper if oil were only $20 per barrel. Electric cars, which recharge overnight during off-peak hours, use what equates to less than 50 cents per gallon fuel.

Currently, the ICE Btu are import-petroleum based. Electric Btu can come from U.S. resources. According to the Economist magazine, wind power could provide 20% of grid power in 20 years (but that may be substantially accelerated), and the solar power industry grows by 50% per year [29]. Exciting breakthroughs in electrical generation technologies from fusion power have only recently been reported [30–32]. The electric-vehicle fleet melds well with the growing alternatives for grid power production.

Even with today's electrical infrastructure, the homeland could accommodate at least a 70% switch to all-electric, light-duty vehicles [33]. Currently, most U.S. electrical power production comes from over 500 coal-fired plants and from natural gas plants. Diagrams 3 through 5 [14] in Appendix A show the U.S. source-to-use flow of natural gas, coal, and electricity. In 2006, coal provided 50% of U.S. electric power production, natural gas about 17%, petroleum, nuclear about 20%, and renewables (including hydroelectric) about 10.4%. The United States holds about 260 billion tons of domestic coal reserves. With efficient coal-to-electricity conversion, these supplies could provide additional power for high-efficiency electric cars and not exhaust the domestic coal supply as quickly as conversion of coal to liquid fuel would.

Can the current electric power infrastructure meet the additional demand of an electric fleet? A 2006 DOE study [33] conservatively projected that over 70% of the light-duty vehicle fleet of cars, SUVs, and vans could be powered from the existing electrical power production and distribution infrastructure time, if the vehicles were plug-in hybrids charging on off-peak hours. Different regions of the country have different levels of margin, especially depending on how power is produced. The Pacific Northwest appears to be the least adaptable, and the Northeast and South are particularly adaptable to using an off-peak power margin to charge electric vehicles. The power system is designed for peak loads, which according to the report, only occur a few hundred hours every year. The nation averages about a 16% margin in electrical production capacity over peak loads. Because the electric vehicle fleet would not instantly spring into existence, the electricity infrastructure should have time to adapt.

Until electrical storage endurance improves or fuel-cell technology improves, the all-electric vehicle might meet limited DoD mission needs. However, electric vehicle technology is here and readily deployable. The companies FEV Global and Raser Symetron recently showed off their proposed electric hybrid drive train, which would provide 100-mpg capability to a full-sized SUV [27]. Additionally, others are already developing electric-hybrid efficiency for DoD. DoD can be a principal enabler in reducing the cost of electrical storage by using its huge development and acquisition investment resources.

In the broader U.S. economy, the all-electric vehicle today has sufficient capability for most family uses, with greatly reduced energy-consumption cost. Cost of in-vehicle electrical storage is still an issue, but is being worked along multiple technical paths. Electric hybrids are proliferating and improving in cost and performance. Research and development in batteries, capacitors, fuel cells, and superconducting-coil-storage systems offer multiple avenues for breakthroughs, as well as continued incremental progress.

Electrical storage performance will improve. Cost will drop. An all-electric-vehicle fleet offers the potential to eliminate U.S. foreign-oil dependence and mitigate geopolitical tensions, eliminate the need for extra petroleum refineries (~8 Mbbl/day deficit in the next decade), decrease operating costs for vehicles, improve vehicle reliability and lifetime, reduce military logistics burden and save lives, eliminate fossil-fuel based carbon emissions in the atmosphere, and increase domestic jobs and economic opportunity. Economics will produce an all electric fleet. A government-encouraged market would make it happen faster.

Synthetic and Renewable Fuels

The Air Force has programs to demonstrate that renewable and synthetic fuels can power jet airplanes [34–37]. The Naval Research Advisory Council in 2005 recommended synthetic fuels as the way ahead to assure military fuel needs. The military needs high-energy density in its platforms for performance and endurance. Renewable fuels can deliver those capabilities without using imported or domestic petroleum. According to Department of Transportation statistics [24], the government as a whole used about 6.3 billion gallons of vehicle fuel in 2006, of which about 3.89 billion gallons were DoD JP and aviation gas, and 1.7 billion gallons were DoD diesel use. With this level of demand, DoD can establish a market and, thus, the industry to produce fuels from domestic sources and, in the process, provide the pathway to imported petroleum independence for the whole country.

In the summer of 2008, the airline industry was particularly hard hit by the high price of fuel. JP fuel accounts for roughly 75% of DoD vehicle fuel consumption—though that JP comes in a couple of varieties and is used in more than just aircraft. DoD is a big consumer. Although one may argue that cars and even trucks can be made all electric, as of today, long-range aircraft used by airlines cannot be made all electric. A renewable fuel industry and the airline industry make a good match [38]. DoD and the airline industry can help each other with investments to help birth an assured source for domestic, high-quality jet fuel.

Although most auto and truck engines run on diesel or gasoline derived from petroleum, vehicles could burn a wide variety of fuels from nonpetroleum sources. Economics of rising petroleum prices should drive development of a U.S. synthetic/renewable fuel industry. However, past fluctuations in world oil prices have severely hampered development of such an industry. Illustrative of this effect is the 1999 report by the DOE National Renewable Energy Laboratory (NREL), which reported both the high potential for the use of algae as a renewable fuel source but also that the project was cancelled because oil prices had dropped below $20 per barrel and *were projected to stay low for the next 20 years* [39].

Synthetic fuel research and development projects proliferate. Each product-process pair has benefits for specific utility. Dozens of companies stand ready to produce and deliver synthetic/renewable alternatives to petroleum-based fuels. If DoD (and/or other federal agencies) by high-volume, long-term contracts provided a price floor for the product, the market could drive full development of the synthetic fuel industry. Ideally, the best of breed will flourish. See Appendix B for a discussion on business model and market influences in regards to development of a new fuel/energy industry.

The DOE lists about a dozen alternative fuel options, such as ethanol, butanol, green diesel (diesel from renewable sources), biodiesel, and hydrogen. Not all alternative fuel options are environmentally and economically benign. The United States must be careful not to induce negative, unintended consequences when producing petroleum alternatives, such as Michael Grunwald reported in his article, “The Clean Energy Scam” [40]. Using staple food crops, such as corn or soy bean, and using the high-quality farmland to the exclusion of growing food in order to produce renewable fuel, have significant negative consequences. Although ethanol from corn offers many farmers new financial gain, consequences threaten in higher food prices and potential food commodity shortages. Even if all the U.S. farmland were planted with corn for ethanol production, the United States would be hard-pressed to replace its current petroleum use with the resulting ethanol. However, ethanol from cellulosic plants grown in marginal soil might be a potential boost to the fuel supply but will still require huge areas of land.

Although replacing all food crop production in the United States with corn or soybean growth for ethanol would not provide sufficient synthetic fuel to replace the 21 Mbbl/day demand for oil, an area about 250x100 miles (equivalent to a 12.5 mile strip spanning the length of the U.S.-Mexican border) of algae production could provide synthetic fuel equivalent for the U.S. energy needs [39]. DoD action could guide the nation forward

Synthetic products (from crops that grow on marginal land, from algae, from waste, from sewage, from coal, and from natural gas) have the potential to completely replace U.S. petroleum consumption and end U.S. energy-import dependence, while enabling the United States to share excess energy with needy countries. Proper government incentives can prevent use of high-quality cropland (and crops) to produce fuel, ensure a price floor to synthetic fuel so that the synthetics will begin to predominate and eventually replace petroleum, and prevent expensive and environmentally damaging approaches to producing synthetic fuel.

The DoD, or the federal government in a wider action, could ensure a price floor for synthetic/renewable fuel that would give investors and entrepreneurs the needed safety net to invest and build the synthetic fuel industry. In addition to whatever energy consumption the United States can avoid through advanced efficiency measures or increased domestic petroleum production, synthetic fuels can remove the U.S. bondage to imported oil. Renewable synthetic fuels offer not only U.S. independence, but also a potential domestic fuel produced in enough quantity to export. The additional source of renewable energy offers a wider global security. Renewable fuels offer an environmental bonus since they can eliminate new atmospheric carbon emissions.

A special case of renewable and synthetic fuel options relates to the concept of creating a hydrogen economy. In this concept, hydrogen would become the fungible energy storage and exchange mechanism for potentially all or most sectors from military to industrial to commercial to residential to transportation. The hydrogen would be made by some high-efficiency means, stored, and distributed or perhaps produced in a distributed fashion so as to avoid the technical challenges of storage and distribution. Other such whole-economy solutions have been suggested. But there are problems.

Hydrogen is the most plentiful element in the universe and exists in vast quantities combined with oxygen as water in the world’s oceans. Hydrogen for energy storage or as an energy carrier interests because of its high energy-to-mass ratio as shown in Table 1. Also, when it is used in an engine or fuel cell it does not directly produce pollutants or problematic greenhouse gases. Hydrogen is at least notionally producible by all countries of the world. For DoD to make wide-scale use of hydrogen as fuel, it would have to find some processes currently unavailable to efficiently produce this fuel at the site of use and/or find a mechanism to make it volumetrically more energy dense and easily transportable, and less potentially dangerous as a target of attack, since hydrogen gas is explosively flammable. Also, in the broader context of U.S. national needs, these and other problems of hydrogen fuel present themselves.

Can the various problems for the hydrogen economy in production, distribution, storage, and final energy use be overcome? One kilogram of hydrogen can produce more than three times the amount of energy that a kilogram of gasoline or diesel will produce when they are burned. A hydrogen fuel cell has theoretically much higher efficiency than an ICE. Compactly stored hydrogen used in fuel cells operating at over 80% efficiency might provide a path to conserve energy, provide several factors increase in platform endurance for military vehicles, and potentially eliminate (certainly mitigate) carbon emissions to the atmosphere. Research may provide an enabling breakthrough

Table 1. Fuel Energy Comparisons

Fuel	Megajoules/kilogram	Megajoules/liter
Hydrogen	143	10.1-liquid hydrogen
	143	5.6 -700 bar compressed
	143	.01079 – room temp& bar
Liquid Natural Gas	55	25.3
Propane	49.6	~26.8
Butane	49.1	~26.8
Gasoline	46.9	34.8
Aviation Gas (not JP)	46.8	33.5
Diesel	45.8	38.6
Jet Fuel (JP)	43.8	35.1
Gasohol (Ethanol 10%)	43.54	28.06
Biodiesel	42.2	37.8
Coal	32.5	72.4
Butanol	36.6	29.2
Ethanol	31.1	23.5
Methanol	19.9	17.9

in mass production, storage, and distribution. However, at this time, technical readiness level appears to not support marshalling a national program to implement a hydrogen economy. The newly published MIT discovery in catalytic production of hydrogen from water turns into the best possible result: it would enable a solar/electric economy with residential hydrogen storage [41, 42]. However, even with this technology breakthrough, DoD and other users of hydrogen in vehicles and by industry would still be problematic.

Other metallic, molecular, or phase-change energy-carrier mechanisms (e.g., zinc, aluminum, compressed air, ammonia, hydrogen peroxide, and liquid nitrogen) have been proposed that would somewhat emulate the hydrogen economy concept. Each would be used by various mechanisms (e.g., batteries, fuel cells, and heat engines) to produce energy and be recycled or produced by some other prime power (e.g., nuclear, solar, hydroelectric, and geothermal). These other economy concepts in general are significantly less well thought out and less well financed in research than the hydrogen economy [43–45].

The United States need not wait for solutions to the hydrogen or similar "economies" problems. Other renewable fuel options appear achievable both in the near term and with bright promise for the long range. What specific government actions can help? From the DSB Task Forces' reports and related discussions, the energy strategy report for the DoD Transformation Office, and sources such as the National Resource Defense Council and others the following are synthesized [1–3, 46, 47].

DoD, as a normal course of business, strives—through various mechanisms, including contracting and acquisition—to maintain and/or develop the U.S. industrial base that supplies DoD and enables the country's military strength. DoD consumes more fuel than any other single user in the nation. Fuel industrial base is crucial to DoD. DoD accounts for over 90% of total federal government fuel use even thought the Postal Service uses almost as much gasoline as DoD. DESC, as fuel acquisition hub for the federal government, could be instrumental in developing a renewable fuel industry that provides the standard of fuel required by DoD at an ensured, consistent price, which is both favorable to the government and develops and maintains this new industry. The government could ensure a floor-price for all domestically produced renewable fuel. However, this action might require that the government be the purchaser of last resort and eventually mandate the use of government fuel stocks to distribute to gasoline stations. Since the Defense Logistics Agency's (DLA's) Defense DESC contracts for all fuel used by the government, DLA could contract for acquiring all government fuel with the following stipulations:

a. Define required fuels to encourage competition from synthetically produced diesel, jet fuel, aviation and motor gasoline, and fuel oil. Do not compromise on fuel performance standards or systems compatibility—the providers would have to deliver high-quality fuel, which the DESC would certify.

b. Purchase domestic nonpetroleum fuel production from domestic sources, which could be renewables, coal, or natural gas.

c. Encourage carbon neutrality in the production and use of the fuel, which will reinforce the industry to produce more renewable fuel and/or carbon reuse/sequestration when sources such as coal and natural gas are used. Discourage the use of food crops and food-crop farmland in production of the fuel. Encourage the use of marginal or usually nonarable land or even marine agriculture in renewable fuel production—such as growth of switch grass, seaweed, and algae for fuel production.

Broader government actions to encourage industrial base development might include mandating more stringent fleet fuel efficiency for automobiles and trucks sold by manufacturers in the United States. Mandates against carbon emissions with fines against vehicle owner-operators would hasten fleet renewal. Tax credit incentives for purchase of very high-efficiency ICE and electric vehicles and hybrids would push rapid fleet replacement.

As suggested by the DSB Task Force and mentioned previously, DoD could establish an Office of National Energy Security with the duty and resources to set energy use requirements on all future systems and facilities, as well as mandate retrofit and Planned Program Product Improvement for substantial energy conservation. The office could be supported by a laboratory or consortium of government labs and industry resourced through that office on a project-by-project basis to produce prototypes specifically designed to make DoD more energy efficient and petroleum independent. The $500 million/year recommended by the DSB would be sufficient to run this office and support labs. Establishing this office would not violate the law of bureaucracy that ensures that any bureaucracy established to end a problem will never achieve that goal so as to stay in existence. This office would serve more as a combination police department and venture capital office to ensure DoD adheres to energy goals and encourages efforts to achieve them.

Nuclear Power Options

Three technologies usefully exploit nuclear energy today. Radioisotope thermoelectric generation produces isotope-decay-generated heat and has been used in space probes, pacemakers, and lighthouses. Hirsch-Farnsworth nuclear fusion reactors fuse deuterium to generate neutrons, but they have not yet been demonstrated to produce net power. For more on half-life fusion, see the nuclear fusion section under "Technology Options." The third type, nuclear fission reactors, is based on a controlled chain reaction of neutron emissions from uranium, plutonium, or thorium. All nuclear power plants and naval vessel power are nuclear fission reactors [48, 49].

In a prime example of DoD leading the way in technology deployment, the U.S. Navy pioneered the use of nuclear fission power in the United States. The first U.S. naval vessel powered by nuclear fission, USS *Nautilus*, put to sea in 1954, 3 years prior to the first U.S. commercial fission-powered reactor went on the grid in Pennsylvania in 1957 [49]. In a 2008 action, Congress has mandated that the next-generation cruiser, the so-called CG-X, will be nuclear powered.

Enormous amounts of power can be generated by very small amounts of uranium, plutonium, or thorium or fusion materials, such as deuterium. Estimates indicate that enough of the heavy elements are mineable or can be produced in breeder reactors to power civilization for at least hundreds of years—tens of millions of years in the case of fusion materials. The United States has access to sufficient domestic supplies of uranium through the 21st century and perhaps as long as 1500 years. Nuclear power does not directly produce carbon emissions. Wide-scale replacement of current fossil-fuel driven power generation with nuclear power could mitigate carbon-emission-based climate change and perhaps help other nations with energy shortages.

However, wide-scale use of nuclear energy to replace fossil fuel presents complex problems. The 2003 MIT cross-disciplinary study, *The Future of Nuclear Power* [50] recommends maintaining the nuclear fission power industry as a viable option specifically to reduce the effects of carbon-emission-induced climate change. It cites three other potential mechanisms to mitigate carbon emissions: improved efficiency in use and production of electricity; renewable energy sources; and, carbon sequestration from fossil-fueled power plants. Not intending to exclude or rank any of these choices the report recommends nuclear fission power expansion only because it is an additional path to carbon- emission reduction. The report cites four major obstacles to expansion of nuclear fission power: cost, safety, proliferation, and waste.

Nuclear power by itself does not directly replace most U.S. use of petroleum. Nuclear power plants could eliminate the demand for the 30 quads of fossil fuel (mostly coal and natural gas) that the United States burned to produce electricity in 2007, but only 0.72 quads were petroleum [14]. Nuclear-generated electricity could power the electric-vehicle revolution which, as previously discussed, could eliminate foreign oil need. Also, nuclear power's ability to efficiently produce mass amounts of hydrogen gas could enable help to usher in a hydrogen economy, if hydrogen's other issues could be resolved. The extremely high-temperature (800–1000 °C) designed reactors can very efficiently produce hydrogen from water.

Nuclear fission plants are not the only option for nuclear power. Apart from the standard tokamak/ITER nuclear fusion research that DOE has pursued, a brand of nuclear fusion pioneered by Philo Farnsworth in the 1960s and augmented by Dr. Robert W. Bussard may provide a power-producing fusion plant by 2015.

Other than through nuclear weapons or solar radiation, mankind (to date) has been unable to obtain net energy from nuclear fusion. Potentially fusion can produce more energy than fission with none of fission's problems of fuel source, waste products, or weapons proliferation. Fusion of a mass of deuterium and tritium (the easiest fusion to accomplish) yields three times the energy produced by fission of an equivalent mass of U-235. Light-element fusion does not produce the extremely long-lived nuclear waste of heavy-element fission. High-energy neutrons, released by the tritium-deuterium fusion, impact the fusion-containment material and can make that material radioactive. With proper selection of materials, the timespan of radioactive danger from such irradiated material can be on the order of hundreds of years, rather than hundreds of thousands of years—fission's legacy. Fuel is abundant. Tritium can be bred in a fusion reactor. Enough deuterium exists to power worldwide energy consumption many times the current level for over a billion years [51].

The vast majority of research money in fusion has been spent on the tokamak-style magnetic containment technology [52]. Other technical approaches have been suggested such as the famous low-energy approach by Pons and Fleishman [53], and sonoluminescence [54]. Recent success in Polywell fusion promises a near-term path to the promise of nuclear power without the problems. Various technologies are discussed in "Technical Options." The information on fusion research and development herein is not intended to be exhaustive, but representative of the promise and status of human-harnessed fusion power.

Current nuclear power technology offers potential to replace all electrical-grid power production without need of any fuel source import and without carbon emission. However, fission systems pose various significant long-term safety and security hazards. Research offers significant potential improvements in fission reactor performance, safety, and potential to store waste. Assured mechanisms to prevent weapons proliferation and catastrophic accidents must emerge, or U.S. security could actually suffer from fission power production expansion.

The ITER nuclear fusion program is still about four decades away from projected net power production. The ITER-based systems, if successful, will be physically far too large for naval vessel use, but could serve as grid power should they eventually be developed.

The Bussard Polywell machine has shown remarkable recent success [55–57]. The Navy could use such systems on future naval vessels to eliminate the energy tether for ships—perhaps as early as the CG-X, which has been mandated by Congress to be nuclear powered. Large-scale expansion of this potentially affordable, safe nuclear power could enable all other approaches to alternative-fuel economies, energy independence and, ultimately, national security. While DoD uses of the Bussard systems could revolutionize military operational capability, in the world at large the ramifications of its adoption as the principal mechanism to produce power are perhaps too all encompassing to project—no less than emergence of a new civilization.

Virtually all U.S. Navy aircraft carriers and submarines are nuclear powered. New forms of nuclear fusion power may reduce the cost and size of nuclear power plants and increase safety to the point that they can be deployed quickly to the need of any DoD units, even forward-deployed in theater, to power aircraft and space vehicles as well as naval vessels—without danger of meltdown or generation of nuclear waste. Such nuclear plants use small amounts of fuel, a fuel that is abundant enough to last mankind for many millennia. Nuclear power can eliminate the need for fossil fuel use, which has limitations both in known quantity, distribution, access, processing, and global environmental impact. The United States, beyond independence, can be a net energy exporter with emerging nuclear power options.

A Brief Recount of Some DSB Task Force 2007 Recommendations

Getting more efficient DoD platforms and engines [1–3]. This paper is devoted not so much specifically to military energy issues as to relating the broad mix of national security issues and synergies for solutions and the potential for DoD to lead and enable the national response in this crucial security area. References 1–3 examine at length the subject of platform and engine efficiency and other core military energy problems and options. There's no intent to duplicate those extensive reports here, but a thrust of their findings is particularly worth noting—DoD can do much more with less by better energy efficiency.

The DSB 2007 Task Force reported on various technologies for more fuel efficient platforms (e.g., aircraft, ships, and land vehicles). Not just the engines but the platform as a complete system must be designed for fuel efficiency. Both DSB Task Forces (2001 and 2007) recommended that DoD incorporate fuel efficiency as a key performance parameter in specifying and buying new equipment—what DoD refers to as "acquisition."

The February 2008 report discussed various efficiency approaches. For example, an armored land vehicle can be made viable, robust, and more easily transportable with materials that weigh less. Aircraft design and materials can help provide extra range and operational performance. As previously noted, if some aircraft can extend their range by 30%—evidently quite achievable by DSB findings—the air refueling fleet can be significantly reduced. Huge savings would accrue in reduced fuel use and increased operational security by removing a vulnerable link in the combat chain.

The possibility of much more efficient aircraft—which the 787, as the first whole body composite commercial aircraft suggests—offers military and national payoff for security. Also, electric hybrid, or all electric commercial aircraft may one day be possible. Aircraft could benefit from the efficiency, reliability, cost, and size advantages of the electrical motor as prime power. Ninety percent of the thrust from a turbojet engine comes from the large bypass fan. Therefore, performance in some missions would not be sacrificed by using electric powered aircraft with an advanced, efficient electrical storage/generation technology.

The 2008 report shows many worthwhile technologies for fuel conservation that also improve operational performance. According to References 1–3, finding technologies are not the issue so much as DoD policy and acquisition processes. DoD can improve operational capability, increase operational security, and save fiscal resources by giving priority to and integrating fuel use issues into requirements setting and acquisition options analysis. The DoD is confronted with a broad and complex scope of challenges and alternatives, which include high-performance alternative fuels, more efficient fuel use, assured access to power for critical installations, and consideration of energy related issues in the national military strategy.

Addressing Infrastructure Vulnerabilities. The 2008 Task Force publication specifically addresses the sensitive issues of power-grid vulnerability and assured access to energy for critical civilian and military facilities. Some considerations are already being addressed. The report itself gives sufficient discussion concerning the unclassified areas.

Considerations ranged widely on solutions. As an example option, military installations might be able to produce fuel from waste (trash and sewage) and use high-efficiency engines, such as previously noted, to run electrical generators. This might not solve grid-dependence but could help in an emergency and also in terms of cutting overall fuel requirements. The report discusses these and other topics. A classified appendix is available.

Sensitive and classified issues are involved in energy infrastructure in the homeland and in military installations worldwide. No matter what else happens, DoD must deal with these and consider augmenting infrastructure robustness in the light of climate change. These issues are not detailed here.

TECHNICAL OPTIONS—A NONEXHAUSTIVE DISCUSSION OF 15 TECHNOLOGY AREAS

1. Heat Engines

Lift up the hood of almost any truck or car and you will find an ICE running on the Otto, Miller, Atkinson, or Diesel Cycle. Practical considerations of cost to produce, expansion fluid used, and engine endurance help determine the actual efficiency of these engines. However, fundamentally the ratio of heat source temperature and ambient temperature determine an ICE's maximum theoretical efficiency. Alternatives to current ICEs exist in fact and in design. Not to give an exhaustive options list (which might include the quasiturbine and Stirling designs), but to show the feasibility of rapidly fielding high-efficiency engines, two examples are discussed below.

The StarRotor engine is a Brayton cycle engine being developed by StarRotor Company, Texas A&M University Professor Mark Holtzapple's start-up company [58]. The engine consists of two cylinders containing rotors that compress air in one cylinder and expand air to extract energy in the other cylinder. The first cylinder compresses air and feeds it to an external combustor, which then passes the compressed-and-heated air into the expander which extracts the energy. The folks at StarRotor believe the engine will be at least 50% energy efficient. That performance compares very well to the typical 20–25% energy efficiency of automotive ICEs. Because the engine is an external combustion engine, it can run on virtually any fuel that burns.

Another example of a potential revolutionary engine improvement comes from the new company, Cermetica. It is commercializing breakthrough materials-processing technology developed by former Georgia Tech Professor, Katherine Logan (now at Virginia Tech). Robert Wisner's, one of Cermetica's founders, concept is similar to the Wankle engine but would use the proprietary materials-processing technology to make a titanium-diboride, high-temperature ICE with basically only one moving part and very low part count otherwise. Wisner believes that this engine will be able to achieve 50% efficiency and run on a variety of petroleum or synthetic fuels.

Either of these engines should be smaller and require much less maintenance than current production ICEs. Their flexible fuel capability synergistically enables proliferation of alternative fuel production. Cermetica and StarRotor exemplify the potential but are not the only new engine options. Totally new engines are not the only answer.

Diesel engines already offer higher efficiency than most gasoline engines. The DOE's Energy Efficiency and Renewable Energy office sponsors a Vehicle Technologies Program. As part of that effort, the Advanced Combustion Engine program has a goal to increase production diesel engine efficiency by fifteen percentage points (for light truck diesels, 30% to 45%, and for heavy truck diesels, 40 to 55%) by 2012 [59]. However, diesel engines have advantages even with today's capability. Diesel engines have a higher compression than spark-driven gasoline engines. Because the fuel in a diesel is ignited by the compression of fuel not by a spark plug, the fuel throughout the volume of the cylinder is more evenly exposed to the ignition condition. A gas engine's spark plug does not evenly expose the complete volume of the gasoline in a cylinder to the spark. A larger ratio of fuel in the diesel is detonated compared to that in the gasoline engine. Diesel engines typically can achieve greater than 40% efficiency at full load. Notionally, although with many assumptions and caveats, replacing gasoline engines with clean diesel engines could reduce consumption of petroleum for vehicles by 15% (about 1.35 Mbbl/day) and thus reduce oil imports by the same amount.

Turbine engines (or microturbine engines) can theoretically be made highly efficient -greater than 50% [60]**.** Turbines vary greatly in efficiency depending on the load/speed condition in which they operate. However, they can use multiple types of fuel. They can be made with only one moving part, to need little or no lubricant to rotate, and to need much less maintenance than piston engines. Turbines have operating lives as long as 20,000 hours, which would be about 30 years of service for a 20,000 mile-per-year vehicle averaging about 30 mph (miles per hour) over the course of all trips for a year. Currently turbines cost more than production vehicle ICEs. However, turbines need not cost any more than ICEs if they were produced in the same quantity yearly as ICEs are.

2. Hybrid Electric Vehicles

Hybrid electric vehicles can take advantage of the high efficiency of electrical motors and electrical storage devices and combine that with running high-efficiency engines at maximum efficiency, only to charge electrical storage when required. A hybrid electric vehicle could theoretically milk maximum efficiency from a microturbine. If a Tesla turbine for a vehicle could indeed achieve 80%+ efficiency [61] at optimum operation, a hybrid could enable that mode of operation. Replacing the entire vehicle fleet in the United States with such hybrids could cut petroleum imports to the level that no imports need come from outside North America.

Current hybrid vehicles achieve over 50–60 mpg with proper driving style by the operator. Hybrid vehicles can give a range today that current all-electric vehicles don't. Plug-in hybrids with a 60-mile range will, for most people on most days, run only on the plug-in charge. These plug-in cars will contribute advantages of the all-electric fleet until the all electric fleet comes. All-electric vehicle technology is discussed separately.

3. Fuel Cells [62]

Fuel cells produce electricity electrochemically not by combustion. They are not subject to the limitation in maximum efficiency of a heat engine. Fuel cells theoretically can achieve over 80% energy production efficiency. Conceptually, fuel cells could reduce demand for petroleum-based fuel by a factor of four. In practice, current automotive fuel cells average 25–35% efficiency. However, other applications of fuel cells typically achieve 50–60% efficiency. Systems in which the heat produced by the chemical reaction is also captured for energy production achieve as much as 90% efficiency.

Fuel cells have no moving parts and can be extremely reliable as well as quite. The Germans have a fuel-cell driven submarine. NASA uses fuel cells for space missions. Fuel cells can run on hydrogen and oxygen and have nothing but water as an exhaust. Other fuel and oxidizer options also are used.

Current fuel cells are not as energy dense as ICEs and are relatively costly. Most current fuel cells use the very expensive metal platinum as a catalyst. New much less expensive catalyst options are available. Nanotechnology offers help. A new membrane technology developed by an MIT chemical engineer, Paula Hammond, offers much better performance (50% power increase) for straight methanol fuel cells [63]. Currently, platinum costs alone can price fuel cells out of the market for replacing ICEs. However, potential use of nickel, iron, or other catalysts (usually nanotechnology assisted versions), can replace platinum and make fuel cells more affordable and perhaps more effective [64, 65].

Many fuel cell technology options are being pursued in commercial development and research. The cost versus performance will continue to improve. Fuel cells will compete with other technologies to deliver power to both the automobile and the home [66].

4. All-Electric Vehicle Technology

Let's look at the cost to provide power to a petroleum fueled vehicle. As an example, assume a 30 mile/gallon vehicle traveling at 60 mph and that requires 13 horsepower (10 kilowatts (kW)—typical for an automobile on a straightaway) to drive it at that speed. In one hour, the vehicle will travel 60 miles, expend 10 kilowatt-hours (kWh) of energy, and use 2 gallons of fuel. At $3.00 per gallon, the vehicle costs, in fuel use alone, $6.00 for 10 kWh, which equals 60 cents per kilowatt-hour. Consider that a kilowatt-hour of coal-supplied electricity averages 5 cents, even solar power price per kilowatt-hour is only 20 cents, and that the price of the petroleum-based fuel is probably significantly more than $3.00 per gallon.

Multiple car companies are producing or developing the electric hybrid and even the all-electric car such as the Tesla. These cars require hefty electrical storage and/or onboard electricity generation. Batteries for electricity storage, depending on how they are made, have their own problems—safety and environmental. However, much is being done to produce high-performance batteries and battery alternatives. For example, the Tesla entrepreneurs chose to use lithium-ion batteries such as computer manufacturers install, because they believe that the computer industry will drive better battery development [67]. Still other developers are exploring other nonlithium ion options that are potentially less expensive, longer lasting, energy dense batteries [68]. If electrical battery storage improved as the computer industry's famous Moore's Law predicts for computing technology, within 10 years the future electrical vehicle storage device would cost less than $300 and have similar to the same energy delivery capability per kilogram as the ICE. This slope of improvement may not be achievable, but electrical battery performance and cost will improve and will directly benefit the electric vehicle.

In a different approach, the company EEStor in Cedar Park, Texas, in partnership with Lockheed Martin, is developing an assembly line for a new kind of ultracapacitor (ultracap) based on the dielectric, barium titanate [69, 70]. This ultracap unlike the much smaller capacitors in commercial and military electronics will be able to store dozens of kilowatt-hours of electrical energy. Richard Weir, company cofounder, says that these ultracaps will have three-to-four times the energy density (energy per kilogram) as a lithium-ion battery (such as Tesla and General Motors are using for their electric cars) and ten times as much energy density as lead acid batteries (such as are currently under the hood of most cars). These ultracaps supposedly will be able to take full charge within minutes. The company is planning to ship its first commercial product within months. Zenn Motor Company, a Canadian electric-car company, plans to use them in their all-electric sedan to be sold in the Fall of 2009. Other ultracapacitor options are being pursued such as the carbon nanotube approach at MIT [71].

How does electric power compare to other alternatives? *Popular Mechanics* magazine in 2006 published a cost comparison for various fuels to drive similar cars from New York to California. Table 2 [72] shows the dollar-cost based on fuel prices in 2006 for that cross-country trip.

The list shows that even if the electric vehicle prices may not be lowest, running on electricity might be a bargain anyway. The Honda EV Plus's trip was not only lowest in cost, its distance was farther because of the electrical energy available from 1 ton of coal, which allows a 3311-mile trip versus a 2999-mile trip for the gasoline-powered Honda Civic. Thus, the electric-powered Honda got 55.19 miles per dollar versus 14.1 miles per dollar for the gas-powered Honda.

Not in this table is the Roadster all-electric from Tesla Motors. Tesla advertises a 220-mile range per charge and 50 miles per dollar cost to run the Roadster [73]. Considering that the cost of electricity production has not suffered the same price rise as gasoline since 2006, electricity as prime vehicle power looks very attractive but not just for cost of fuel.

Electric vehicles also recycle energy. EV Plus and the Roadster were designed to produce and capture electricity from braking. The kinetic energy in the moving vehicle is captured by a mechanism such as by making the motor serve as a generator or by running a generator from the rotating motion of the wheel-drive train. Because of this electricity regeneration, driving in stop-and-go city traffic gives the electric vehicle a longer run on a battery charge than highway driving allows. The opposite situation applies for the ICE-car. Most automobile travel is city driving.

Also, unlike the ICE, electric motors do not have to expend power unless they are actually providing motion to the vehicle. When sitting at traffic lights, while a combustion engine would be burning fuel, an electric-car motor need not drain electricity. Also, electric motors are vastly more efficient at using energy than combustion engines. Three-phase-electrical-motor operating efficiency is typically 90% compared to the typically 20–25% efficient ICE. The 500-horse power Raser Symetron motor installed in a Formula Lightning racing car for an appearance at Monaco is rated at 92% peak efficiency, produces more torque than the ICE it replaces in similar fuel-burning Formula vehicles, and is about half the weight of that ICE [74]. Similarly, Tesla Motors advertises 85–95% efficiency for its motor [75].

The industrial base for production of millions of electric motors already exists. Electric motors, using cheaper and more plentiful energy, operate as much as five times more efficiently than ICEs. New electric motor technology offers possibly even better efficiency and lower cost. For example, faculty members at Lund University in Sweden have developed a means to use iron powder and plastic to make the magnetic components in permanent magnetic motors [76]. The inventors believe the technology will double the energy density and cut the cost in half.

The major problem with electric vehicles is limited, expensive storage of electricity. A lead-acid battery pack, which might provide less than 100-mile range for a vehicle and which has a 3–4 year life, costs around $2000.00 [77]. The Tesla electric car company has chosen to use the type of battery used by laptop computers, lithium-ion batteries [78]. The lithium-ion batteries can last three (or more) times longer than the lead-acid batteries but cost 10–15 times more than lead-acid per watt-hour of energy stored. The Tesla entrepreneurs intentionally chose computer batteries to take advantage of the ongoing push by computer makers to produce better and less expensive

Table 2. Cross-Country Trip Fuel Cost Comparisons

Vehicle	Fuel	Trip Cost
1997 Honda EV Plus	Battery charge (1 ton coal)	$60.00
2005 Honda Civic GX	Compressed Natural Gas	$110.00
2006 Honda Civic	Gasoline ($2.34/gallon)	$212.7
2006 VW Golf	B100 Biodiesel	$231.00
2005 Taurus	E85/Ethanol	$425.00
1998 Taurus	M85/Methanol	$619.00
GM HY-Wire	Hydrogen	$804.00

batteries. The Tesla 220-mile range is more than adequate for most needs. However, the $100,000+ price tag is a stumbling block for many would-be electric car owners.

The DoD may be able to afford the price tag, but the performance substantially lags diesel or gasoline power. Energy density greatly favors carbon-based fuels. A lead-acid battery holds around 100 kilojoules/kilogram, lithium-ion batteries as much as 700 kilojoules/kilogram, but gasoline's energy density is 46,900 kilojoules/kilogram. However, as much as 85% of that gasoline energy is typically wasted in 15–25%-efficient combustion engines and gives delivered net energy of around 5,000 kilojoules for each kilogram of fuel. Even so, fuel burnt in combustion engines is about ten times better at storing and delivering energy than the lithium-ion battery.

To make a specific comparison, the 450-kilogram Tesla battery pack with 53-kWh capacity provides an energy density of 424 kilojoules per kilogram (1 kWh = 3600 kilojoules—see Appendix A). Assuming an average-energy-use efficiency of 90% for the Tesla system, the electric vehicle provides 171,720 kilojoules of useful energy per battery charge. Assuming a 20%-efficient-ICE vehicle burning gasoline with 46,900 kilojoules/kg, the gas vehicle needs only 18.3 kilograms of gasoline to equal the electric vehicle's energy delivery. One gallon of midgrade gasoline can provide about 132,000 kilojoules and at 20% efficiency delivers 26,400 kilojoules of useable energy. Therefore, 6.5 gallons of gasoline will deliver the same energy for the gas vehicle to use as one battery charge delivers to the electric vehicle. The 6.5 gallons of gasoline weigh about 43 lb, while the Tesla battery pack weighs about 900 lb. But that is not fair comparison for the electric vehicle, since the standard gasoline vehicle's engine, transmission, cooling system, and exhaust system will likely outweigh the electric-motor-battery-pack system. However, when compared only by system total energy delivered, a notional 15-gallon-gas-tank ICE vehicle gets about two-and-a-third times better range or endurance than the described electric power supply. This fact gives the battery (and other energy storage developers) a clear goal to surpass. A threefold increase in electric energy density over the current lithium-ion battery pack will allow the electric vehicle not only to equal but to exceed the performance of the typical (15–25% efficiency) ICE gasoline burner.

Another potential electrical storage alternative are the various types of flow battery, which use liquid electrolytes stored in tanks to store charge, which is extracted in the battery's power cell [79, 80]. Such batteries can deliver power very quickly depending on the size of the power cell and the rate of flow of the electrolytes. In such systems the electrolyte can be recharged electrically, or the battery can be recharged by replacing the electrolyte. These batteries are not particularly compact nor energy dense and are currently employed by electrical power production load stabilization, where megawatts or many kilowatts of storage are needed, but volume is not a limiting factor. However, they have been demonstrated to be greater than 70% energy efficient [81] and can be charged and recharged many times.

5. Alternative Fuel Comparisons

Here are some basics about a few popular alternative fuels as compared to gas and diesel. Table 1 from Reference 82 shows the relative energy density for each of the most well-known fuel options. Note that the energy density for the second column in the table is in megajoules per mass, while the third-column energy density is given by volume.

The table reveals some interesting comparisons. The first four fuels are all gases at room temperature. They have high-energy content by mass, but are among the least energy-dense by volume (gallons or liters). Gasoline has higher energy per kilogram than diesel (a.k.a., #2 fuel oil). Because of diesel's higher mass-to-volume, diesel is the more energy-dense fuel per liter (or gallon) than either automotive gas or aviation gasoline.

Both gasoline and aviation gas are composed of short carbon-chain molecules with the relative quantity of eight-carbon-chain molecules determining the octane performance rating. Gasoline is more volatile and more easily sparked into flame and detonation than diesel. This makes them perform well in spark-driven engines and makes them more dangerous than diesel or jet fuel. Jet fuel is a kerosene-based fuel that shares characteristics with diesel in that they both have high concentration of molecules near or at 16-carbon-chain molecules. The quantity of cetane (16-carbon-chain hydrogen-saturated molecule) determines the performance rating of diesel. However, cetane above 60% does not appear to increase performance significantly [83].

The three alcohol fuels at the bottom of the table are noteworthy especially because of the rapid production rise of ethanol from corn and methanol from waste such as wood chips. Less well known by the general public, butanol, like the other two can be formed from bacterial fermentation. Butanol, however, has a significantly higher energy density, and does not have the corrosive effects on pumps, pipes, and engine seals that methanol and ethanol have. Butanol at 85% concentration can run in most any engine that currently uses gasoline and can be delivered by the same infrastructure without damage or special precautions. These butanol-deployment conveniences cannot be said of ethanol or methanol. Butanol is more toxic to the bacteria that produce it than ethanol and methanol are to their bacteria generators. This fact makes butanol somewhat more difficult to produce [84]. Because of the butanol advantages British Petroleum (BP) has begun a small-scale production project [85].

A potential biofuel of interest not mentioned in the table is 2,5-dimethylfuran. Researchers at the University of Wisconsin in Madison announced recently in *Nature* that they have developed a catalytic method to make this liquid from fructose, which is a sugar derivable from many plants [86]. The liquid has 40% greater energy density than ethanol, and it is not water soluble and does not absorb water as ethanol does.

6. Fischer-Tropsch Synthetic Fuel Generation

For many decades we have known how to produce synthetic versions of gasoline and diesel as well as alternative fuels, such as the alcohols and biodiesel. One mechanism previously mentioned, the FT process, is particularly worth examining for both positives and negatives [87–91]. FT was developed in the 1920s in Germany by the scientists for whom it was named and was used extensively by the Germans in World War II to produce diesel for the Wehrmacht since access to petroleum was largely denied them.

The FT process gasifies coal, biomass, and natural gas (methane) into a carbon-monoxide-and-hydrogen synthetic gas (syngas), which can then be recombined into a high-quality liquid fuel that can be engineered to desired specifications. A similar process exists called the Mobil process, which converts the feedstock into methanol as the intermediate building block before further engineering the desired fuel product. The Air Force has tested FT-natural-gas-derived JP fuel in multiple air platforms, including the B-1 and B-52. The fuel shows at least equivalent performance to standard JP, but the synthetic is mixed in 50% ratio with regular JP.

The FT process is energy intensive. FT can emit more carbon waste to produce the synthetic fuel than just burning petroleum-derived JP. The air force currently aims to meet half of its domestic-based fuel consumption needs by 2011 with FT-based JP. The result will probably be oil that's less expensive than JP derived from the $140-per-barrel oil. Desperate circumstances drove Nazi Germany in WWII and South Africa by SASOL under apartheid to develop substantial FT capacity to process coal to liquid fuel. Some significant improvements in FT processing have been made [92], but the environmental impact and limited ability to boost domestic production of natural gas suggest a better avenue through a complementary Defense Advanced Research Projects Agency (DARPA) program.

Using coal and FT poses several issues [2, 88]. The United States has perhaps 200 years of coal reserves at current consumption rates. However, switching to coal as a primary source of liquid fuel would cut that time to decades of reserves rather than centuries, while potentially causing tremendous pollution problems unless extensive and expensive carbon sequestration were employed. Also, FT plants are expensive, with entry level plant cost in the billions. China is pursuing a large effort on this path. China is spending $5 billion for a plant commissioned to produce 80,000 barrels of fuel a day (greater than $62,000/barrel/day). Typical oil refinery cost is about half that per barrel processed per day. To get toward 11 Mbbl/day (half our current use) would require on the order of $1 trillion. China is employing much of the workforce of the world competent to build such plants.

7. Renewable Fuels

Numerous alternative fuel options exist besides FT's coal-to-liquid synthetic fuel. Industry and government in the United States have a plethora of alternative fuel projects underway. Here are just a few to add to the Air Force projects already discussed.

Shell Oil has partnered with Virent Energy Systems to produce a synthetic gasoline from biomass [93]. BP, with partner DuPont, plans to produce butanol from bacterial-processing of biomass. BP and DuPont plan synthetic production of other fuels as well.

Still another company, Changing World Technologies (CWT), with an operating plant in Carthage, Missouri, uses the remains of turkeys from the nearby Butterball plant to produce #4 diesel [94]. CWT's plant powers itself from methane produced as part of the process. CWT uses a technology, called Thermal Conversion Process (TCP), to liquefy and depolymerize the feedstock by heat and pressure. The resulting product depends on the feedstock and processing parameters. Plastic, old tires, and pig manure are all particularly good feedstock. The diesel is being used at a local electrical power generation station. According to the joint DOE/USDA publication *Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply* [95], even without counting conversion of food grain to fuel over a billion tons of waste biofeedstock is available in the United States yearly. One ton of high-quality waste can produce about 2 barrels of fuel. With a rough estimate of 1.5 billion tons of waste available annually from various sources including agriculture, sewage, and disposal of used plastic and other high-carbon trash, about 3 billion barrels of fuel could be generated yearly from TCP. The United States consumes about 8 billion barrels of petroleum per year. In addition, the high-carbon-content material already stored in landfills could be mined. Conversion of waste to fuel is particularly interesting because it addresses two important problems simultaneously-waste/sewage glut and energy shortages.

Other groups have competing technologies to turn waste into fuel and other useful petroleum products. Some examples include Global Resource Corporation (GRC), Texas A&M, and Green Power Inc [96–100]. The GRC technology uses a giant microwave to reduce material previously made from oil back into oil. Professors from Texas A&M developed a combined biological-chemical method to turn any biodegradable material into alcohols, which can be useful for a variety of purposes, including fuel. Their plant built at Bryan, Texas uses this process called MixAlco. Green Power Inc., uses a catalytic process at its plant in Washington State that can convert any high-carbon-content material into high-quality diesel fuel called nanodiesel. Green Power projected in 2006 that it could sell diesel profitably at under a dollar a gallon. Their technology as CWT's could be used to mine landfills and convert any high-carbon-content waste to high-quality diesel and with some upgrades could also produce gasoline.

Los Alamos has announced a concept called GreenFreedom which would use a newly-developed electrical-catalytic process to extract carbon dioxide from the atmosphere and convert it into designable fuels [101].

University of Maryland professors Steve Hutcheson and Ron Weiner have created a process to convert plant products from any cellulosic source into biofuels [102]. Called the Zymetis process, it is derived from a Chesapeake Bay marsh grass bacterium, which the scientists found has an enzyme that converts plant materials into sugar. Unable to isolate the bacterium in nature, they discovered how to produce the enzyme responsible for the conversion. This chemical they named Ethazyme in a one-step process dissolves cellulosic-material's (e.g., switch grass, algae, seaweed, wood chips) cell walls and converts the result into sugars. The sugars can then be used as feedstock for alcohol fuel generation.

Other biomass options also exist. Jatropha, a perennial bush, produces poisonous seeds rich with oil that can be extracted for fuel. The plant grows in marginal soil with low water need after the plant is established. However, some concern exists that jatropha will be cultivated by Indian and African farmers on prime farm land for profit of big companies at the cost of eliminating that land's use for desperately needed food crops.

8. Algae—A Notable Renewable Fuel Source

Algae, the original source of petroleum, can produce various renewable fuels. Algae grow very densely. Certain species of algae consist of as much as 50% oil. Enough algae feedstock to replace U.S. fuel needs could be grown in an area roughly 250 miles by 100 miles in open ponds on marginal land, such as in the U.S. desert southwest. But algae grow just about everywhere, and local varieties tend to displace the special high-oil-content algae, the best fuel feedstock. The less expensive means of growing algae in open-air tanks is problematic because of the threat of contamination. However, some are pursuing options to grow algae in enclosed silos or other such containers that expose algae to the required sunlight and perhaps enhance its growth by feeding it such as with carbon exhaust from coal-fired electric power plants.

A DARPA/Air Force joint effort is aimed at producing standard JP 8 fuel from biomass such as high-oil-content algae [36, 37]. The prime executors of the project are the DOE Sandia Laboratory and the Honeywell Company, UOP.

PetroSun Biofuels has started an algae farm in Harlingen, Texas, in a salt-water swamp and plans more farms in Alabama, Arizona, Louisiana, Mexico, Brazil, and Australia. PetroSun will ship the product to refineries to make biodiesel or biojet fuel [103–105].

Valcent Products Inc., and Global Green Solutions, in a joint venture, built a facility in Anthony, Texas, that is growing algae in an enclosed environment [106, 107]. Inside tall stacks of transparent, water-packed plastic bags that reside inside a greenhouse, the algae grow as the water is continuously circulated throughout the system of plastic bags. Algae are continuously extracted from the water. The system, because it is enclosed, can breed any particular type algae desired which fact allows for adjusting the algae crop to the desired fuel product. Thus algae production can be tuned to produce diesel, jet fuel or other petroleum products.

Algae are the premier renewable "crop" in growth density. Corn with the stover may be able to produce 1300 gallons of ethanol per acre per year. Soybeans and palm oil plants can yield respectively, about 48 gallons and 630 gallons of oil per acre per year, and pond-grown algae about 10,000 to over 15,000 gallons. The Valcent entrepreneurs project that they can produce 100,000 gallons of algae oil per year per acre. According to this projected production, about 13.6 million acres of algae would replace the entire world fossil-petroleum production of 88 Mbbl/day (about 32 billion barrels per year). To replace the U.S. military's 300,000 barrels per day using Valcent technology would require about 46,000 acres which is one-and-a-half times the size of Disney World.

A San Francisco company, Solazyme, approaches the use of algae for fuel production differently [108, 109]. They grow algae without sunlight in stainless-steel containers. The algae feed on sugar and produce a range of different types of oils which can be converted into different sorts of fuels. Because the algae grow in the dark and are fed sugar to grow rather than relying on sunlight and photosynthesis, the algae produce more oil and can be more densely grown than in ponds.

The use of densely and/or inexpensively grown algae to produce fuel could allow every nation to be a fuel producer and could eliminate the expense, risk, and ecological impact of drilling for oil or importing it. The technology to replace petroleum with algae-based products is neatly in hand. The question of whether an algae industry can deliver economically on a large scale remains to be demonstrated.

9. Hydrogen Fuel (or Zinc, or Aluminum, or Ethanol, or Compressed air, or Nitrogen, or…)

Some General Characteristics. Hydrogen concentration in the atmosphere is 500 parts per billion. Hydrogen readily and explosively combines with oxygen to release energy. There's no place on Earth to "mine" hydrogen in a form that is ready to use as an energy source [110]. Some energy-expending process must be used to get hydrogen into energy-currency form. Typically hydrogen is obtained from hydrocarbons by chemical or biological reactions, or from water by hydrolysis (high- and low-temperature techniques exist), or high-temperature steam forming [111].

However, using hydrogen as a fuel on an industrial scale has many fundamental issues that have not been resolved. Current industrial production capacity of hydrogen is not sufficient to meet the orders-of-magnitude increase necessary to supply the scale of demand required to replace current fuels. Hydrogen transportation is impeded by its being a gas at room temperature, and large volume must be sent to provide significant energy, by its embrittlement of metal pipes used to transport it, and by the high infrastructure and energy cost to convert it to liquid for storage and shipment [112].

Because hydrogen is a gas, its energy density by volume is very small. Even when hydrogen is converted to a liquid, it is only 25% as energy dense as gasoline. Liquid hydrogen has fewer hydrogen atoms per gallon than gasoline or diesel. For all these reasons, an automaker of a fuel-cell-powered car would tend to use standard petroleum fuel and extract the hydrogen from the hydrocarbon. Even though fuel-cells are perhaps 30% more efficient than ICEs, today they are technically, logistically, and economically challenged compared to the ICE or batteries. Hydrogen-fuel-cell cars currently are sold only by Honda and, in the United States, sold only in southern California where hydrogen filling stations exist.

Storage. The DOE funds research projects to improve hydrogen energy storage with a goal of 6% by weight hydrogen to storage system [113]. The DOE Hydrogen Program reports funding approximately 70 hydrogen storage research projects in 2007, some related to using metal hydrides as the storage mechanism about 80% of these at the DOE Metal Hydride Center of Excellence at Sandia National Lab and a similar number of projects in their Chemical Hydrogen Storage Independent Projects.

Through the DOE Hydrogen Sorption Center of Excellence at NREL, over a dozen projects examined such things as aerogels and nanotubes for hydrogen sorption storage. Another 20-odd projects explored various other storage concepts and issues including advanced compressed gas and cryogenic storage methods, storage using new materials such as glass microspheres, and storage safety issues.

Other storage examples not in the DOE list include using tiny quills from chicken feathers as suggested by Dr Wool at the University of Delaware [114], or using fullerenes. Rice University researchers showed how hydrogen could be compacted into 60-carbon fullerenes [115]. The researchers concluded that as many as 58 hydrogen atoms could be contained within the 60-carbon cage—a density that would exceed DOE's goal of at least 6% by weight hydrogen/absorber ratio. However, the H58C60 buckyball is also a hydrocarbon which if burned has energy comparable to other hydrocarbons and still produces greenhouse gas. Despite all of this research the current standard is to use compressed gas at about 750 bar which makes for a volumetrically challenged energy source.

Distribution. Hydrogen distribution is daunting. There is a single hydrogen-dispensing fuel station in Washington, DC, run by Shell. Southern California has a number of hydrogen stations. Honda plans to market (for lease) their FCX hydrogen fuel cell vehicle in southern California because this is the only place of significant public availability to hydrogen refueling. Hydrogen transports most inexpensively through gas pipelines. About 700 miles of hydrogen pipelines exist today compared to the million miles of natural gas pipelines. Using natural gas pipelines could immediately provide an infrastructure for distribution, but hydrogen embrittles the metal. Compressed hydrogen at 3000 psi (200 bar) travels in tube trailers via truck, rail and water vessels. Investigations to improve transport currently explore a safety sanction for 10,000 psi to improve efficiency and reduce cost. For long range transport hydrogen is liquefied and stored in cryogenic tank trucks. Liquification and cryogenic storage are expensive and energy intensive. The current lack of good options for transport drives the need for research into other storage and transport mechanisms [110–113, 116].

Production. Hydrogen is produced on an industrial scale to make ammonia for fertilizer, to hydrocrack petroleum, and as an essential ingredient in domestic steel production. But the scale of production required to replace petroleum is enormous in comparison [111]. The DOE's 2007 hydrogen program reports on about 70 projects investigating various mechanisms for hydrogen production in ten categories. These categories include hydrogen distributed production from natural gas and bioderived liquids, production from electrolysis, from biomass gasification, from solar high-temperature thermochemical water-splitting, by photoelectrical chemical (e.g., a material such as a semiconductor reacts with water in the presence of sunlight to separate the hydrogen from the water), from biological processes, from coal, by nuclear power, and by a category called "crosscutting," which included work in hydrogen fuel cells [113]. Simple electrolysis is the least efficient mechanism to produce hydrogen. High-temperature versions—such as might be enabled by high-temperature (800–1000°C) nuclear reactors—are much more efficient [111, 117–119].

Getting Hydrogen From Solar Power and Water? Distributed production would mitigate distribution and storage problems. A common question arises, "Could hydrogen production be dispersed such that people make hydrogen at home from water via electrolysis?" If this form of hydrogen production were viable, electricity with an already well-established distribution system would serve as a means for hydrogen distribution. Thus, hydrogen could be produced remotely on demand. The electricity could come from traditional power plants, such as coal and nuclear or from renewable and perhaps distributed electricity sources, such as solar and wind power.

As mentioned above, DOE funds many paths to hydrogen production, including using photovoltaic power from the sun. One DOE study from 2005 [120]—which specifically addressed solar- and wind-generated electricity as the means to produce hydrogen—was not very positive based on electrolytic capability of the day. However, a recent MIT announcement of a new kind of artifical photosynthesis, as explained in *Popular Mechanics*' August 2008 issue, might be the long-sought enabler for hydrogen production from solar power [41].

Solar power must have some concurrent mechanism to store energy because the sun does not always shine, nor always with the same level of ground-incident power. Hydrogen conceivably could fill that need. Solar-panel energy-conversion efficiency varies widely by price, but 20%+ efficiency is found in the highly expensive governmental-use-in-orbit sort, but less than 10% efficiency for the more mundane variety. To produce a kilogram of hydrogen requires about 50 kilowatt-hours of electrical energy. In good conditions, the sun provides about 1 kilowatt instantaneous power incident per square meter. A 10-meter by 5-meter array of solar panels producing electricity for 1 hour at 10% efficiency would provide 5 kilowatt-hours. With good weather conditions at optimum latitude at the right time of year, that size solar panel array may be able to generate 50 kWh per day. That much solar-provided electricity would supply, via electrolysis, 1 kilogram per day of hydrogen. The energy in one kilogram of hydrogen is about the same as the energy in one gallon of gasoline. Conceivably, in 15 days of ideal conditions, the solar array could make enough hydrogen to equal the energy contained in a car's full 15-gallon gasoline tank. For those who don't drive much, this might be sufficient, but probably not for most.

However, as previously noted, MIT researcher Daniel Nocera published results in *Science* magazine in August 2008 that seem to demonstrate a highly energy-efficient mechanism to use a cobalt/phosphate catalyst to electrolytically split water molecules at neutral ph and room temperature and pressure into constituent gaseous hydrogen and oxygen molecules [42]. This development, as announced by MIT News, could completely change the equation. However, the engineering tasks remain undone to apply this new scientific discovery [121].

If the Nocera discovery can be engineered to increase electrolysis efficiency sufficiently so that a household's photovoltaic array could produce enough electricity in the day to run the house and simultaneously extract enough hydrogen to generate the 6–10 kilowatts required by the household at night by use in a fuel cell or high-efficiency engine, then the world could conceivably convert largely to solar power. This prospect becomes especially attractive as the price for solar arrays drop to a dollar a watt (see note in Solution 6). However, as of today in 2008, engineering to produce hydrogen from solar-electric power is not viable.

Use in Fuel Cells. Fuel cells and the use of hydrogen, however derived, are worth special mention. ICEs generally have efficiency of 20–25% or less, even with a theoretical maximum efficiency of 60% for an Otto cycle. Fuel-cell maximum theoretical efficiency exceeds 80%, but in practice, current automobile fuel cells run at about 35%. Today's fuel-cell systems do not compare well to ICEs in energy per mass. Nor do they compare well to electric-motor/battery systems. The theoretical achievement of 80% efficient- hydrogen-fuel-cells, even with the factor-of-four disadvantage in energy volume-density compared to gasoline, would make a 15-gallon hydrogen-fuel-cell system comparable in endurance to a 15-gallon gasoline-burning-ICE.

10. Nuclear Fission Technology [122–127]

Thirty-one countries worldwide currently operate a total of 441 nuclear-fission-reactor electric power plants. Outside the United States, an additional 32 plants are under construction. The United States has 104 commercial nuclear-fission power plants. The U.S. plants provide about 20% of the nation's electric grid power. In addition, the U.S. Navy has built and run about 250 nuclear-fission power plants in deployed ships and submarines, and training and development sites.

Fission power plants run as heat engines, with fission-released radiation generating the heat. Generally, reactors use Uranium-235 or Plutonium-239 as fuel. Over 99% of Uranium is Uranium-238 (which is not in itself a fuel), less than 0.01% is U-234, and about 0.7% is U-235. However, when bombarded with neutrons, U-238 can be "bred" into Plutonium-239, which is a spontaneously fissile material and a good nuclear fuel. "Enriched Uranium" is made by increasing the U-235 content relative to the U-238 content. "Depleted uranium" has the U-235 isotope removed from the U-238 portion, which is the so-called depleted uranium. Other artificial isotopes exist and are important. Breeder reactors are designed to produce Plutonium-239 and can expand the fuel supply. Although natural quantities of U-235 for reactor fuel use are estimated to last about 1500 years, U-238 quantities, when used as a breeder fuel, have been projected to last beyond 10,000 years [122–126]. Thorium-232 has been proposed as a fuel. It absorbs a neutron under bombardment and beta decays ultimately to U-233, which is itself a nuclear fuel with a half-life over 100,000 years. Thorium-232, although 400 times more plentiful than U-235, is generally not used as a prime fuel in power plants [127]. Germany built a 300-MW Thorium pebble bed reactor but shut down the reactor for technical reasons after a year.

In general, reactors comprise seven major components. The nuclear fuel produces heat energy from fission, which converts water to steam. The steam drives a turbine that turns an electric generator. About 60% of the reactors today use U-235 as fuel. A metallic fuel cladding protects and contains the fuel. A moderator slows high-energy neutrons to levels under 1 electron-volt (eV) (used in "thermal" neutron reactors—see more below). The coolant material captures the heat and imparts it to the water for the steam turbine. Neutron-absorbing-material "control rods" modulate the rate of fission and, if fully engaged, shut the reactor down. A pressure vessel prevents radiation release from overpressure. Finally, a containment structure shields the external world from the radiation produced in the reactor.

Nuclear-fission power plants are designed and classified by neutron speed (energy): slow neutrons (less than 1 eV of energy), intermediate, and fast neutrons (millions of electron-volts). The intermediate speed appears suitable only for thorium reactors. The slow-neutron reactors use a moderator to slow down fission-produced neutrons so that they are more easily captured by U-235, which will then continue the fission cycle. The fast-neutron reactors require enriched uranium or plutonium and do not use a moderator. They are designed to have U-238 capture the high-speed neutrons, which starts the decay to produce plutonium and sustained reaction while "breeding" plutonium. In reactors, fissile uranium releases neutrons and radiation energy. The neutrons collide with other uranium atoms and cascade the fissions. The fission rate and quantity of material in fission determine the radiation energy level. A nuclear explosion requires a special set of circumstances and configuration that a power plant cannot achieve. Uncontrolled fission cascade in a power reactor can raise the temperature and possibly melt the core, but will not detonate.

Most reactors are thermal neutron reactors, which use some type of moderator to slow neutrons to "thermal" energy. Moderators include graphite, heavy water (deuterium water), light water (common distilled water), molten salt (a Gen IV concept—see Appendix C), liquid metal, and organic moderators (e.g., biphenyl). The liquid metal reactor allows higher energy density than other coolant/moderators and was first designed for submarine use. Metals used include sodium, sodium-potassium alloy, lead, lead-bismuth eutectic, and mercury.

Reactor coolant, depending on the design, can be the same or different from the moderator. In addition to the moderators mentioned, reactors can use gas (helium, nitrogen, and carbon dioxide) coolant. The water-cooled reactors come in three designs—pressurized water, boiling water, and open pool. Each has advantages and disadvantages.

Appendix C provides a summarized look at nuclear fission technologies and issues. For additional information, a 2003 MIT study entitled "The Future of Nuclear Power" [125] gives great insight into the technologies and issues of nuclear fission power. The MIT study noted that wide-scale use of nuclear energy to replace fossil fuel presents complex problems. Nuclear-power-plant initial cost compares poorly to any other conventional power plant type. Nuclear plant safety is inherently complex. The study states "the management and disposal of high-level radioactive spent fuel from the nuclear fuel cycle is one of the most intractable problems facing the nuclear power industry…" The MIT study suggests that nuclear power expansion should not proceed "unless the risk of proliferation from operation of the commercial nuclear fuel cycle is made acceptably small. Finally, the MIT study concluded that "nuclear power will succeed in the long run only if it has a lower cost than competing technologies."

11. Nuclear Fusion—Magnetic Confinement Fusion

References 50 and 51 provide an overview of the current state of mainstream fusion programs and technology. Most fusion research funds Maxwellian-distribution plasma confinement with magnetic devices (e.g., the tokamak project at Princeton and ITER) that use various configurations of electromagnets to contain tritium–deuterium plasma. The system pumps energy into the plasma until the nuclei can overcome the Coulomb barrier (electrostatic positive-charge repulsion of positive charge) and fuse . These "magnetic bottle" devices follow the concept of the Russian original tokamak (a Russian acronym for their fusion project).

When a tritium atom fuses with a deuterium, the result is a helium atom, a high-energy neutron, and 17.6 MeV. Other elemental atomic species can be used, but the energy required to produce fusion is higher for other species. Lithium Deuteride, He-3/He-3, Lithium-6/Lithium-6, and Hydrogen/Boron-11 pairs each have specific advantages as fuel. See more on H/B-11 below.

In 1997, the Joint European Torus (JET) produced 16.1 MW for less than a second and thus achieved an output of 65% of the total power put into the device. The JET did not reach break-even power output, even for this short span of time, but achieved the current record output for magnetic confinement fusion. The International Thermonuclear Experimental Reactor (ITER) is a planned magnetic plasma confinement experiment designed to achieve more energy out than input (ten times more peak power and five times more steady-state power) [128]. The ITER-expected costs range from $7.6 billion to $9.3 billion. The planned schedule shows 10 years of construction and 20 years of experiments. The ITER program plans no actual electric power generation—only thermal power for scientific and engineering research. The United States, Japan, China, European Union, Russia, Republic of Korea, and India have joined the ITER agreement, which went into force in 2007. Plans call for a follow-on device based on lessons learned from ITER. DEMO, as it is called, would be the first nuclear fusion electric power plant [129, 130]. DEMO would start operation in 2050.

Unlike nuclear fission—which has a multibillion dollar, power-producing industry; hundreds of working electric plants across the world; U.S. naval vessels safely powered for decades; and multiple, ever-improving designs for advanced reactors—net fusion power through the official DOE planned program is decades away.

12. Nuclear Fusion—Inertial Confinement Fusion [131, 132]

As part of its nuclear Stockpile Stewardship Program, DOE does research on producing fusion by concentrating extremely high-power laser or particle beams for nanoseconds onto a small pellet of fuseable material. This research also may provide useful insight into fusion power production and other high-energy particle physics. It is not principally a power-production research program but seems often to be confused as such in public discussion and reporting.

13. Nuclear Fusion—The Farnsworth-Hirsch Fusor [133]

The DOE and international groups have invested hundreds of millions of dollars and decades on the tokamak approach. If all works well for the ITER, a fusion power plant will come online in 2050. However, a device derived from the Hirsch-Farnsworth fusor may enable operation of a fusion power plant to begin by 2015—or earlier.

Philo T. Farnsworth invented the electron tube technology that enabled television. He also discovered a technique to produce fusion with a sort of electron tube. The basic concept of the machine is the confinement of energetically injected nuclei into a chamber containing a positive grid electrode and a concentrically interior negative grid electrode. The injected particles fly through a hole in the outer grid and accelerate toward the inner grid. Nuclei fuse when they collide with sufficient cross-sectional energy in the center of the machine. Particle-grid collisions limit obtainable output power. This fusion method is known as Inertial Electrostatic Confinement Fusion (IECF). Robert Hirsch joined Farnsworth in his lab and developed a more advanced version of IECF, which uses concentric spherical grids.

Tuck, Elmore, Watson, George Miley, D.C. Barnes, and Robert W. Bussard have extended the research. Many people have developed "fusors" (including a high-school student), which produce fusion from deuterium-deuterium reactions but do not produce net power. These devices have been used as compact neutron sources.

14. Nuclear Fusion—Bussard Polywell Fusion

Dr Robert W. Bussard published results in 2006 claiming that he had achieved 100,000 times better performance than had ever previously been achieved from an IECF device [134–136]. Bussard's machine replaces the physical grid electrodes with magnetic confinement of an electron gradient known as a "polywell" that accelerates the positive ion nuclei into the center of the negative gradient. His paper in the 2006 proceedings of the International Astronautical Congress states that he had developed a design based on his previous success that, if built, would produce net power from fusion. Bill Matthews's article in *Defense News* covered the story in March 2007 [137]. In November of 2005, the machine achieved 100,000 times greater performance than any previous fusor. Analysis of those experimental results led Bussard to conclude that his design will produce net power. Bussard's company, EMCC, continues his work since his death in October 2007. Alan Boyle at MSNBC.com covered recent developments at EMCC [138] in an online column in June 2008, and Tom Ligon, former Bussard employee, wrote a combination history and technical description published in 2008 [139].

Bussard referred to his confinement mechanism as "magnetic grid" confinement. The system has no actual, physical electrode grids, such as in the Farnsworth-Hirsch machines. In Bussard's concept of a net-power-producing machine, the high-energy fusion particles produced from fusion would directly convert their energy to electricity. The high-energy charged particles resulting from the fusion will fly toward an electrical-energy-capture grid (not used for particle confinement) and expend their energy by being decelerated by this grid, which will be tuned to the energy and charge of the fusion products. The high-energy particles need not actually impact the grid and heat it. Rather, they can decelerate as the electrical grid extracts energy from the charged particle's motion, thus "pushing" a voltage onto the grid and yielding direct electric power from the fusion. About 25–35% of the power in this type of device will be in bremsstrahlung power, which will have to be thermally converted. The total power efficiency will probably be in the 60–75% range.

One of the great advantages of IECF is the potential to use boron and hydrogen as the fusing elements. In a Bussard fusor, a sphere—with a strong magnetic field imposed on it and electrons injected into it—would develop a gradient of those electrons, such that the center of the sphere would appear to a positively charged particle as if it were a negatively charged electrode (somewhat like the electrode grid of the Hirsch-Farnsworth device). Positively charged nuclei of boron and hydrogen would be injected at appropriate angles into the sphere and would "fall" into the negative well of electrons toward this virtual anode at the center of the sphere. If the particles do not collide with each other, they will fly an oscillating path within the vessel by alternately traveling toward the center of the sphere and then out toward the sphere limits until the force of the "virtual" negative electrode at the center of the sphere again attracts the positively charged nuclei toward the center again. If the virtual electrode has sufficient power (about 156 kilovolts for boron/hydrogen fusion), when the hydrogen and boron nuclei collide, they will fuse. A high-energy carbon atom will be formed, which will instantly fission into a helium nucleus with 3.76 million eV of energy and a beryllium atom. The beryllium atom will instantly divide into two additional helium nuclei, each with 2.46 million eV of energy. Boron and hydrogen, when fused in this matter, produce 6.926 E13 joules/kilogram.

To place this ability in context, the United States consumed from all sources (e.g., nuclear, fossil fuel, and renewables) in 2007 approximately 107 exajoules (E18 joules). One hundred thousand kilograms of boron-11 with the proportional amount of hydrogen (which would be vastly smaller than the amount required for a "hydrogen economy") could produce about seven times more energy than the United States consumed from all sources by all modes of consumption in 2007. Therefore, (assuming 100% efficiency for simplicity's sake) about 120 metric tons (not 100 tonnes, because only boron-11, which is 80% of natural boron, gives the desired fusion with hydrogen) of amorphous boron would provide equivalent power for all U.S. energy needs for over 6 years. About 1.8 million metric tons of boric oxide (about 558,000 metric tons of boron) were consumed worldwide in 2005, and production and consumption continue to grow [140]. The United States produces the majority of boron yearly, although Turkey reportedly has the largest reserve [141]. At $2 per gram for 99% boron, the cost in raw boron to produce six times the United States 2007's energy supply (not just utilities but *all* energy) would be $240 million (120,000 kilograms × $2.00/gram)—6 years worth of U.S. power for a little more than the price of coal to run one coal-fired power plant for 1 year.

If a Bussard power plant consumed one gram of boron-11 per second, this fusion rate would produce approximately 69 gigawatts, roughly the simultaneous power output of 69 major electric power generating plants—more than one tenth of all coal-plant power generation in the United States. About 320 kilograms of boron-11 fuel ($640,000 worth of boron) at one of these fusion plants would provide 1 year's continuous power output at 700 megawatts. A typical coal-fired electric utility power plant nominally produces 500 megawatts of electricity, but it requires about 10,000 short tons of coal *per day* (a short ton is only about 91% the size of a metric ton). A short ton of coal for electric utilities cost around $56 in 2008. So, one day's worth of coal for a single coal-fired plant cost about $560,000, and a year's worth for a single plant cost over $204 million. The United States has approximately 600 coal-fired power plants, about 500 of which are run by utility companies for public power. A 500-gigawatt (or even larger) Polywell fusion plant (which could cost less than $500 million to build) built to replace a coal-fired plant will pay for itself by coal-cost savings in less than 3 years of operation if the charge per kilowatt-hour remains constant. Because the fusion plant has fewer moving parts and fewer parts in general, it should be less expensive to maintain and operate as well.

Over the past year, Bussard's Company, EMCC, has built a new device to verify and extend the 2006 results. Contingent on continued funding, a prototype power plant with 100 megawatts of net power production could be built at a cost less than $300 million, and producing power within 5 years—perhaps as early as 2015. Because of the nature of this device, the power output versus input is directly proportional to the seventh power of the radius of the containment sphere. A 100-megawatt power producer requires a sphere about 3 meters in diameter. A gigawatt power producer would require a sphere approximately 15–20 meters in diameter. EMCC's decade-ago designed machine size for a 100-megawatt generator to power a naval vessel is a cylinder about 20 feet in diameter and 30 feet in length.

With no way to convert a Bussard Polywell machine to a bomb, no radioactive waste produced, small relative size, ability to operate on abundant boron and hydrogen fuel, relatively inexpensive to build, and only moderate operational safety issues (high voltage and X-ray emission during operation), these machines offer a path to a magnum advance in civilization; elimination of the carbon emission aspect of climate change; a whole new realm of platform propulsion capability and deployed electricity abundance for the U.S. military; and abundant, inexpensive energy for all who adopt its use. These machines could be exported worldwide without concern that they would proliferate nuclear bomb technology.

15. Getting Off the Grid & Less-Tethered Logistics—Solar Power and Distributed Fuel Production

Some options on improving security robustness include finding ways to not be tied to a grid. Relieving the tether to a grid must address providing not only electricity to homes and facilities, but also vehicle fuel. Distributed solar power and alternative fuel production offer an opportunity to distribute power production and eliminate distribution bottlenecks.

As solar cells decrease in cost and increase in energy conversion efficiency, at some point they may be so economically attractive that many U.S. households will start installing them as their primary power. Coal-powered electricity currently costs 5 cents per kilowatt-hour. As reported in the June 21, 2008, *Economis*t magazine [29], the cost of a kilowatt of solar photovoltaic power went from 50 cents in 1995 to 20 cents in 2005 and continues the downward slope. In comparison, wind power costs about 8 cents per kilowatt-hour. Large-scale wind farms require a grid, but single-building windmill generators and building-mounted photovoltaic cells do not require the electric grid to power that building.

Various researchers have recently announced breakthroughs that should increase photovoltaic power-output efficiency, lower cost, and make production and deployment easier. Photo cells with greater than 40% conversion efficiency have been demonstrated [142], while less efficient cells are being produced in mass quantities that will potentially drive the cost of solar power below that of coal power production [143]. The renewable industries are making steady advance toward cheaper-than-coal electricity.

The solar industry is only a tiny fraction of the current national power production, but is growing by 50% per year. But just as the wind doesn't always blow, the sun doesn't always glow. To free facilities from the grid with solar and wind power, some commensurate improvement in electricity storage must emerge—also at affordable prices. However, even if only daytime solar power were available, cost of additional utility power backups could be reduced.

Let's examine the numbers for solar energy requirements for a simple example—a home. A forward-deployed, solar-powered military unit away from easy-access fuel logistics might be comparable to a home. Homes in an area where grid power had been shut down or otherwise not available would be the exemplar for not having to rely on the power grid. A large, all-electric house at maximum power consumption would need 12 kilowatt on-demand production. A 5-meter by 10-meter solar panel array, which could easily fit on most home roofs, could produce that much power if the array could achieve 24% conversion efficiency. Current technology for commercial photo cells is less than 10%. But let's assume the homeowner could deploy a 15-meter by 15-meter array that, even at 6% efficiency, would produce more than enough power when the sun is shining. Sun certainly does not always shine with 1.5 kW/m^2 ground incidence, as in ideal circumstances, but various options exist for electrical storage, and technology will improve. Assuming 12 hours of 1 kW/m^2 daylight, to enable the residents with 6-kW consumption through the night requires 12 hours × 6 kW = 72 kilowatt-hour storage.

Lithium batteries could certainly accommodate that requirement, but they are expensive. Flow batteries and fuel cells are options. Perhaps ultracapacitors, as previously mentioned in the electric-vehicle section, will soon be available at a price that would enable large-scale use. Storage mechanisms continue to improve in performance and price. The MIT-Nocera potential breakthrough in hydrogen production from water may be the needed enabler in energy storage to make solar power predominate [41, 42]. The research has suggested the promise, but an engineered prototype is an undetermined time away.

Another example of useful progress in photovoltaics comes from MIT researchers, who reported this year a mechanism to capture sunlight in a window-like solar concentrator that consists of a plastic or glass plate coated with a light-absorbing dye [144]. The light entering the window is absorbed by the dye and re-emitted toward the edges of the window, where it can be converted to electricity by photovoltaic cells. The window acts as a solar collector/concentrator that does not need to mechanically track the sun's motion. Others have proposed photo cells that could achieve 80% electrical conversion efficiency [145].

With the combination of extremely high-efficiency energy conversion and a mechanism to collect light from a large area created by the marriage of these two technologies, one could transport power over long distances via laser. Example military uses could include beaming power via high-efficiency laser on nuclear-powered naval vessels and charging, with the laser light, an unmanned vehicle's electrical storage unit. An unmanned vehicle could thus deploy indefinitely as long as the laser could periodically hit its recharging, light-collecting window with enough laser power. This concept gives another look at going around the typical power delivery infrastructure.

What about distributed fuel production? Algae grow everywhere. Everywhere people live, they make waste streams of sewage and garbage that can be turned into fuel. Technologies previously discussed (e.g., CWT and/or Green Power, Inc.) could generate diesel, and perhaps gasoline as well, from waste and from algae. The processing technology is not that of the typical refineries used for petroleum. Such fuel-production technologies could be built in many sites across the country to take advantage of the waste streams and distributed growth of algae. If fuel were produced from distributed inputs in towns and cities across the nation, production and distribution vulnerabilities from the infrastructure bottlenecks just about disappear.

ADOPTING SOLUTIONS—A TOTAL SYSTEM'S APPROACH

As previously discussed, the total scope of defense and energy security is broad and complex. The DoD faces internal strategic, operational, fiscal, and environmental challenges, such as the military implications of climate change in operational tempo and force structure, as well as mitigating energy infrastructure vulnerabilities both for its own assets and the nation's. Further, the nation and DoD, as a consequence, are impacted by the economic drain of high oil prices and the bondage to foreign oil, the possibility of denial of access to foreign oil, broader infrastructure vulnerability, and the homeland security implications of climate change. Energy security is complex and cross-disciplinary in nature, and requires the coordinated application of various solutions. Let's examine a set of options informed by the solution set just discussed that can address all of these requirements.

More Fossil Fuel

One approach to getting additional energy is to mine more fossil fuel by converting coal to fuel and by drilling for more oil and natural gas. This tactic will produce energy sources. Whether the cost of energy would be substantially reduced is not certain. The demand from China, India, and other emerging societies could swamp any such fossil-fuel, supply-side increases for a fundamentally nature-limited resource. Both oil and coal are finite commodities. The required time to develop a new oil field is not exact, but projections [12] suggest 5 to 10 years for significant new amounts of oil reaching the market as a new reserve is explored. The cost of converting coal to oil could wash out any financial benefit and more rapidly deplete the known coal reserve. The FT process would require carbon sequestration to prevent a huge increase in fossil-fuel-based carbon emissions and would raise the price for the fuel produced.

Efficiency

Less energy would be required by using it with greater efficiency. Current automobiles and trucks achieve about 20–25% efficiency of energy use. Converting fossil fuel to electricity consumes about 64% of the quads available in the fuel. Certainly, for vehicles, multiple options can improve fuel efficiency: to at least 50% with new heat engines, perhaps 60–80% with fuel cells using alcohols or even current fuels, and as much as 95% with all electric vehicles. Efficiency in airplane fuel consumption (airplane consumption is a tenth that of the car and truck fleet) can also improve by at least 30% and perhaps double in efficiency. The technologies are no longer research, but require significant investment to make them commercially abundant and affordable. The potential impact of a low-cost, high-energy-density electrical storage mechanism (such as the reported ultracapacitor from EEStor) cannot be over emphasized. All ground vehicles could quickly evolve to all-electric power, and some issues related to stationary power from renewable sources would resolve. Upgrading coal/gas power plants to combined-cycle power production can increase electrical-energy production efficiency.

The U.S. military could play the key role in making these investments for vehicles and become the first to derive the benefits in improved operational capability at lower cost and less logistics burden. This tactic will help alleviate infrastructure vulnerabilities and perhaps mitigate climate change effects the military would have to prepare to handle.

Renewable Fuels

Many renewable fuel options could service the task of developing renewable energy sources for fuel and electric grid power. Brazil has already shown that a large country can achieve oil independence with renewable fuel. However, governmental supervision must ensure that approaches to renewable fuel do not, in themselves, harm the environment and do not deplete or drive up the cost of other crucial commodities, such as food grains and, therefore, must not monopolize land needed for food crops. Various approaches to turning waste into fuel and to producing fuel from algae offer potential abundant, inexpensive petroleum substitutes. If the military and government help to develop this industry by providing an assured demand at an acceptable price to both fuel consumer and provider, the industry should be able to quickly (less than 15 years) fill the reduced demand achieved by increased efficiencies.

In 2008, wind power is still about 60% more costly than electricity from coal plants. Solar power is over twice as expensive as wind power. But the technologies are improving, and the costs to produce power are plummeting. The potential for distributed power—which removes customers and facilities from dependence on the grid—is, in itself, a huge security boon that could help alleviate infrastructure vulnerability problems.

Photovoltaic power could be particularly valuable to the military. Especially as conversion efficiencies increase, the military could use high-energy lasers to deliver power to unmanned vehicles and other remote locations. All-electric vehicles with high-density storage could stay deployed or engaged in mission indefinitely as long as they could replenish charge from time to time by laser via their photovoltaic arrays. Emerging approaches to photovoltaic technology suggest the possibility of 80% conversion efficiency per cell. An interesting synergy might derive from using the MIT window-light-gathering unit combined with the high-efficiency photovoltaic converters to provide a compact power array, while most of the area it occupies on the surface of the vehicle can also be used for radio frequency sensors or communications arrays.

A market with government incentives could quickly make wind and/or solar preferred electricity providers for various applications.

Nuclear Energy-Polywell Fusion

The use of nuclear energy can be expanded by developing and deploying the Polywell machine. Nuclear fission technology has unresolved challenges: potential for weapons proliferation and nuclear terrorism, continued international stress and military requirements from trying to prevent nuclear weapons proliferation, nuclear accidents at power plant and processing sites with potentially catastrophic results, long-term waste storage and environmental contamination, and the high cost for plants and slow return on investment. Polywell fusion avoids all these issues.

As far as can be determined without actually building a fully power-producing nuclear fusion plant of the Bussard Polywell kind, this technology has been demonstrated and is being developed. A Polywell power-producing plant that uses non-polluting boron-11/hydrogen fusion should be constructed and operating by 2015—according to current plans. Proliferation of this technology will not threaten the U.S. security from nuclear bomb proliferation and would remove an excuse for rogue countries to claim that they need to develop fission power for commercial uses.

Summary Solutions

In summary, the U.S. government could establish policies and programs to quickly build a Polywell fusion plant and enable a fusion industry based on this technology; replace the national vehicle fleet with one that uses high-efficiency engines and slashes energy demand with hybrids and/or all-electric drives; develop a renewable fuel industry with government emphasis and oversight so as to avoid unintended negative consequences; invest in photovoltaic cells for military use; use government demand for energy products to encourage industry growth and lower costs; and insist that DoD incorporate energy use as an essential, integral element in requirements setting and acquisition.

Military Prep for Some "Worst-Case Scenarios"

It has been said about the September 11, 2001, terrorist attacks on the United States that they were "unthinkable." How does a military or national security authority defend the United States if its support staff does not push itself to think the "unthinkable" and, thereby, identify needed remedies and precautionary measures? With this question in mind, let's take a quick look at some "unthinkables" regarding energy security for which the U.S. military and nation must be prepared. Let's ask some questions to promote *thinking responsibly*.

Robert Duncan, in his Olduvai theory [146], projects an end to industrial civilization should the world run out of petroleum.

There are certainly other ways than petroleum to power civilization. But the United States and its allies are not self-sustained in petroleum production and rely on parties whose interests often do not coincide with ours. The world can quite literally run out of producible petroleum, but even before that event, petroleum can serve as an economic weapon and can be cut off from delivery to the United States. Such a denial of access can come from a contrary political decision from abroad, by weather and other aspects of nature, and by terrorist attack (no matter what the national source or philosophical bent of the terrorists), by criminal action, by war waged upon our nation, or by acts of war between other nations. Disruption in shipping of oil could be devastating and is not "unthinkable." The DoD would play a key role in dealing with these potentialities. How should the DoD prepare?

Access-denial problems also pertain to the delivery of electricity and fuel within the homeland and to military facilities at home and abroad. The United States has never faced wide-scale power outages that last for months or even years. The results would be devastating. The DoD's mission of national defense suggests that the DoD must actively engage to provide energy access assurance by various means, including infrastructure protection, augmentation, and off-loading. The national command authority's broader responsibility suggests that industry's engagement and partnership is essential and must be informed by national security needs and guidance, which the military is qualified to provide. What missions, structures, and agreements need to be defined that are not?

A 2003 Pentagon-commissioned report [147] on the security implications of climate change, the *National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030* report to Congress [6], together with the IPCC 2007 [17] report, which tied together climate change and energy use, all suggest that DoD must again think the "unthinkable." What if the oceans rise, crops fail, large populations migrate, resource wars proliferate, nuclear powers confront one another over tightened resources springing from climate change, the economy tanks from rocketing energy prices, terrorism is intensified and expanded, and the military is tasked to stability operations in multiple places, including perhaps within the homeland? How can the DoD's strategy toward its own energy use help defuse the climate issue within its own lifelines and in the broader national community?

"What's the worst type of biological attack or limited terrorist nuclear attack against energy such as pipelines, oil fields, or shipping choke points? What part of the world or against what population, nation, or infrastructure would be attacked? What risk mitigation or repair needs to be in place? Is it ready? Or, what if the military had to deal with the most significant implications of climate change, as suggested by the Pentagon report? Or, what if there were no more oil to be had?" Asking such questions can only help DoD prepare and be ready for the "unthinkable."

One of the most dangerous events that can happen on a naval vessel is a fire. The U.S. Navy excels at damage control, such as the heroes of USS *Stark* showed in the 1980s. A fire usually starts small and can be put out by a single sailor with a bucket of water or fire extinguisher if detected early by the watchstander. If discovered after 15 minutes, the fire's firefighting requirement can include the entire crew. Who has the watch for energy security?

Military Prep for a "Best-Case" Scenario-Technology with Inspired Leadership

The DoD can lead the way in developing and implementing many changes in technology and energy resource use. The military can begin to incorporate logistics (and energy logistics in particular) integrally into total DoD capability requirements and acquisition processes. The DoD can invest development and acquisition dollars to enable rapid deployment of new forms of energy and energy conservation that do not decrease capability, but increase operational capability. The federal government, as a whole—with its buying power for energy-using equipment and energy sources and policing guidance—can prevent the vagaries and perhaps excesses of the free market from contributing to energy security problems.

The military has a historic opportunity to influence production of high-efficiency land vehicle engines. The wars in Iraq and Afghanistan are wearing out the land vehicle fleet. The Army and Marines will have to reconstitute, which means buying tens of thousands of new land vehicles. If DoD established a demand and industrial infrastructure for high-efficiency engines, electric hybrids, and perhaps even all electric vehicles, not only could DoD cut its future fuel consumption dramatically and logistics force, but would also spin-off the benefits to the entire country. Rapid development of an electrical storage device, such as promised by EEStor, would create several revolutions in alternative energy use and production.

The military is investing in high-efficiency aircraft engines, as the DSB 2007 report identified. With incorporation of fuel use as a key performance parameter in all acquisitions, rapid deployment of such technologies could become a priority. Again, the entire nation would benefit as airlines were able to use such assets.

In trying to relieve possible infrastructure vulnerabilities, the military can promote more rapid deployment of wind and solar power, which would not only contribute to a distributed military power system, but a distributed national power system. These power sources, if used to charge electric and plug-in hybrid vehicles, can produce quads of energy that would otherwise have to be imported as petroleum. Wind and solar have the additional benefit of not contributing to atmospheric carbon and that, in itself, can be both a security bonus, as well as a public relations bonus. Creating high-efficiency and inexpensive photovoltaic technology helps everyone, and the military may get a particularly useful benefit from it by allowing a tether-free approach to refueling forward-deployed vehicles and units, both manned and unmanned.

The Bussard Polywell fusion machines can be quickly prototyped, contingent on funding. The Navy could particularly benefit from a relatively inexpensive and compact power source for naval vessels that needs no refueling for years and does not share the issues that nuclear-fission power plants have. Polywell technology offers the opportunity for a new world civilization that does not have energy constraints suffered by the current fossil-fuel-based civilization.

The DoD is the largest single consumer of petroleum products in the nation. Its purchasing actions can be determinative in promoting development of an alternative fuel industry. According to a report from the Congressional Office of Technology Assessment [148], the U.S. government owned over a half million land vehicles in 1989. According to that report, the federal government keeps vehicles from 3–6 years and, consequently, buys about 100,000 vehicles per year. The DoD and Postal Service each owned about 30% of this fleet. According to Department of Transportation statistics [24], the government as a whole used about 6.3 billion gallons of vehicle fuel in 2006, of which about 3.89 billion gallons were DoD JP and aviation gas, and 1.7 billion gallons were DoD diesel use. The federal government and DoD especially are major vehicle and fuel customers, with the potential for great influence with purchasing power and development investment.

The military—together with the additional purchasing power of the entire federal government, which owns and operates these mass quantities of vehicles—can set a target of buying exclusively alternative fuel, set the standard for that fuel and police that standard, and develop an industry of suppliers by guaranteeing a certain level of purchase at a certain price. No one in the private sector has comparable resources or the flexibility to so act as a monolithic buyer. The best alternative fuel options and best alternative fuel production options can be guided largely by the military. The various and many alternative fuel technologies can compete in a guided competition orchestrated by DoD. The competition would result in an industry that can provide not only all DoD fuel needs, but is launched to provide national needs.

The DSB Task Force in its 2008 report specifically recommended that a single office be installed in DoD to orchestrate all such matters energy-related and be resourced with at least $500 million per year and be given technical laboratory support. When has there been a better time to “make it so”?

Just as recessions for the last 40 years have resulted from high oil prices, the economic booms of the 1960s and 1990s benefited greatly from cheap oil. But oil is a limited resource, a world commodity largely beyond U.S. control or control of its first-world allies. A best-case scenario for energy can be achieved with abundant availability of renewable fuels produced in the United States and all countries (such as from algae) from high-efficiency use of fuels, especially from high-efficiency vehicles; from rapid deployment; and from price reductions for abundant sustainable energy sources such as wind, solar, and Polywell fusion. A world of abundant energy would be a world of abundant water resources and food. Abundance could contribute substantially to world stability and greatly influence military force requirements.

GENERAL OBSERVATIONS: ENERGY, SECURITY, CHANGE, & COMPLEXITY

Diverse Challenges and Responses—A Clear and Present Danger

The current global status of energy cost, access, potential disruption of use, and climate change related to energy use constitute a clear and present danger to the United States and its allies. Because of the complexity and breadth of the energy security issues and problems, no single solution, no single technology delivers the robustness of responses required. However, many Knights on White Horses (KOWH) are racing to the rescue. Various targets of opportunity present themselves for resolution. Controversy and debate surround some approaches. Let’s sum this up and call for action.

KOWH—Nuclear Fission. Some environmentalists (such as James Lovelock), nuclear engineers, and power companies tell us that non-carbon-producing nuclear fission power can replace our use of fossil fuel [149–153]. By building several thousand nuclear-fission power plants around the world (only about 400 exist today), the supremacy of petroleum and the power of petroleum-owning states can be lessened, the potential economic ups and downs of petroleum reliance alleviated, and the potential end-of-oil scenario avoided, while global warming may be slowed, and the worst effects of climate change may be averted. Opponents argue with challenges of nuclear waste disposal, environmental contamination from processing and perhaps reactor accidents, nuclear proliferation dangers, and the high cost of the facilities [125, 154, 155). An advocate such as James Lovelock tells us about the revival of Mother Nature around Chernobyl since humans have deserted the place. However, opponents also point out that full proliferation of nuclear fission as the way out of the current energy conundrum means a multimillennial commitment of trust in the goodwill, willpower, perseverance, consistent competence, and unyielding management of a nuclear fission industry for the good of man above other motives, such as profit. Such opponents suggest that a breach in this trust for hundreds of thousands of years into the future could cause the extinction of mankind. Proponents suggest that even with today’s fission technology, the power plants in the United States are safe and reliable alternatives to imported energy, and research can resolve all other issues.

KOWH—More Petroleum. Oil companies tell us that they must explore and drill more, and that oil simply cannot be replaced in this half of the 21st century. The Saudis, with the largest proven oil reserves, tell us that they have plenty of oil to fuel civilization but refuse to release information to prove the assertion [11, 156]. Neither are they producing prolifically extra oil. Various experts, however, believe that "peak oil" has arrived. To the contrary, some traditional energy experts point to the vast quantities of shale oil and tar sands, which may have become economical to mine—though they may have to break some environmental eggs to make that omelet.

KOWH—Renewable Fuel. Many, many people are trying to cost effectively produce renewable and synthetic fuels to replace petroleum-based fuels. Algae, switch grass, sewage, agricultural waste, plastic garbage, food crops, wood chips, jatropha, and carbon plucked from the atmosphere all offer the potential to serve as replacements for fossil fuel. Advocates show, with convincing figures, that the entire national requirement for energy, and even excess for export, can be produced in this country from these sources, with the added benefit that they are "carbon neutral" because their use will release to the atmosphere only carbon, which is taken from the atmosphere to produce the feedstock.

KOWH—Fischer-Tropsch. Among other fuel ventures, the U.S. military is investing to produce synthetic fuels via the venerable, old FT process, which the regimes of Nazi Germany and apartheid South Africa used to produce fuel from their abundant supplies of coal. The Air Force feedstock would be natural gas. FT is energy intensive, approximately doubles carbon pollution versus simply burning petroleum, and the FT facilities are expensive to build. However, folks with lots of coal to burn tend to be strong advocates of FT deployment. China is moving quickly to build a host of FT plants—an 80,000 barrel per day plant prices at about $5 billion which is about twice the price of an oil refinery with the same throughput.

KOWH—Wind and Solar Power. "Alternative energies" do not own much of the market right now, but new developments are quite promising. Solar power has been held back because of poor efficiency in conversions and other technical and cost aspects, but recent new technical breakthroughs may change that situation rapidly. However, solar power is only a fraction of a percent of current electricity generation and costs at least double wind power per kilowatt-hour. Wind power costs about 8 cents per kilowatt-hour compared to coal's 5 cents per kilowatt-hour (the cheapest today). Wind power appears about to take off and power much of the electric grid. The recent push by T. Boone Pickens certainly does not endanger that prospect.

KOWH—Nuclear Fusion. Nuclear fusion power has seemed to be perennially 5 decades away from net power production, as it was in the middle of the last century, and still appears to be—even by the most recent international plans concerning the ITER and DEMO projects. However, a very significant piece of just-demonstrated technology, Polywell fusion, may quickly bring fusion power to reality by 2015.

KOWH—The Hydrogen Economy. Can technology overcome all the problems with producing, storing, and transporting hydrogen to enable the *hydrogen economy*? Versus all the other alternatives, is hydrogen fiscally, environmentally, and logistically worth the efforts?

Targets of Opportunity—DoD and Transportation. Transportation is U.S. oil's Achilles' heel. Oil does not contribute substantially to grid power. Rather, it drives cars and trucks, and flies airplanes. However, will the industries that produce cars, trucks, and airplanes (which account for about 70% of U.S. oil consumption and about 30% of carbon emissions) affordably utilize new technologies available to them to provide vehicles that do not waste 75–80% of the fuels poured into them? Vehicle energy consumption equals U.S. oil imports. Producers and proponents of extremely high-efficiency engines, hybrid plug-ins, and all-electric vehicles argue the advantages of conservation, which does not have to mean less capable or more costly vehicles. Vehicle heat engines with 50%+ efficiency would cut oil imports by about 50% even if they used standard petroleum-based fuel. Their use of renewable or synthetic fuel would eliminate imports while reducing the amount of renewables infrastructure needed. An all-electric fleet powered by electricity from windmills (or other sustainable/renewable domestic sources) would simultaneously eliminate oil imports and looming oil-refinery undercapacity, which may exceed 8 Mbbl/day worldwide by the end of the next decade.

The U.S. military uses less than 2% of the total U.S. oil consumption. But the military wants to ensure itself a source of fuel and is pursuing various technical alternatives to do so. DoD faces significant cost and operational capability problems today because of past practices of largely ignoring total fuel costs, ignoring fuel efficiency in platforms acquisitions, and in setting operational requirements and analyzing how to fill those requirements. As the Army and Marines have totally worn out their land vehicle fleets (purchased under Ronald Reagan as Cold-War deterrence) in the current two-front South Asia war, they and the nation are presented with a world-historic opportunity. Within 2 years from initiation, the military could prototype and validate a combination of extremely high-efficiency engines, electric hybrids and all-electric vehicles, as well as develop the organizational processes to include all of logistics and, especially, energy logistics integrally into future force design and acquisition. The development and validation could be done for much less than a billion dollars, which is less than the price of a single day's U.S. oil imports, or about 2 weeks of military fuel consumption costs at $4.00 per gallon of fuel.

If the military preferentially buys these fuel-efficient alternatives and develops a reliable market for them, a new industry—able to provide the American public cost-effective fuel efficiency—can prosper. Similarly, military and NASA demand helped jump-start the semiconductor industry over 40 years ago,as well as helping develop radar, communications, and computing technology. Today, an all-electric, high-performance military truck or HMMMV-like vehicle, with range exceeding 500 miles, and which could be recharged by solar panels, is technically achievable, even if expensive. Repeated experience seems to indicate that military investment can drive down the cost of new technology to the level of consumer affordability. In the process of saving the U.S. citizen's money and making the country more secure by reducing or eliminating oil imports, the military could provide itself with more flexible, logistics-reduced, operational capability.

The United States has the best potential to lead the world through these rough times in partnership with both long-time allies and emerging, responsible international partners, such as China and India. A coalition of North America, the rest of the former British Empire, other NATO nations, Israel, Japan, Korea, China, India, and Brazil could lead the world into a new civilization through the huge readjustments required, while avoiding large-scale, full-fire belligerence.

Energy and the Environment [6, 17–19, 157, 147]. Climate change is happening and has happened multiple times in human history. Global warming could produce widespread political instability and resource wars, the spread of tropical disease to northern latitudes, and famine from loss of crops in prime, arable land that would rock civilization. The United States would face reengineering its infrastructure and, to some extent, the economy, and switching away from carbon-emitting energy use, while being ready to act in many places in the world to foster/enforce stability and not allow a general international collapse. Prudence suggests that the potential catastrophes of climate change and its causes be considered and addressed as the United States and DoD approach energy security solutions.

Taking Action The various technical solutions already discussed in this paper should indicate that the United States faces no physical dearth of energy sources. And these KOWHs will eventually come home. The United States is confronted primarily with a leadership challenge. The challenge is as much economic, business model, and worldview, as technical.

Acting wisely could bring a new age of plenty, with energy enough to export, to create excellent jobs and new career fields, to provide more bang for the buck in the military, to establish national security, to promote international stability and prosperity, and to discourage the causes of extremism. The DoD could lead the way in prototyping new energy technologies and establishing market demand for them. With that potential transformation comes the removal of energy scarcity as a cause of inflation and economic woe, and mitigation of the impact of climate change. Such is the promise for prompt and wise action.

WHERE TO NOW?

"True wisdom is less presuming than folly. The wise man doubteth often, and changeth his mind; the fool is obstinate, and doubteth not; he knoweth all things but his own ignorance." Ahkenaton [158]

In a 2004 speech [156], Ali al-Naimi, the Saudi Arabian Minister of Petroleum and Natural Resources, suggested that the world was not even close to "peak oil," that the Saudi oil reserve projections were very conservative, that they could produce oil for another 100 years, that they could easily raise daily production by 10–15 Mbbl/day (more than their daily exports to the United States) to stabilize world supplies and prices, and that the Saudis were dedicated to keeping the $22–$28 price-per-barrel range for OPEC oil. What happened? The author of *Twilight in the Desert* suggests that the Saudis have passed peak oil production, and cheap oil from the Saudis just is not there to be had.

Many alternative fuel production options offer the ability today to provide nonfossil, renewable fuel but need help to establish national-level production capacity. Emerging and already available transportation vehicle-efficiency options could dramatically cut petroleum demand and within years (not decades) eliminate U.S. petroleum imports. Several extremely promising technologies will likely overtake fossil fuel in producing grid electric power and will produce it inexpensively and reliably, while eliminating problems of using fossil fuel and nuclear fission. But which voices will leadership heed, where will the choices lead, and will they act with sufficient speed?

In his book, *Collapse*, Jared Diamond [159] describes in detail how some rather famous lost societies chose not to husband their resources, chose not admit to their existential resource problems, and thus failed to make absolutely essential changes. Although some argue that the coming of "peak oil" entails the end of industrial civilization, such need not at all be the case. A society and, for that matter, our military that runs on energy and can be economically devastated by fluctuating energy prices, must guarantee itself responsible access to energy or the Olduvai consequences might arise.

Strong, united national leadership; rapid, concerted exploitation of new technologies; and truly admitting that "we must change" can bring the United States and the world to a safer, more prosperous civilization than ever before. Energy runs modern civilization, and defines standard of living and military power. Energy exploitation and climate change appear to be linked, and though climatic change is unavoidable, we can wisely consider it while addressing energy security. We can add robustness to our infrastructure, prudently maximize use of our resources, accelerate adoption of needed changes, guide the free market to help, rather than to exacerbate problems, and protect those least able to fend for themselves. Government must lead. The largest energy user in the government, DoD has many paths to better use fuel and realign force structure for better mission capability with less fuel.

The potential for catastrophe is real. The United States must not wait for desperate times and then take desperate measures. Winston Churchill said, "An optimist sees opportunity in every danger, a pessimist sees danger in every opportunity." Vast opportunities surround us.

APPENDIX A—ENERGY STATISTICS AND THEIR IMPLICATIONS

Some Useful Energy-Related Units and Measures [160, 161]

- An International Table British thermal unit (Btu) = 1055.06 joules.
- A million billion Btu (i.e., 10E15 Btu) is called a quadrillion Btu or simply a "quad." The United States uses about 100 quads a year.
- 1 quad = 1.05506 E18 joules; 10E18 joules is called an exajoule.
- Thus, 1 quad is approximately 1 exajoule (actually 1.05506)
- 1 barrel of oil equivalent equals 5.8 million Btu (MBtu).
- One barrel of oil is 42 gallons.
- A gallon is a measure of volume.
- A ton of coal is an English unit measure equal to 2000 pounds.
- A tonne (metric ton of coal) is 1000 kilograms (which is about 2200 pounds).
- One ton of coal equivalent equals 25.2 MBtu.
- One tonne (metric ton) equivalent equals 27.5 MBtu.
- A watt is a unit of power or expenditure of energy over time:
- 1 watt = 1 joule/second (i.e., it takes a joule of energy each second to deliver a continuous watt of power)

Power is often given in thousands of watts known as kilowatts, millions of watts known as megawatts, billions of watts known as gigawatts, or even a million times a million watts known as a terawatt. The U.S. electrical power system at peak power can produce about 1 terawatt.

When calculating how much power was delivered for how long, the units are frequently given in kilowatt-hours. The number of kilowatt-hours for a battery or other electrical storage system for an electrical vehicle is an indicator of the range of that vehicle. If a vehicle requires 15 kilowatts of power to drive a vehicle at 55 mph, and the vehicle travels for 4 hours at 55 mph and thus 220 miles, then the electrical storage system had to have a capacity of at least 15 kilowatts times 4 hours or 60 kilowatt-hours (60 kWh).

1 kilowatt-hour of electricity equals 3412 Btu

Running the Numbers on U.S. Energy Demand

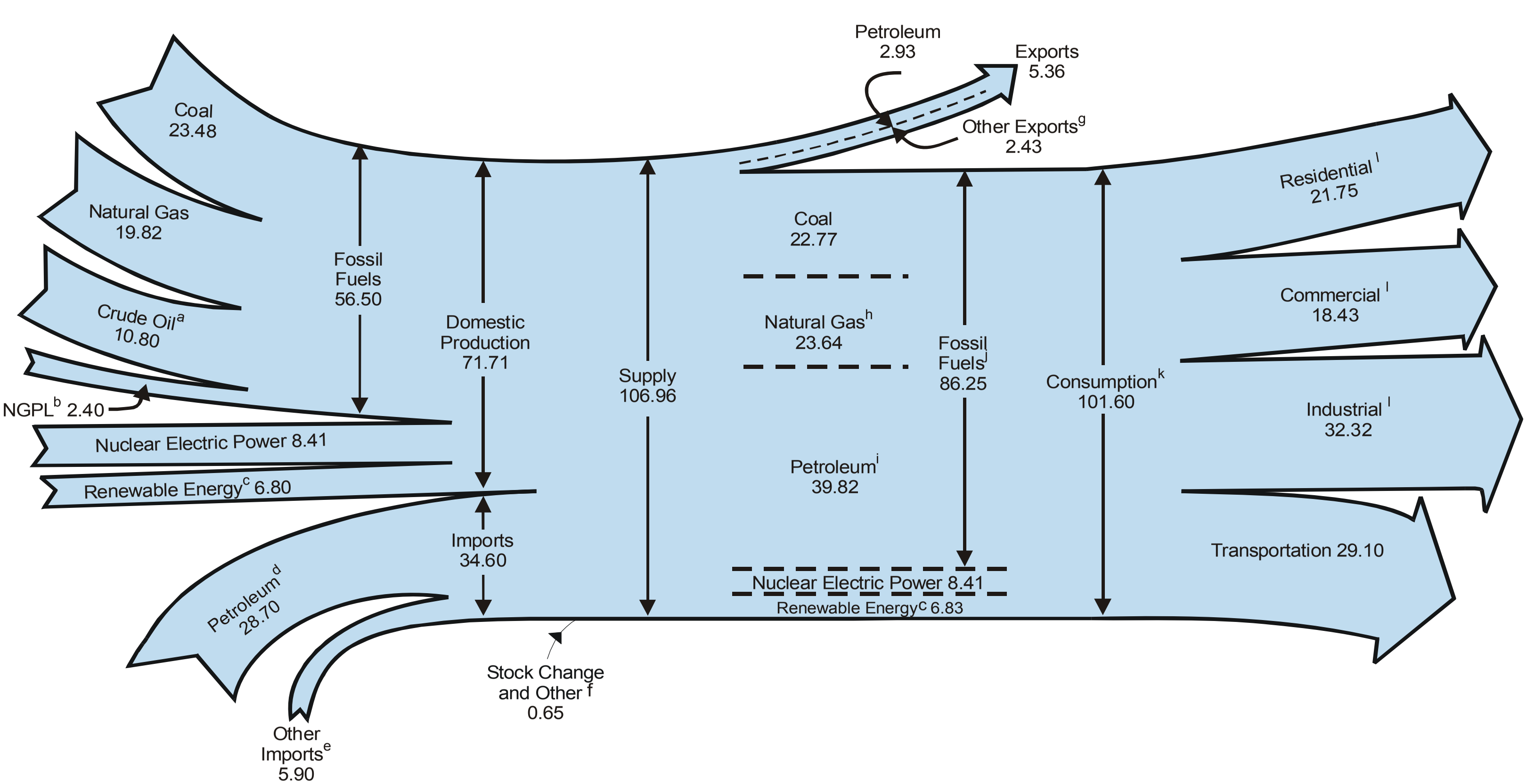
The following statistics reveal a crucial aspect of U.S. energy vulnerability. To grasp the magnitude and nature of the vulnerability, one must look closely at the numbers. The DOE's EIA produces a wealth of documents and statistics on energy, including sources and means of production and consumption of energy. The following information comes from EIA statistics.

How much energy does the United States use and where does it come from? According to the EIA's Annual Energy Review (AER) 2007 [14], in 2007 the United States consumed a total of 101.6 quadrillion Btu (quads) of energy from all sources. In total, the United States imported 34.6 quads of energy. About 83% of the imported energy was petroleum in the form of crude oil or refined petroleum products. Diagrams 1 through 5 are taken from the EIA 2007 AER. Diagrams 1 and 2 elegantly show, respectively, the total U.S. energy input and consumption flow, and the total petroleum flow. The statistics cited below are slightly different from those in the diagrams because of numerical rounding.

Looking at the total energy picture, not just petroleum, U.S. 2007 total domestic contribution to energy supply (101.6 quads minus imports) came from the following sources: *Coal 23.48 quads, Natural Gas 19.82 quads, Domestically Produced Crude Oil 10.80 quads, Natural Gas Plant Liquids 2.40 quads*, Nuclear Electric Power 8.41 quads, and Renewable Energy 6.80 quads. In addition to these domestic energy products, the country imported 34.6 quads, including 28.7 quads of petroleum and 5.46 quads total of natural gas, coal, coal coke, fuel ethanol, and electricity. The United States also exported 5.36 quads, of which 2.93 were petroleum. Therefore, the United States imported 28.7 quads of petroleum of the total 101.6 quads of energy consumed. Except for petroleum imports from outside of North America, continued U.S. access to energy seems well in hand. But how the U.S. accesses and uses petroleum is crucial to the energy security question.

The U.S. total daily petroleum consumption in 2007 was 20.698 Mbbl/day, while 2006 daily consumption equaled 20.697 Mbbl/day, and 2005 was 20.802 Mbbl/day. Imported petroleum for 2007 equaled 13.439 Mbbl/day and came predominantly from nine countries: Canada (2.426 Mbbl/day), Mexico (1.533 Mbbl/day), Saudi Arabia (1.489 Mbbl/day), Venezuela (1.362 Mbbl/day), Nigeria (1.132 Mbbl/day), Iraq (0.485 Mbbl/day), Russia (0.413 Mbbl/day), United Kingdom (0.278 Mbbl/day), and Brazil (0.202 Mbbl/day), over 50 other countries supplied the remaining 3.494 Mbbl/day. The United States supplied from domestic petroleum sources

Diagram 1. Energy Flow, 2007
(Quadrillion Btu)

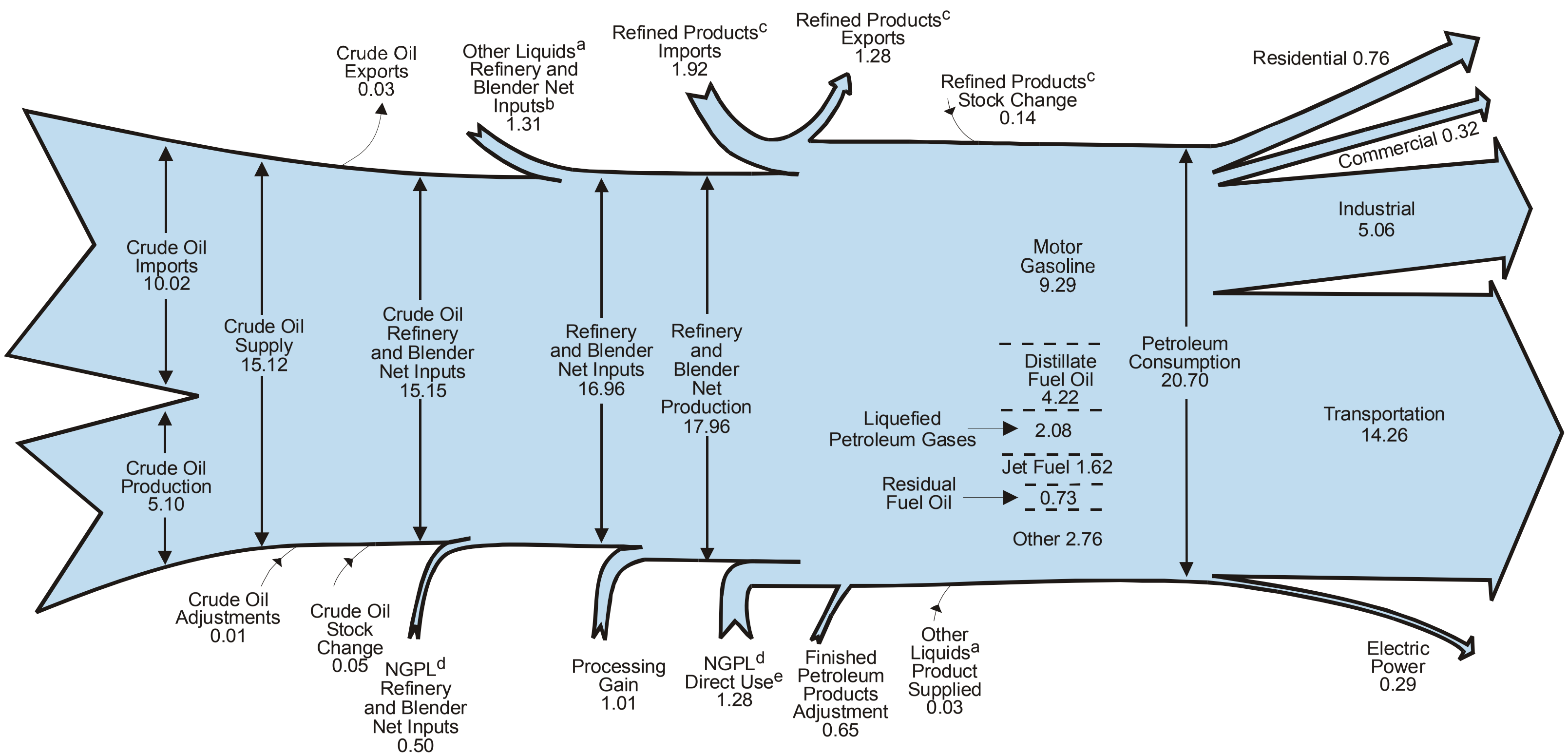


[a] Includes lease condensate.
[b] Natural gas plant liquids.
[c] Conventional hydroelectric power, biomass, geothermal, solar/photovoltaic, and wind.
[d] Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve.
[e] Natural gas, coal, coal coke, fuel ethanol, and electricity.
[f] Adjustments, losses, and unaccounted for.
[g] Coal, natural gas, coal coke, and electricity.
[h] Natural gas only; excludes supplemental gaseous fuels.
[i] Petroleum products, including natural gas plant liquids, and crude oil burned as fuel.
[j] Includes 0.03 quadrillion Btu of coal coke net imports.
[k] Includes 0.11 quadrillion Btu of electricity net imports.
[l] Primary consumption, electricity retail sales, and electrical system energy losses, which are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note, "Electrical Systems Energy Losses," at end of Section 2.

Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 1.1, 1.2, 1.3, 1.4, and 2.1a.

Diagram 2. Petroleum Flow, 2007
(Million Barrels per Day)

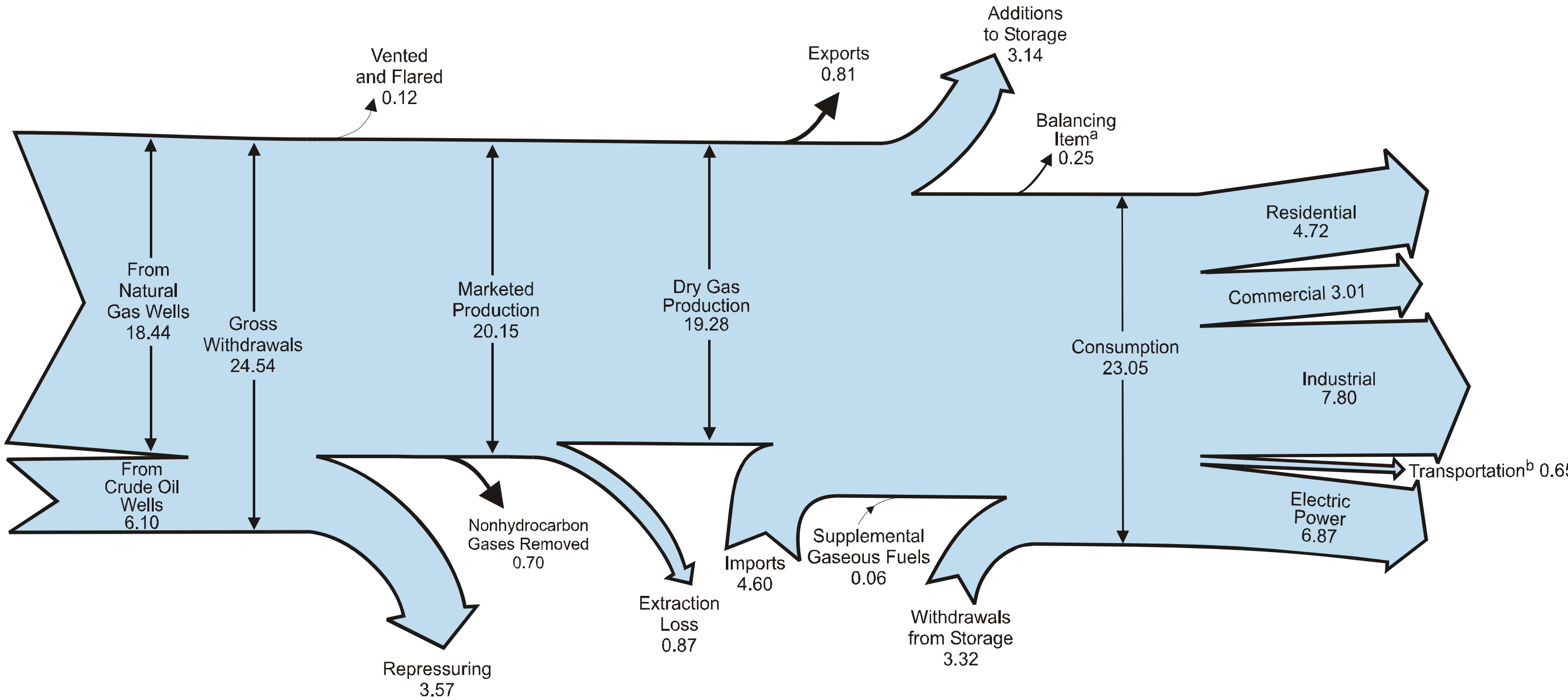


[a] Unfinished oils, other hydrocarbons/hydrogen, and motor gasoline and aviation gasoline blending components.
[b] Net imports (1.41) and adjustments (-0.05) minus stock change (0.02) and product supplied (0.03).
[c] Finished petroleum products, liquefied petroleum gases, and pentanes plus.
[d] Natural gas plant liquids.
[e] Production minus refinery input.

Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 5.1, 5.3, 5.5, 5.8, 5.11, 5.13a-5.13d, 5.16, and *Petroleum Supply Monthly*, February 2008, Table 4.

Diagram 3. Natural Gas Flow, 2007
(Trillion Cubic Feet)



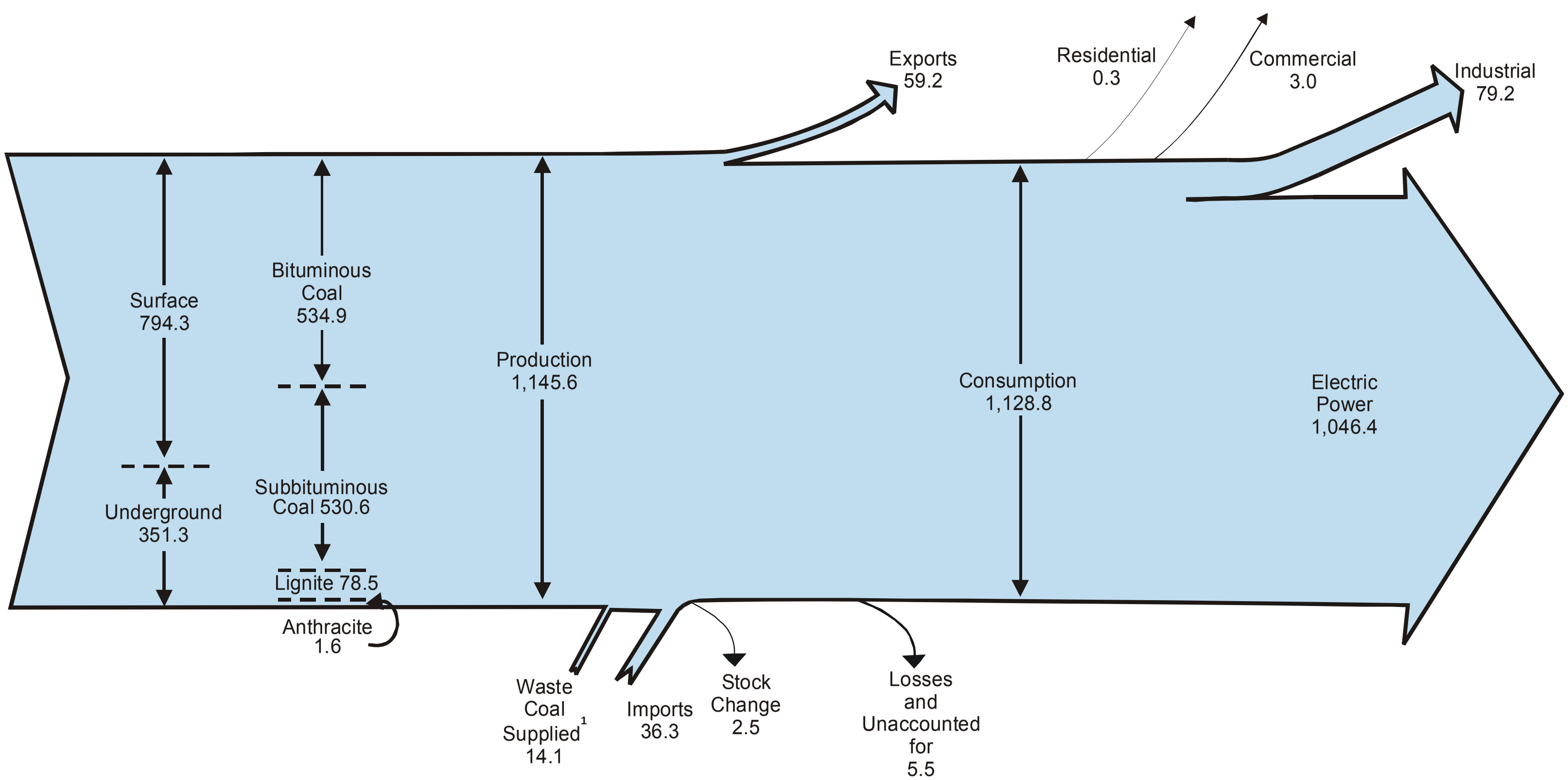
[a] Quantities lost and imbalances in data due to differences among data sources.

[b] Natural gas consumed in the operation of pipelines (primarily in compressors), and as fuel in the delivery of natural gas to consumers; plus a small quantity used as vehicle fuel.

Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 6.1, 6.2, and 6.5.

Diagram 4. Coal Flow, 2007
(Million Short Tons)

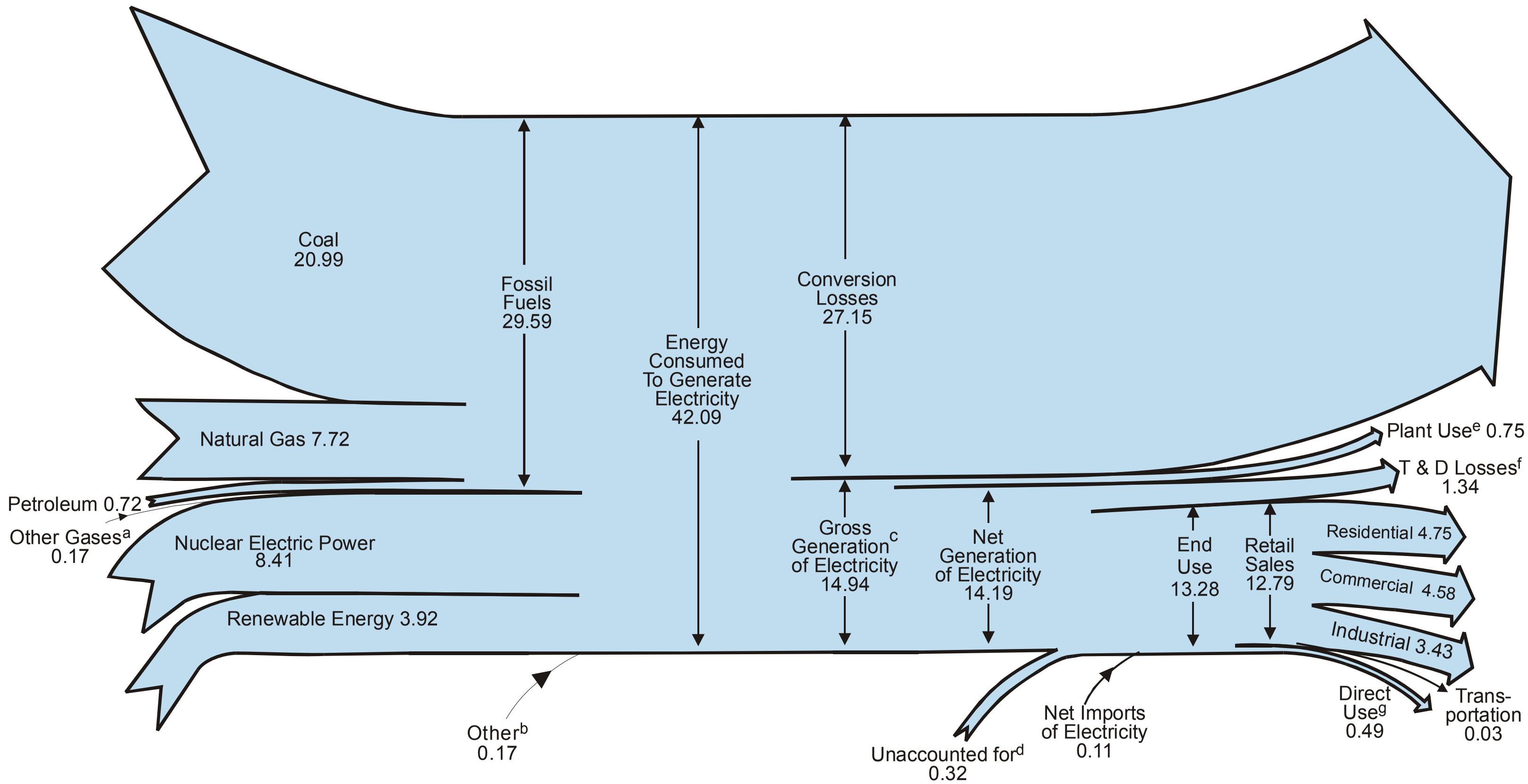


[1] Includes fine coal, coal obtained from a refuse bank or slurry dam, anthracite culm, bituminous gob, and lignite waste that are consumed by the electric power industrial sectors.

Notes: • Production categories are estimated; other data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 7.1, 7.2, and 7.3.

Diagram 5. Electricity Flow, 2007
(Quadrillion Btu)



[a] Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels.

[b] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, miscellaneous technologies, and non-renewable waste (municipal solid waste from non-biogenic sources, and tire-derived fuels).

[c] Estimated as net generation divided by 0.95.

[d] Data collection frame differences and nonsampling error. Derived for the diagram by subtracting the "T & D Losses" estimate from "T & D Losses and Unaccounted for" derived from Table 8.1.

[e] Electric energy used in the operation of power plants, estimated as 5 percent of gross generation.

[f] Transmission and distribution losses (electricity losses that occur between the point of generation and delivery to the customer) are estimated as 9 percent of gross generation.

[g] Use of electricity that is 1) self-generated, 2) produced by either the same entity that consumes the power or an affiliate, and 3) used in direct support of a service or industrial process located within the same facility or group of facilities that house the generating equipment. Direct use is exclusive of station use.

Notes: • Data are preliminary. • See Note, "Electrical System Energy Losses," at the end of Section 2. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 8.1, 8.4a, 8.9, and A6 (column 4).

7.884 Mbbl/day, and this includes a 1.005 Mbbl/day gain in volume expansion from refinery processing of petroleum into products, such as diesel and gasoline, which are not as dense as crude oil. A total of 58 non-OPEC states (including Mexico, Canada, and Russia) and 11 of the 12 OPEC states (we don't get any Iranian oil) provided processed or unprocessed petroleum products to the United States. Fig. 1 visually displays these domestic and import figures for petroleum.

Not counting the refinery processing gain, the United States and its North American neighbors supplied 10.838 Mbbl/day –55% of U.S. petroleum needs, and the United States alone provided about 35% of its needs. Granted, the possibility of oil supply disruption between North American neighbors seems vanishingly small. But NAFTA partners provided only about 30% of our imported oil.

The way in which petroleum was used breaks out as follows by Consumption Sector: Transportation 14.265 Mbbl/day, Industrial 5.06 Mbbl/day, Commercial 0.32 Mbbl/day, Residential 0.76 Mbbl/day and Electric Power Generation 0.29 Mbbl/day. Transportation accounted for 68.9% of U.S. petroleum consumption, while electric power generation accounted for a little over 1%.

Transportation consumption in 2007, the vast majority of petroleum consumption, divided as follows (in Mbbl/day): Motor Gasoline 9.076, Distillate Fuel Oil (Diesel) 3.048, Jet Fuel 1.623, Residual Fuel Oil 0.414, Lubricants 0.066, Liquefied Petroleum Gases 0.021, and Aviation Gasoline 0.017. All told, the U.S. transportation sector used 14.265 Mbbl/day of petroleum, and U.S. petroleum imports (without deducting the U.S. petroleum exports) equaled 13.439 Mbbl/day. Fuel to power ground vehicles (e.g., cars and trucks) and jet airplanes equaled 13.747 Mbbl/day. An equivalent of the entire petroleum import went to powering those vehicles. *Any efficiency in vehicle fuel consumption buys virtually a one-for-one gain in eliminating petroleum imports*.

As of the last quarter of 2007, the world consumed petroleum at a rate of 86.65 Mbbl/day. The U.S. portion of total world consumption was about 24%, Europe's 18%, China's about 9.1%, Canada's 2.7%, Japan's 6%, and countries from the Former Soviet Union about 5% [162]. What happens when China and India exceed U.S. oil consumption?

Relating the Energy Numbers, Energy Dependence, and Security

Today's world oil economy creates a potential demand on DoD to maintain the international order. U.S. foreign oil reliance sends hundreds of billions of dollars out of the country every year and puts the nation in potential jeopardy from cutoff of that resource. However, the United States must look beyond its own energy needs. High energy prices affect the world economy and can contribute to international instability and masses of desperate people—which can result in tasking to the U.S. military. India and China are blooming industrially and will quickly be able to consume all oil on the international market, which the United States foregoes with alternatives. China has already surpassed the United States in carbon emissions. Ultimately, U.S. energy security must come from a

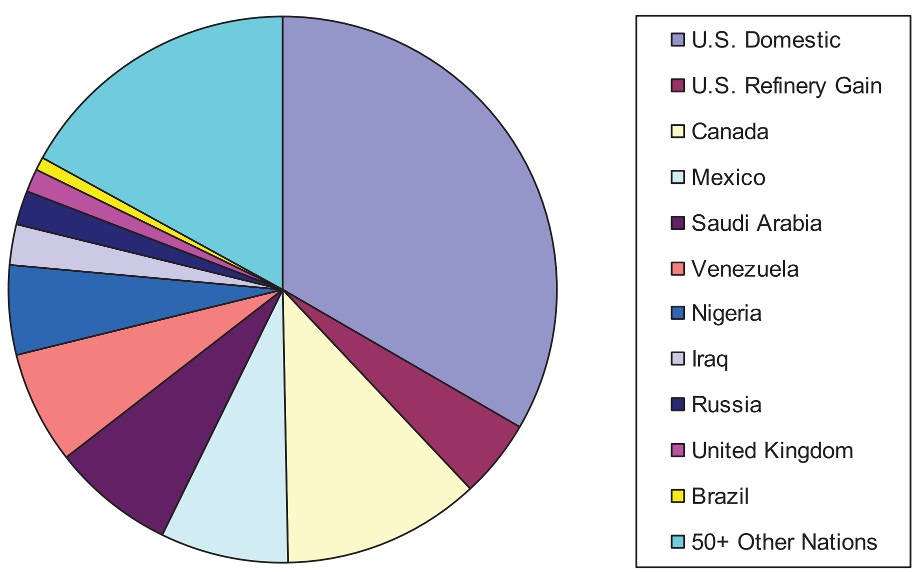


Fig. 1. U.S. Petroleum Sources

worldwide solution. The United States can lead the world, and DoD's ability to influence development of energy options can be a key enabler.

The energy production and consumption figures show that the United States can achieve energy independence if it eliminates transportation fuel imports. Addressing industrial, residential, or commercial energy consumption does not solve the import-dependence problem. According to 2007 data from EIA, and although the situation is not simplistic, if the United States replaced motor gasoline, diesel, and jet transportation fuels with domestically-produced energy, it would not need imported petroleum. U.S. domestic petroleum production has declined since the peak production in 1970 of 9.64 Mbbl/day to about 5.1 Mbbl/day in 2007. In 2007, total inputs to U.S. refineries were about 15.12 Mbbl/day. However, even if domestic crude oil production could be sufficiently increased (tripled), U.S. refinery capacity is barely sufficient to supply national fuel needs. Currently, the United States has enough refinery capacity to process about 17.5 million barrels of oil per day and imports about 2 Mbbl/day of refined product. As previously noted, refinery capacity would have to grow rapidly this next decade to keep up with world consumption. The United States will probably need a combination of solutions, which include improved transportation fuel efficiency, additions to improve efficiency of electric power production and distribution, and domestic production of non-petroleum-based renewable fuels [14].

Freeing the United States from imported petroleum would create domestic jobs, enable a more stable and secure economy, and help get a tighter handle on supply disruption. Developing alternative power sources for the national electric grid can help the United States to develop a more robust infrastructure, achieve economic gain, and decrease carbon emissions. As T. Boone Pickens has pointed out, eliminating the trillions of dollars the United States will pay in the coming years for petroleum imports will also contribute to national security. At $120 per barrel for 13.5 Mbbl/day, the United States would pay $1.62 billion daily—about $3 trillion in 5 years if at that average price, which could very likely rise. That daily cost in fuel would cover the purchase of a *Nimitz*-class aircraft carrier every week or 100 F-22 aircraft every 3 weeks. The financial consequence is of direct concern to the U.S. government and directly impacts DoD resource constraints.

Crude oil import demand, processed petroleum demand, vulnerabilities in energy production and distribution infrastructure, economic impacts from world oil price fluctuations, potential disruption in all aspects of U.S. society, military energy requirements, and environmental impacts together highly suggest that assured, affordable, responsible energy access is the great national security challenge. The rest of the world also faces such challenges. Ultimately, the United States must achieve energy security for itself, and part of that will be achieved by promulgating its success around the world.

APPENDIX B—IMPLEMENTING A NEW ENERGY PARADIGM: A SPECULATION ON A TYPE OF ENERGY AND INERTIA, WHICH DEFINE COMPLEX SYSTEM STATES AND MODULATE SYSTEM CHANGE

The Clayton Christensen and Brian Arthur "effects" [163, 164] suggest that business models, first paths, and level of investment outweigh best technology. These theories indicate that the government should guide industry development and not leave this crucial national security asset totally to free market development.

Since this paper suggests that a new energy paradigm is required in order to assure U.S. energy security, it is only appropriate that it ask how much government leadership versus free market force will be required to establish this new complex state. Will the invisible hand of the free market solve the combined military security, fiscal, and environmental problems? Market mechanisms do not seem to apply to the organizational and fiscal disruption necessary to change DoD's way of setting requirements and acquisition as the DSB and others have recommended. Can market mechanisms provide real-time feedback that provides a guiding hand toward sustainable fuel sources that are initially more expensive than unsustainable sources, or values the slow motion of climate change or potential catastrophic disruptions of energy supply, which have never been experienced? Inertia in organizations, industries, and public opinion may tend to bog down attempts to replace petroleum, especially if the price swings low again. The huge capital investment in current energy solutions will, of course, slow movement away from fossil fuel. People who have power and wealth derived from the current energy paradigm may not willingly relinquish that position to the upstarts who try to bring alternatives.

Perhaps both Clayton Christensen and Brian Author address different facets of this same jewel. Christensen, in his theory of disruptive innovation, points out how difficult it is for the large company, with a solid customer base that asks for specific capability, to go against that tide and bring an innovation that the customers may not even realize they need or want, and which will very likely make obsolete the current products its customers are buying. Prime examples include IBM's failure to capitalize on the personal computer; the Swiss watch industry's failure to produce the digital watch, which they first developed; and the steamship's original use in the low-end inland-waterway transport business rather than the high-profit margin open-ocean transport.

W. Brian Arthur speaks of the economic "law of increasing returns," which hints at the idea that an object in motion tends to stay in motion. When related to a product or technology, this theory says that whatever gets ahead in a market tends to stay ahead, and whatever falls behind tends to stay behind. Arthur says that both laws of increasing returns and decreasing returns function simultaneously in industries. But increasing returns is particularly powerful in high-technology industries—aspects of the energy industry might fit this category.

What factors make this law apply? The need for huge up-front investment to start a project before return on investment gives advantage to the current provider (e.g., costs for new high-efficiency engine production lines, as well as the initial investment to fully test and validate them; costs for alternative energy power plants or other infrastructure; costs to produce and field electrical energy storage; any large-scale production with novel materials and construction needs; and switching to a farming mindset versus a mining mindset).

Arthur also points out that new technologies frequently must fit into an "ecology" or "network." Technologies may need multiple simultaneous innovations to make them work, including the knowledge base of users. Possible energy examples include the utility lines to distribute windmill-generated electricity, the storage capacity to hold electricity when the winds die down, a network of fuel stations to deliver new fuels, and labor skills to build and maintain cars that don't run on the ICE.

Oil companies know how to drill for oil and produce it. They know about expected returns on investment based on the size of an oil field. They can think easily in terms of a trillion dollars of oil waiting under an unexploited oil lease. This does not mean that the industry can relate well to the idea of putting an equivalent amount of funding and effort into producing renewable fuels, even if that project has, not the technical risk, but potentially better return on investment.

Large electric power companies know how to make money from coal, natural gas, and possibly nuclear plants. That does not necessarily translate into their willingness and skill to develop a solar-panel market or windmill farm, or invest in other alternative energy sources. Knowing how to conduct warfare with current sets of tools and being quite innovative in their use does not equate with the ability to design an entirely new military tool set that uses much less resource but delivers more capability. All major military technology innovations tend to be injected against the grain of the existing military power structure. Apparent behavior oddities from "the powers that be" in any domain all seem predictable from the Arthur and Christensen theories.

Arthur and Christensen document this industrial, organizational, and economic-market phenomenon, which the author would characterize as an inertia and energy combination that appears to be common to all complex systems. Every energy equation of physics and engineering has a similar form, with the amount of energy in a system defined by the multiplication of an "inertia-carrying" term, such as mass or spring constant, or dielectric permeability. And, that inertia term is multiplied by the square of a forcing function, such as voltage, pressure, or velocity. Further, the adaptation of that system seems to be broadly definable in time-related equations similar to fluid flow or electrical flow, or simply the equations of motion of an object. Degree of adaptation or ease of change relates directly to the inertia-inducing term, the initial value of the forcing function, and whether or not additional orders of change to the forcing function exist.

To relate this energy/inertia/adaptation concept to the U.S. energy security problem, consider that infrastructure, established market and customer supplier relationships, history of profit, corporate self-image, inability or unwillingness of leadership to see need for a change, uncertainty and fear of change amongst the public and their leaders, entrenched power and wealth, technological maturity, and other factors contribute to an inertia term that mitigates against change. Commodity shortage, rising prices, real and perceived environmental and economic dangers, operational and technological opportunity, and potential profit opportunity serve as forcing functions to change and adaptation. Also, as in the strong-man view of history, a single remarkable leader can be the final required catalyst, or forcing function, for change. Adaptation registers as "movement," such as toward new markets and new customer/supplier relationships, new infrastructure investment, and maturation and proliferation of emerging technology.

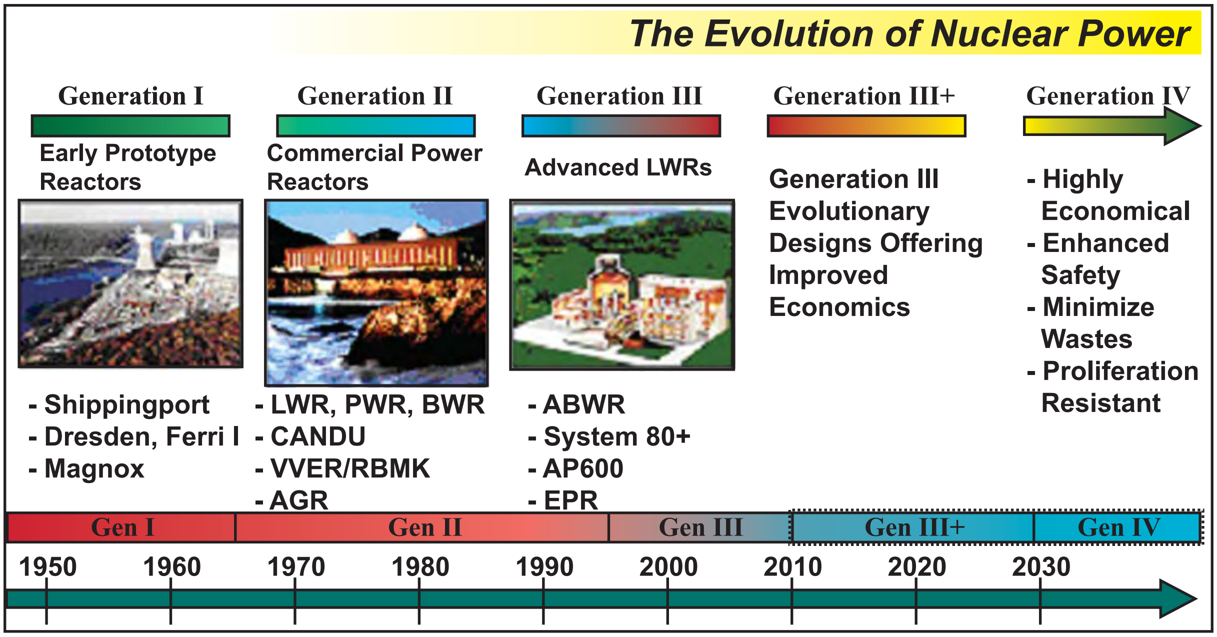
A bottom-line assessment emerging from these concepts is that the current energy paradigm is a fast-moving vessel that will take a very large amount of forcing function to change course. Forcing functions could come from commodity cost skyrocketing to economy-crippling levels; actual petroleum flow disruption; a wild-card psychological phenomenon, such as an announcement of imminent climate calamity from a very well-respected source (would have to be more influential than the IPCC and its report); a revolutionary technological breakthrough (perhaps pioneered by DoD); or an inspiring national leader who applies constant focus on the issue. The disruptive technology effect could eventually change energy source and use by its method of sneaking into nonmainstream markets and improving to the point that its capability to fulfill need is more favorable than the mainstream approach. The Bussard fusion device would definitely be a revolutionary technology. Solar photovoltaics, the wind-power industry, renewable fuels, and high-efficiency engines may be closer to the disruptive technology.

APPENDIX C—NUCLEAR FISSION TECHNOLOGY OPTIONS AND ISSUES

Table 3, taken from the World Nuclear Association [165], shows the type of nuclear fission reactors that are currently being marketed and by whom.

The DOE's insert on the *Evolution of Nuclear Power* from its Generation IV website [166] shows the current and projected "evolution" of nuclear fission power (see illustration and text on opposite page).

Generation IV reactors are either in design or prototype but not off-the-self models yet. Nine founding nations chartered the Generation IV International Forum (GIF) in 2001 to develop the next-generation nuclear reactors. By 2006, 13 members had joined. The GIF is developing six new reactor designs for deployment by 2030.



The Evolution of Nuclear Power

Concerns over energy resource availability, climate change, air quality, and energy security suggest an important role for nuclear power in future energy supplies. While the current Generation II and III nuclear power plant designs provide a secure and low-cost electricity supply in many markets, further advances in nuclear energy system design can broaden the opportunities for the use of nuclear energy. To explore these opportunities, the U.S. Department of Energy's Office of Nuclear Energy, Science, and Technology has engaged governments, industry, and the research community worldwide in a wide-ranging discussion on the development of next-generation nuclear energy systems known as **"Generation IV."**

Table 4 from the World Nuclear Association [167] summarizes the six Gen IV technologies.

No nuclear power plants have been built in the United States since the Three-Mile-Island power plant incident in 1979. Builders of new power plants claim that modern designs significantly improve safety. An Economic Simplified Boiling Water Reactor (ESBWR) uses passive safety techniques that do not require operator or automated intervention [168]. The Pebble Bed Reactor takes advantage of the Doppler broadening effect, which enables U-238 to absorb more neutrons as fuel gets hotter, rather than the U-235, and naturally slows the reaction rate [127].

Norman C. Rasmussen, Macfee Professor of Engineering at MIT, estimated that the likelihood of a serious nuclear accident in any of the current 104 U.S. reactors is approximately 1 in 3.3 million over the next 30 years, which is to the end of their design life [169]. A Nuclear Regulatory Commission (NRC) document, NUREG-1150 [170], shows that expected nuclear accidents are much less probable than the NRC's goals. The NRC Safety Goal is 5×10^{-7} for average probability of an individual early fatality per reactor per year: NUREG-1150's projection depends on reactor type PWR 2x10E-8 or BWR 5x10E-11. NRC's goal for average probability of an individual latent cancer death per reactor per year was 2x10E-6. NUREG-1150 predicted for PWR 2x10E-9 and BWR 4x10E-10. These statistics indicate a very low probability of danger and death from nuclear power plants.

To help revitalize the nuclear industry in the United States, DOE started the Global Nuclear Energy Partnership, in 2007. This controversial initiative is intended to encourage global use of nuclear power among the partner countries, to promote use of reprocessed waste as fuel, and internationally standardize business practices to eliminate proliferation danger. The DOE initiated the national Nuclear Power 2010 Program [171] in 2002 as a government/industry cost-sharing venture to facilitate U.S. production of new plants; development and deployment of better technology; and to examine policy, economic, and other issues related to revitalize a U.S. nuclear power industry. The Energy Policy Act of 2005 [172] promotes nuclear power development. Nine U.S. companies have plans to build 16 new plants. The fact that all the plants built in the United States with a 40-year design life come due for refueling and re-licensing by 2020 highlight the importance of a "reenergized" industry.

Table 4. Generation IV Fission Power Technologies

	neutron spectrum (fast/ thermal)	coolant	temperature (°C)	pressure*	fuel	fuel cycle	size(s) (MWe)	Uses
Gas-cooled fast reactors	fast	helium	850	high	U-238 +	closed, on site	288	electricity & hydrogen
Lead-cooled fast reactors	fast	Pb-Bi	550-800	low	U-238 +	closed, regional	50-150** 300-400 1200	electricity & hydrogen
Molten salt reactors	epithermal	fluoride salts	700-800	low	UF in salt	closed	1000	electricity & hydrogen
Sodium-cooled fast reactors	fast	sodium	550	low	U-238 & MOX	closed	150-500 500-1500	electricity
Supercritical water-cooled reactors	thermal or fast	water	510-550	very high	UO_2	open (thermal) closed (fast)	1500	electricity
Very high temperature gas reactors	thermal	helium	1000	high	UO_2 prism or pebbles	open	250	hydrogen & electricity

However, wide-scale use of nuclear energy to replace fossil fuel presents complex problems. The 2003 MIT cross-disciplinary study, *The Future of Nuclear Power* [125], recommends maintaining the nuclear-fission power industry as a viable option specifically to reduce the effects of carbon-emission-induced climate change. It cites three other potential mechanisms to mitigate carbon emissions: improved efficiency in use and production of electricity; renewable energy sources; and, carbon sequestration from fossil-fueled power plants. Not intending to exclude or rank any of these choices, the report recommends nuclear power expansion only because it is an additional path to carbon-emission reduction. The report cites four major obstacles to expansion of nuclear fission power: cost, safety, proliferation, and waste.

Nuclear Fission Financial Aspects

Nuclear-power-plant initial cost compares poorly to any other conventional power plant type. Nuclear plants can now be built in 40–60 months rather than the 10 years of the earlier deployment era. But the upfront cost of investment while no income is generated, together with discount rates for capital at 10% or higher, launch the capital outlay estimates anywhere from $2000/kW to $6000/kW ($2 billion to $6 billion initial plant cost for 1 gigawatt) according to the Economics of New Nuclear Plants in Wikipedia [173]. The EIA 2006 report is cited in Wikipedia as showing the lifetime cost variance by fuel source as follows:

- Fission—$59.30 per megawatt hour
- Wind—$55.80 per megawatt hour
- Coal—$53.10 per megawatt hour
- Natural Gas—$52.50 per megawatt hour

These figures do not consider the cost for carbon taxes or backup power.

MIT's 2003 report concluded that the real, levelized power cost was $67/MWe-hour for fission, $42/MWe-hour for pulverized coal plants, and $38–$56/MWe-hour for natural gas-fired, combined-cycle plants. Natural gas plants are relatively cheap to build, but the fuel is expensive, and natural gas prices are now higher than MIT's projected "high." Fission fuel costs are comparatively low, but construction and operations are expensive.

A carbon "cap and trade" policy makes fission more competitive. MIT's analysis showed that a carbon emission tax of $100/ton of carbon emitted would raise the cost of coal to $66/MWe-hour, almost equal to fission's, and gas-fired electricity to equal fission's cost if gas prices were as "high" as $6.72/MBtu of gas. Electric power generation in 2005 pumped 2 billion tons of carbon into the atmosphere according to *Discover Magazine—Better Planet Special Issue 2008*. A $200 billion incentive could promote fission power development. MIT's study proposed a $200 thousand/MWe ($200 million for a 1-GW plant) tax credit for new nuclear construction to encourage the builders of the first 10 new plants.

As a separate aspect of cost, the MIT study noted a dramatic difference in life-cycle costs depending on the fuel-cycle chosen—either once-through fuel or reprocessed fuel. The study participants concluded that the reprocessed-fuel cycle, as recommended in the new DOE Global Partnership initiative, was 4.5 times more expensive than the once-through cycle.

Under current lack of governmental regulation of carbon emissions, fission power is the most expensive electrical power plant option to build. It requires the most upfront capital, does not start returning investment for up to 5 years (maybe more) and takes many years to recoup total investment. Under

Table 3. Current Fission Reactor Options

Country and Developer	Reactor	Size MWe	Design Progress	Main Features (improved safety in all)
US-Japan (GE-Hitachi, Toshiba)	ABWR	1300	Commercial operation in Japan since 1996-7. In US: NRC certified 1997, FOAKE.	• Evolutionary design. • More efficient, less waste. • Simplified construction (48 months) and operation.
USA (Westinghouse)	AP-600 AP-1000 (PWR)	600 1100	AP-600: NRC certified 1999, FOAKE. AP-1000 NRC certification 2005.	• Simplified construction and operation. • 3 years to build. • 60-year plant life.
France-Germany (Areva NP)	EPR US-EPR (PWR)	1600	Future French standard. French design approval. Being built in Finland. US version developed.	• Evolutionary design. • High fuel efficiency. • Low cost electricity.
USA (GE)	ESBWR	1550	Developed from ABWR, under certification in USA	• Evolutionary design. • Short construction time.
Japan (utilities, Mitsubishi)	APWR US-APWR EU-APWR	1530 1700 1700	Basic design in progress, planned for Tsuruga US design certification application 2008.	• Hybrid safety features. • Simplified Construction and operation.
South Korea (KHNP, derived from Westinghouse)	APR-1400 (PWR)	1450	Design certification 2003, First units expected to be operating c 2012.	• Evolutionary design. • Increased reliability. • Simplified construction and operation.
Germany (Areva NP)	SWR-1000 (BWR)	1200	Under development, pre-certification in USA	• Innovative design. • High fuel efficiency.
Russia (Gidropress)	VVER-1200 (PWR)	1200	Replacement for Leningrad and Novovoronezh plants	• High fuel efficiency.
Russia (Gidropress)	V-392 (PWR)	950-1000	Two being built in India, Bid for China in 2005.	• Evolutionary design. • 60-year plant life.
Canada (AECL)	CANDU-6 CANDU-9	750 925+	Enhanced model Licensing approval 1997	• Evolutionary design. • Flexible fuel requirements. • C-9: Single stand-alone unit.
Canada (AECL)	ACR	700 1080	undergoing certification in Canada	• Evolutionary design. • Light water cooling. • Low-enriched fuel.
South Africa (Eskom, Westinghouse)	PBMR	170 (module)	prototype due to start building (Chinese 200 MWe counterpart under const.)	• Modular plant, low cost. • High fuel efficiency. • Direct cycle gas turbine.
USA-Russia et al (General Atomics - OKBM)	GT-MHR	285 (module)	Under development in Russia by multinational joint venture	• Modular plant, low cost. • High fuel efficiency. • Direct cycle gas turbine.

PWR-Pressurized Water Reactor uses water under high pressure as coolant and moderator (about 60% of reactors –Three Mile Island is one)
BWR-Boiling Water Reactors use water as coolant and moderator under somewhat lower temperature than the PWRs
(Advanced Boiling Water Reactors and Economic Simplified Boiling Water Reactors are updated subtypes)
PHWR (CANDU) is a Canadian designed Pressure Heavy Water Reactor that uses heavy water as moderator and coolant
RBMK Russian designed reactor uses water as coolant, graphite as moderator and is a Plutonium breeder. Chernobyl had four RBMKs.
GCR/AGCR Gas Cooled Reactor or Advanced Gas Cooled Reactor use graphite moderator and gas (CO_2) as coolant
LMFBR -Liquid Metal Fast Breeder Reactors use lead (lead-bismuth eutectic) or sodium as coolants without moderators and breed plutonium
AHR-Aqueous Homogeneous Reactors have uranium salt mixed with the moderator in heavy or light water and are the easiest to initiate with only a pound of P-239 or U-233 required to run, but they have corrosion problems

deregulation of the power industry, power producers compete in cost to provide electricity to distributors. Electricity providers (the business generating the electricity) can be replaced quickly whether or not their investments have been recouped. This market environment drives power production decisions away from investments that pay off only in the very long-term—such as fission power.

Finally, the MIT study concluded that, "Nuclear power will succeed in the long run only if it has a lower cost than competing technologies."

Nuclear Fission Safety

The MIT study noted that nuclear plant safety is inherently complex. Reactor design, workforce competence, management processes and commitment, and policing of standards all contribute to complexity. MIT concluded, "There is no plant design that is totally risk free." New reactor designs (as previously noted in this paper) can improve safety. However, "the record of reprocessing plants is not good" according to the MIT report. Current NRC safety standards are appropriate and must be extended globally. MIT recommended research focus on fuel-cycle safety analysis and reactor design for safety. The study suggests that nuclear safety requires continuous, sustained commitment to safety performance above all other operational issues.

Fission Waste Management

MIT's study states, "The management and disposal of high-level radioactive spent fuel from the nuclear fuel cycle is one of the most intractable problems facing the nuclear power industry…" The group agreed with other studies that stable geologic formations can contain the nuclear in a stable salt dome waste and prevent its impacting the "biosphere." However, significant issues regarding mechanisms of handling, storage, and transportation are unresolved. The DOE scheduled a 1998 opening of the Yucca Mountain repository that would be the master warehouse for nuclear waste storage in a geologically stable salt dome. However, legal battles have prevented its use for storing nuclear waste. Recently, Congress Daily [174] reported that the planned Yucca Mountain waste repository cost estimate has escalated to $90 billion, which will include 100 years of operation. The waste will remain radioactive for hundreds of thousands of years.

Spent fuel continues to stockpile at reactors and above ground facilities. With the projected expansion of the nuclear industry to an additional 1000 separate 1-gigawatt plants, an additional Yucca-Mountain-equivalent geologic storage site would be needed every 3–4 years.

The MIT nuclear fission study recommended investigation into deep bore-hole storage, alternatives and additions to Yucca Mountain, and investigation into multiple-decade centralized storage for fuel until it can be geologically deposited for the duration of the radioactive threat. Various fission waste-handling schemes have been suggested—from launching the material into outer space, to geologic storage, to recycling the waste to new fuel, to irradiating the waste to quickly reduce its half life. However, no fail-safe mechanism has emerged. Perhaps this area would be a good target for potential research to remove one impediment to nuclear fission industry expansion.

Nuclear Weapon Proliferation

The MIT study concludes that nuclear power expansion should not proceed "unless the risk of proliferation from operation of the commercial nuclear fuel cycle is made acceptably small." Nuclear industry expansion increases the risk of the irresponsible actor or the dedicated foe gaining access to technological information, facilities, and stocks of weapons-grade fuel. The MIT study recommends various approaches to mitigate the proliferation threat.

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Energy & National Security

An Exploration of Threats, Solutions and Alternative Futures

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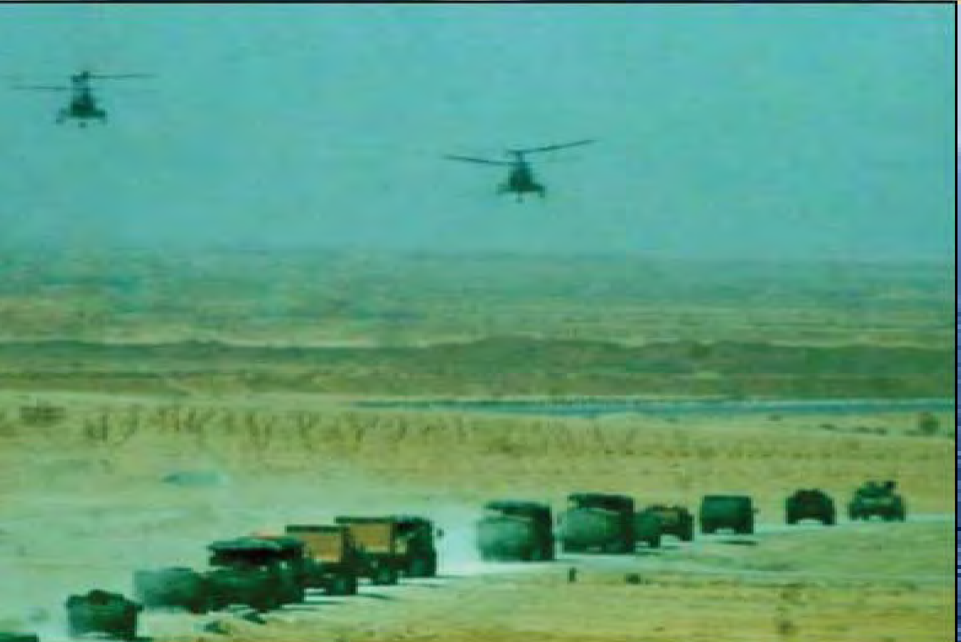
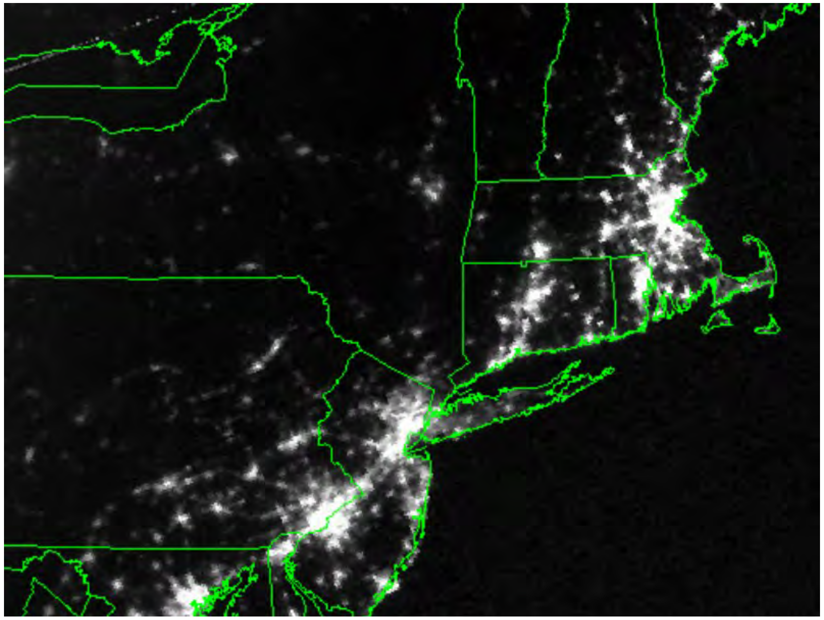
DoD Fuel Use Strategy

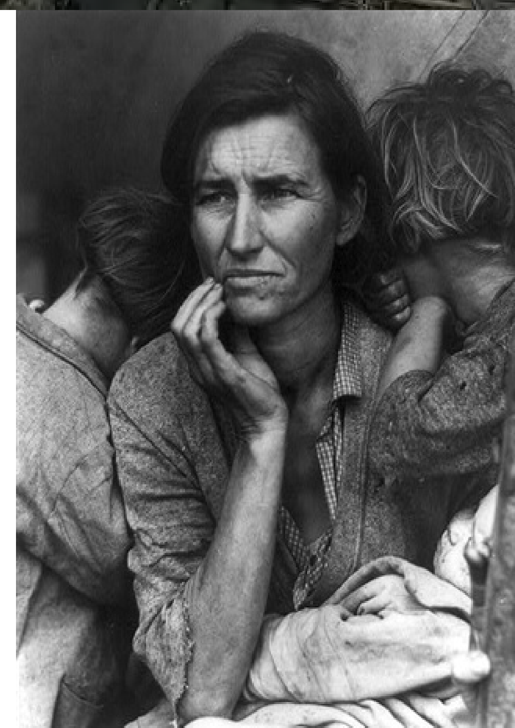





Infrastructure Vulnerability



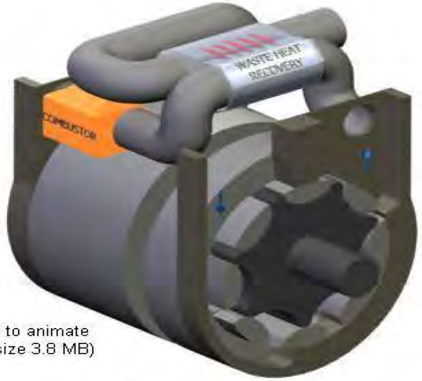
Economic Energy Security



Climate and Implications

Fuel Efficient Platform Design

Engine Efficiency



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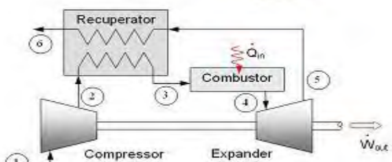
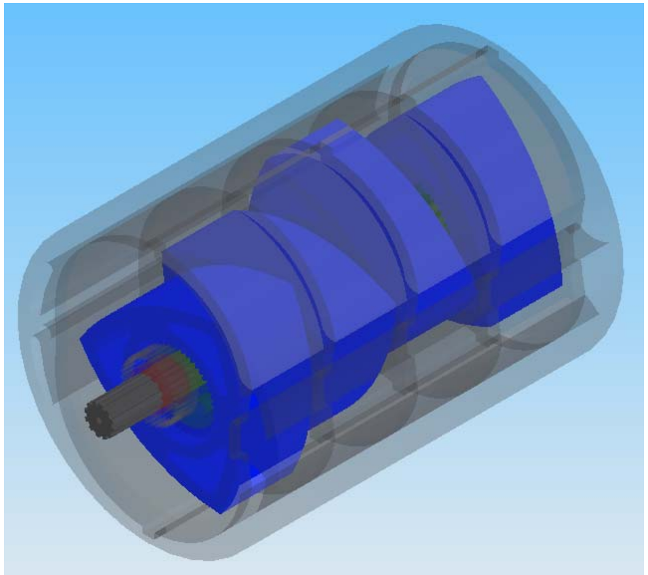
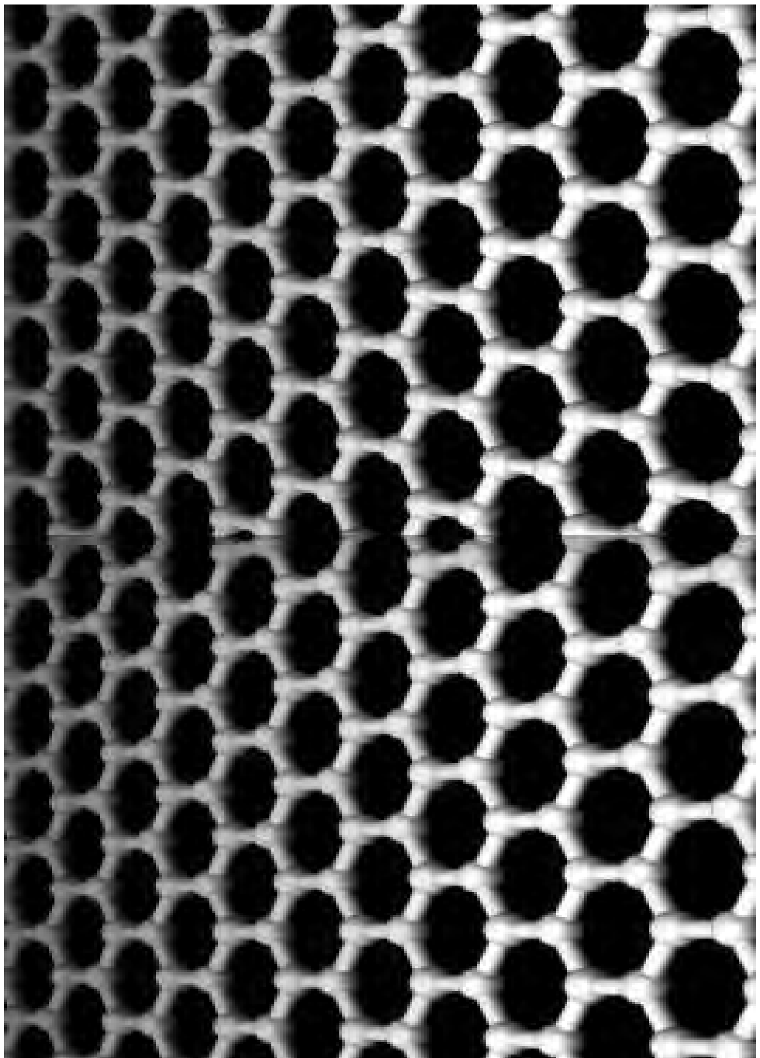


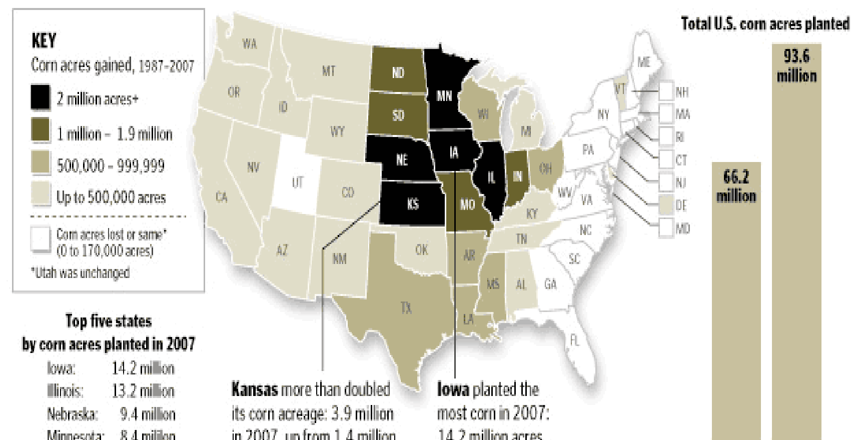
Figure 1: Brayton Cycle



Electric Vehicle Technology



Renewable Synthetic Fuels



Alternative Power and Distribution


DefenseNews March 5, 2007

WORLD NEWS

Fighting for Fusion

Why the U.S. Isn't Funding A Promising Energy T

y WILLIAM MATTHEWS

On Nov. 11, 2005, the day his mall fusion reactor exploded in . shower of sparks and metal ragments, even physicist Robert Bussard didn't know what he had chieved.

For 11 years, the U.S. Navy quitly funded Bussard's research. It vas a small project with a very arge goal: deriving usable energy rom controlled nuclear fusion.

Funding ran out at the end of 005 and Bussard was supposed o spend the tail end of the year hutting down his lab. He kept ostponing that in an effort to finh a final set of experiments.

He completed low-power tests n September and October and bean high-power testing of the rector in November.

After four tests Nov. 9 and 10, n electromagnetic coil short-ciruited as electricity surged hrough it, "vaporizing" part of his eactor, Bussard said, and bringng his tests to an end.

"The following Monday, we tarted to tear the lab down. Noody had time to reduce the data hat was stored on the computer. wasn't until early December hat we reduced the data and ooked at it and realized what we ad done," he said.

Bussard said he and his small eam of scientists had proven that uclear fusion can be harnessed s a usable source of cheap, clean nergy.

But for more than a year now, ussard has been unable to move the next step in his research. t 78, he is in ill health and his cientific allies fear that the longought breakthrough he appears have achieved may fade into bscurity before it can be fully eveloped.

No small part of the problem is hat the U.S. Energy Department as a competing project, and has ent five decades and $18 billion n an as-yet-unsuccessful effort solve the fusion puzzle.

"Who would believe that a tiny ompany based on one person

BORON FUSION

U.S. physicist Robert Bussard believes that a novel form of atomic fusion based on boron could be harnessed to create electricity cheaply and cleanly, without hydrogen fusion's superhot temperatures, dangerous radiation, and enormous reactors.

Bussard says the boron fusion could be induced by creating an inertial electrostatic confinement machine that uses electromagnetic energy to force boron and protons together.

FUSION REACTIONS

HYDROGEN: Hot and dirty
- Powers the sun and thermonuclear bombs.
- Yields heat and neutron radiation.

BORON: Non-radioactive
- Could be tested in new kind of machine.
- Yields helium and electricity.

SOURCE: The Advent of Clean Nuclear Fusion, Robert W. Bussard, Ph.D., Oct. 2006

DEFENSE NEWS GRAPHIC BY JOHN BRETSCHNEIDER

His idea was the basis for the

process does not produce ra-

"Who would believe that a tiny company based on one person could solve the riddle that has escaped literally thousands of researchers?"

Don Gay
Former U.S. Navy engineer

with deuterium, not boron — in November 2005 proved that the boron process will work.

The boron reactor would be similar to, but more powerful than, the reactor that blew up in 2005.

Bussard's reactor design is built upon six shiny metal rings joined to form a cube — one ring per side. Each ring, about a yard in diameter, contain copper wires wound into an electromagnet.

The reactor operates inside a vacuum chamber.

When energized, the cube of electromagnets creates a magnetic sphere into which electrons are injected. The magnetic field squeezes the electrons into a dense ball at the reactor's core, creating a highly negatively charged area.

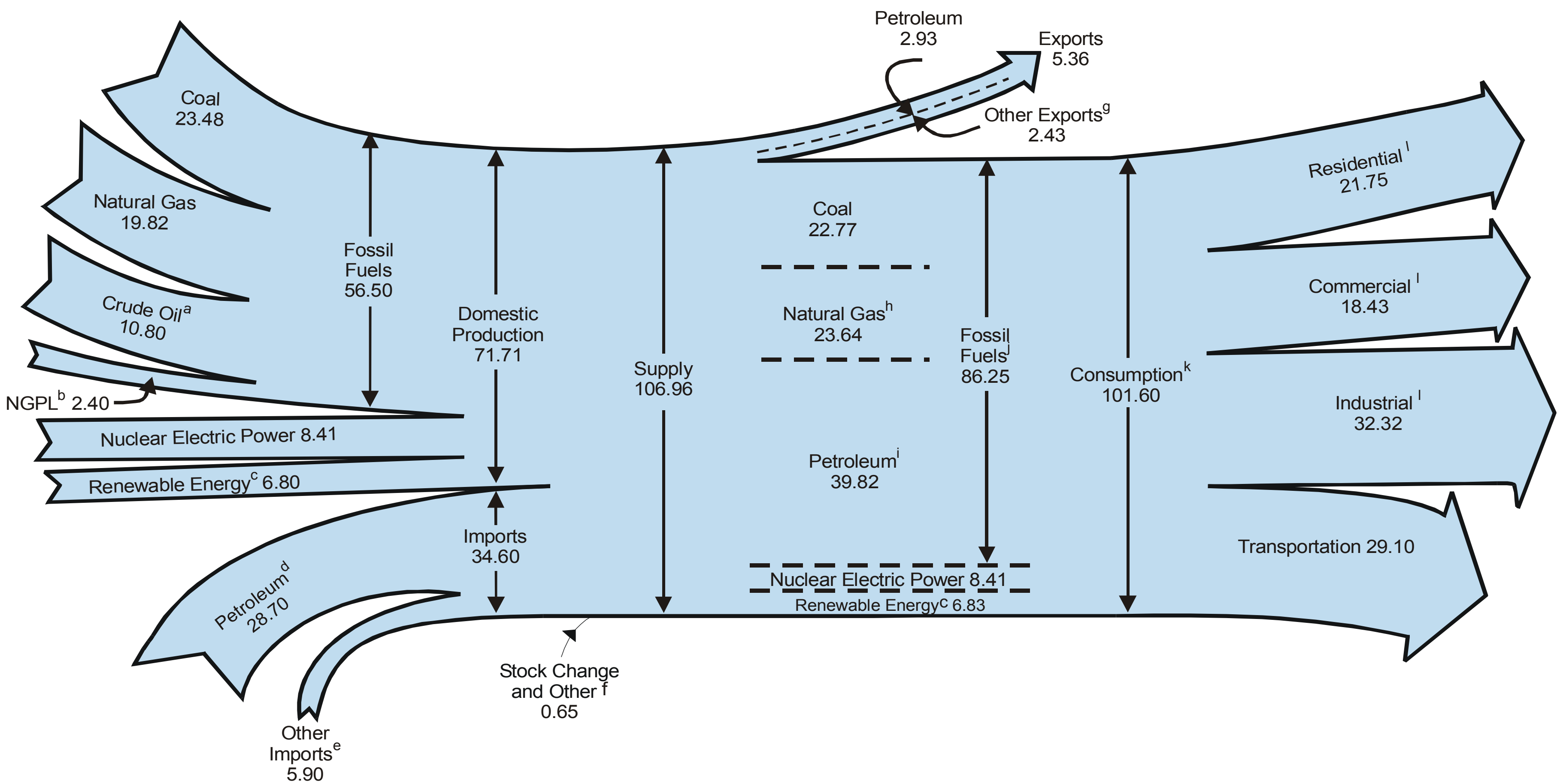
To begin the reaction, boron-11 nuclei and protons are injected into the cube. Because of their positive charge, they accelerate to the center of the electron ball. Most of them sail through the center of the core and on toward the opposite side of the reactor. But the negative charge of the electron ball pulls them back to the center. The process repeats, perhaps thousands of times, until the boron nucleus and a proton collide with enough force to fuse.

That fusion turns boron-11 into highly energetic carbon-12, which promptly splits into a helium nucleus and a beryllium nucleus.

Quo Vadimus?

BACKUP SLIDES

Diagram 1. Energy Flow, 2007
(Quadrillion Btu)



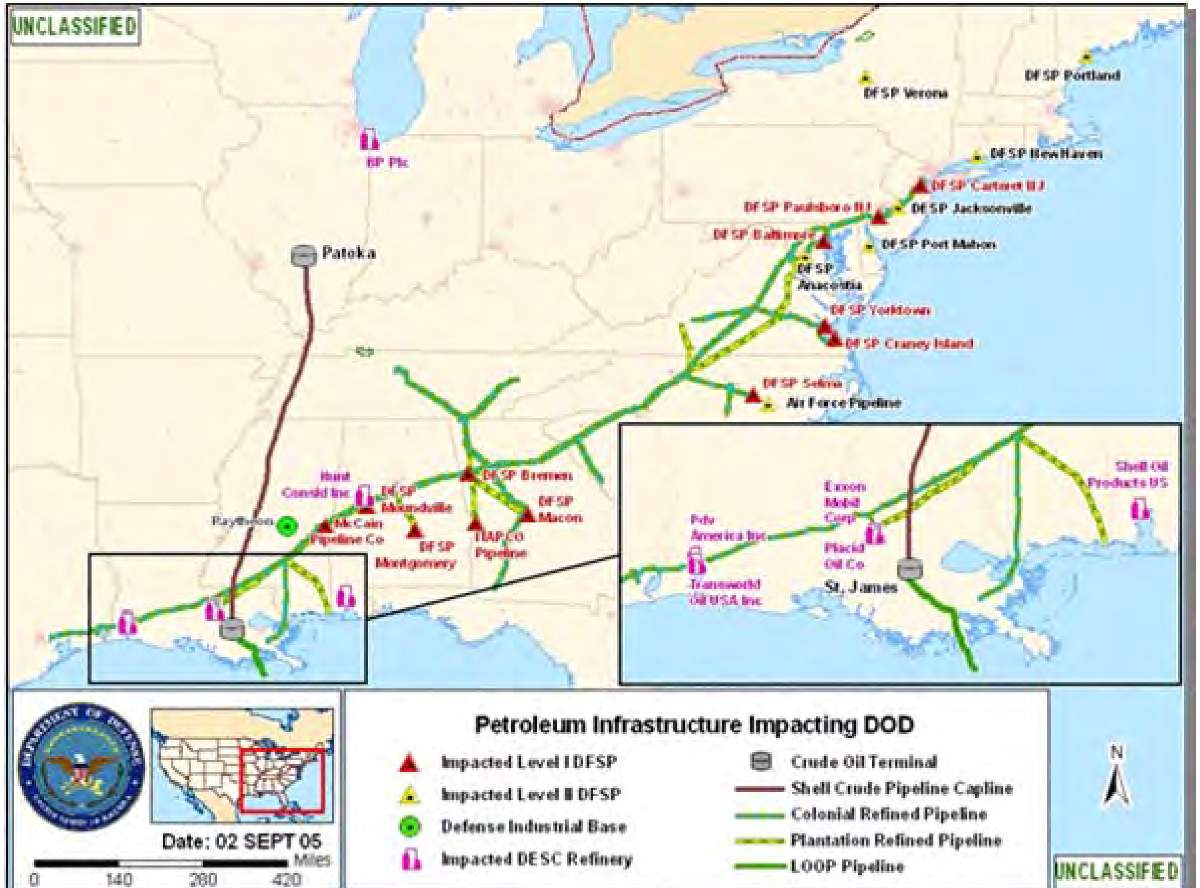
[a] Includes lease condensate.
[b] Natural gas plant liquids.
[c] Conventional hydroelectric power, biomass, geothermal, solar/photovoltaic, and wind.
[d] Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve.
[e] Natural gas, coal, coal coke, fuel ethanol, and electricity.
[f] Adjustments, losses, and unaccounted for.
[g] Coal, natural gas, coal coke, and electricity.
[h] Natural gas only; excludes supplemental gaseous fuels.
[i] Petroleum products, including natural gas plant liquids, and crude oil burned as fuel.
[j] Includes 0.03 quadrillion Btu of coal coke net imports.
[k] Includes 0.11 quadrillion Btu of electricity net imports.
[l] Primary consumption, electricity retail sales, and electrical system energy losses, which are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note, "Electrical Systems Energy Losses," at end of Section 2.

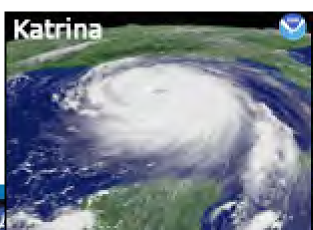
Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 1.1, 1.2, 1.3, 1.4, and 2.1a.

Fuel Convoy

Interdependency Analysis



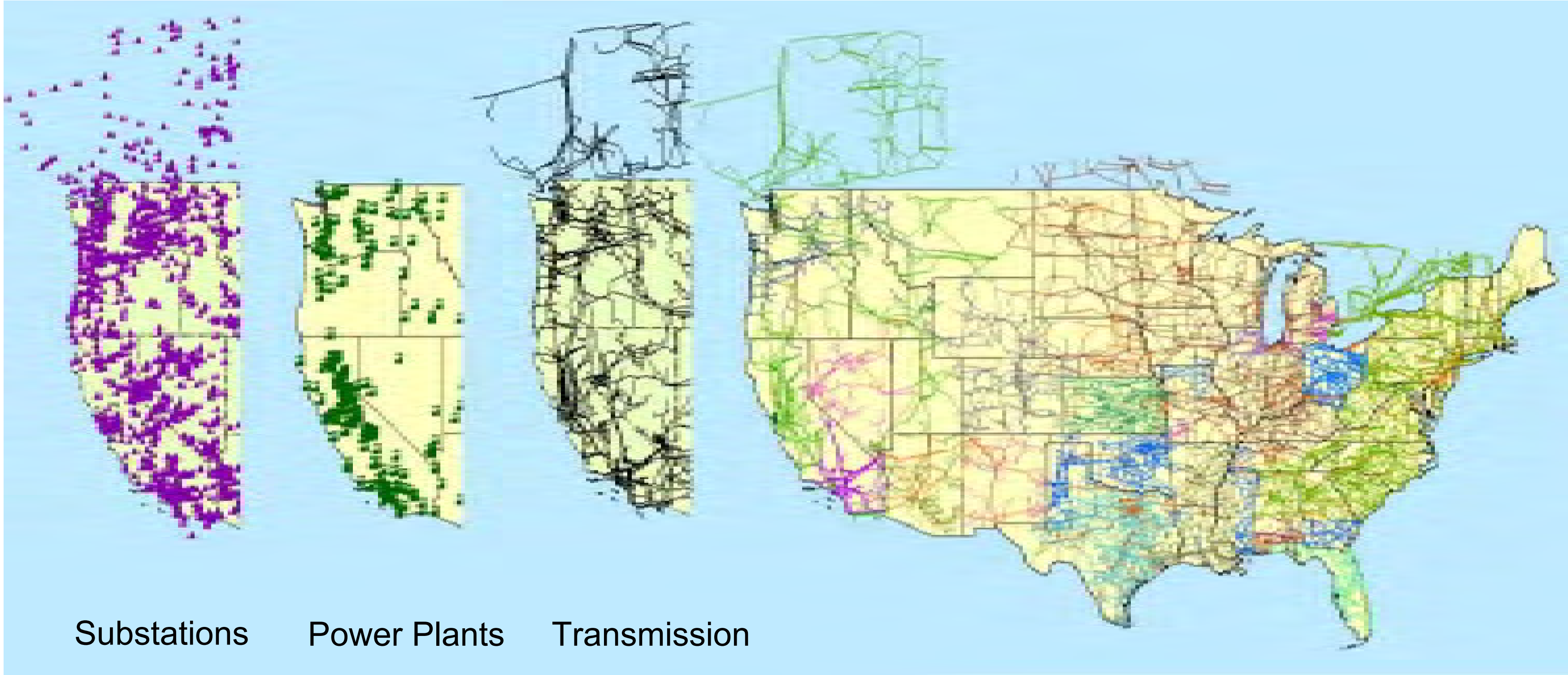


Analysis – Supply to End Users:

- Available networks
- Logistics
- Impact magnitude

Katrina/Rita Effect:

CONUS Electric Power Dataset

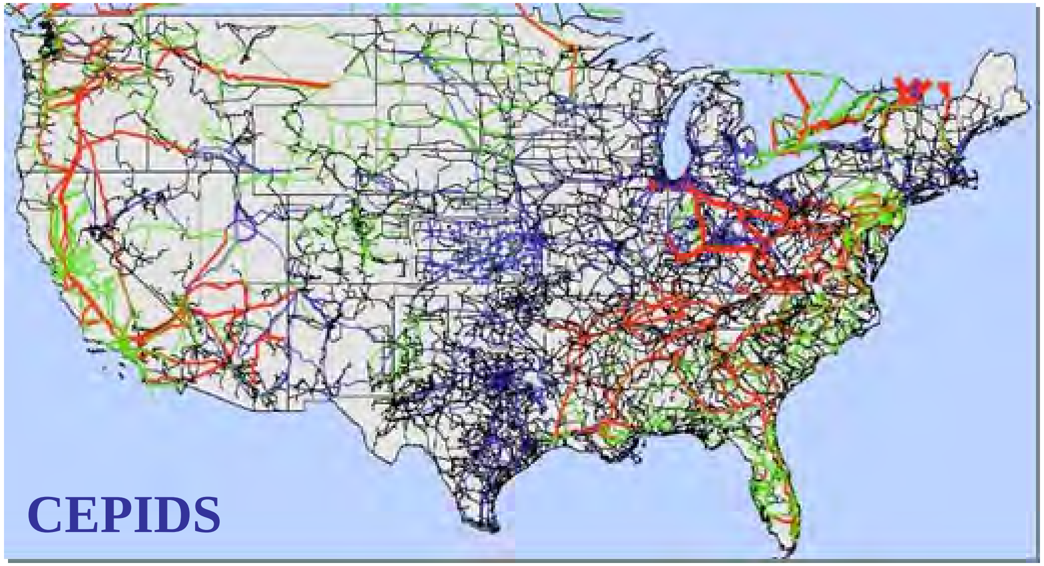


Data Build-out Example

CONUS Electric Power Infrastructure Dataset

ISSUE:

- Insufficient accuracy in commercial datasets
- Unable to add analysis results to commercial datasets



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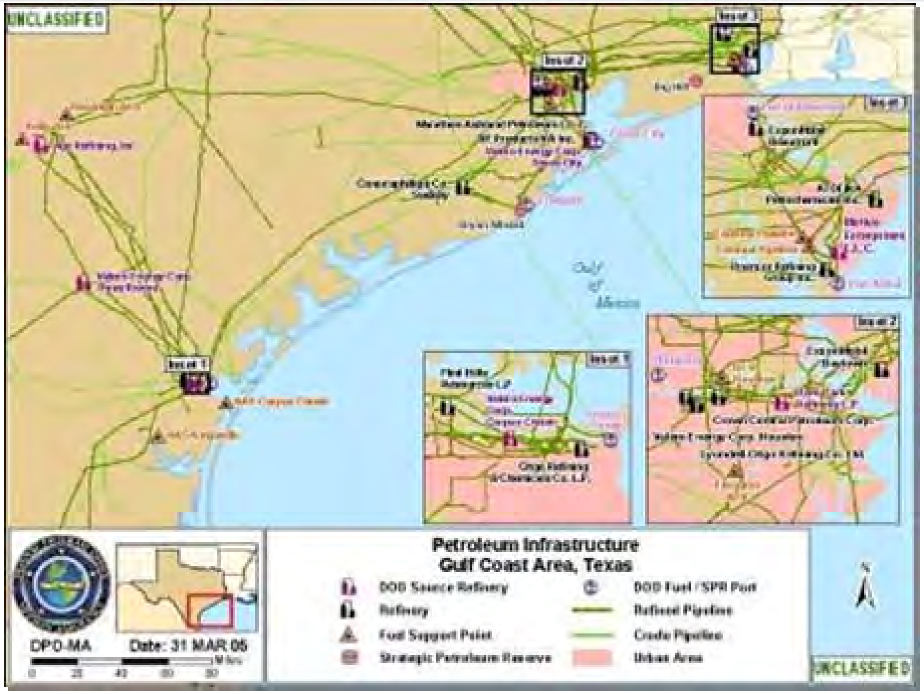

Petroleum

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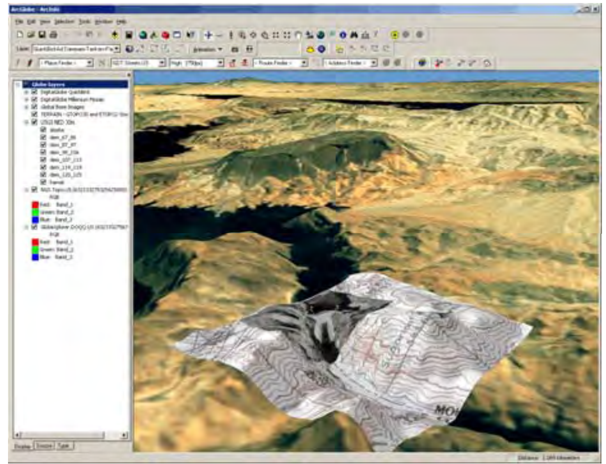
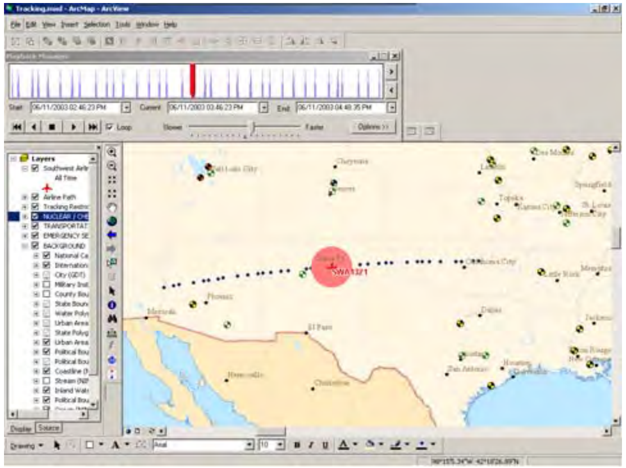


Terrain Modeling/Mobility

3-D Fly Through



Sensor Integration

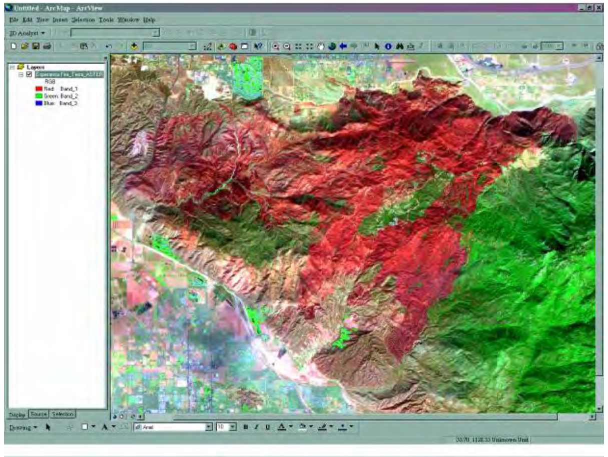
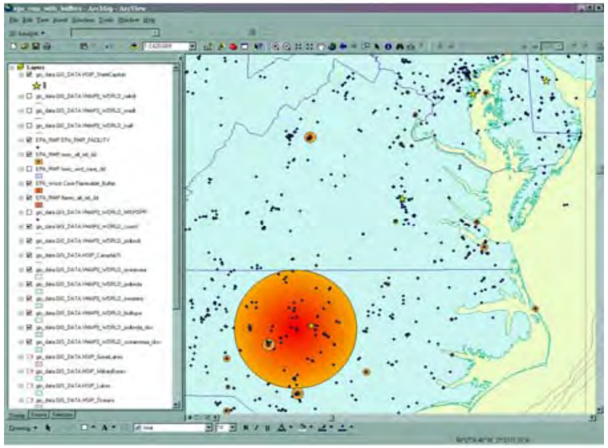


Image Exploitation

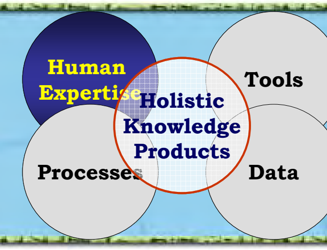


Site Selection

Mission

Enable informed, accurate, and timely risk-management decisions spanning the full spectrum of operations through technical analysis, assessment, integration, innovation, and decision support to assure the availability of physical and non-physical networks and infrastructure for DoD, federal, state, and local agency missions.

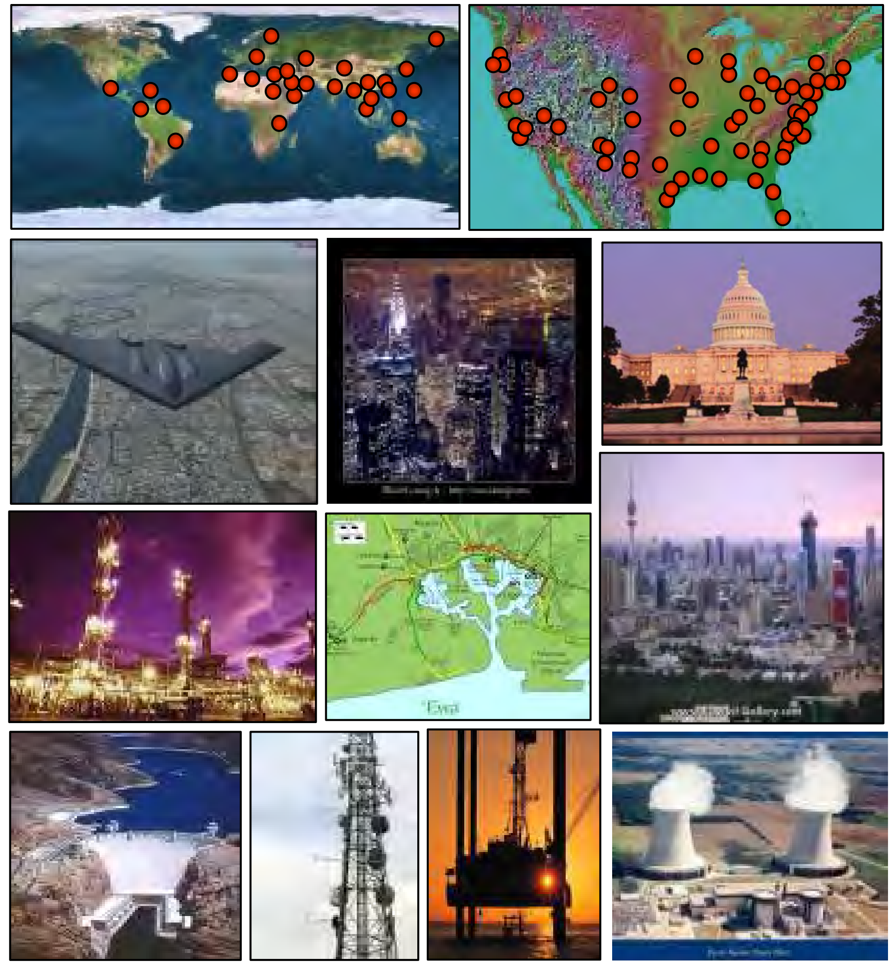
Analyst Backgrounds



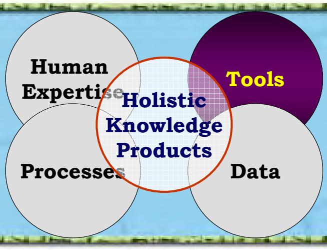
INDUSTRY EXPERIENCE

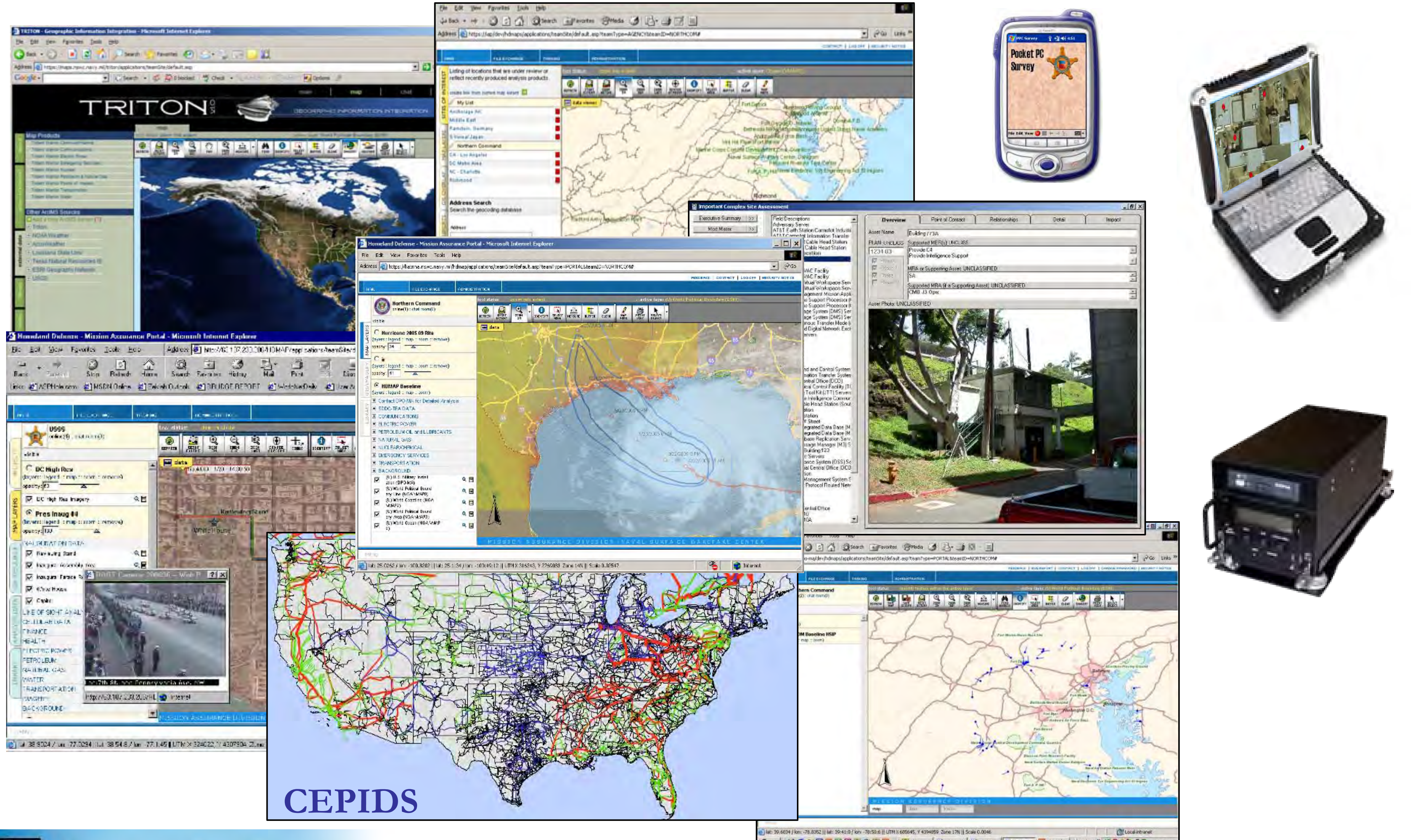
verizon
Dominion
It all starts here.
AT&T
TRW
KOCH INDUSTRIES INC
NORTEL NETWORKS
STATOIL
BASF
ALLTEL
TENNECO
pepco
Constellation Energy
GTE
FMC
ARCO

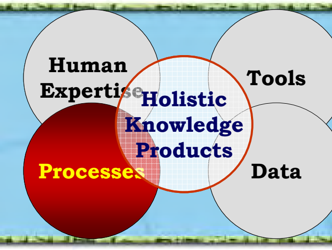
TARGETING & PROTECTING EXPERIENCE



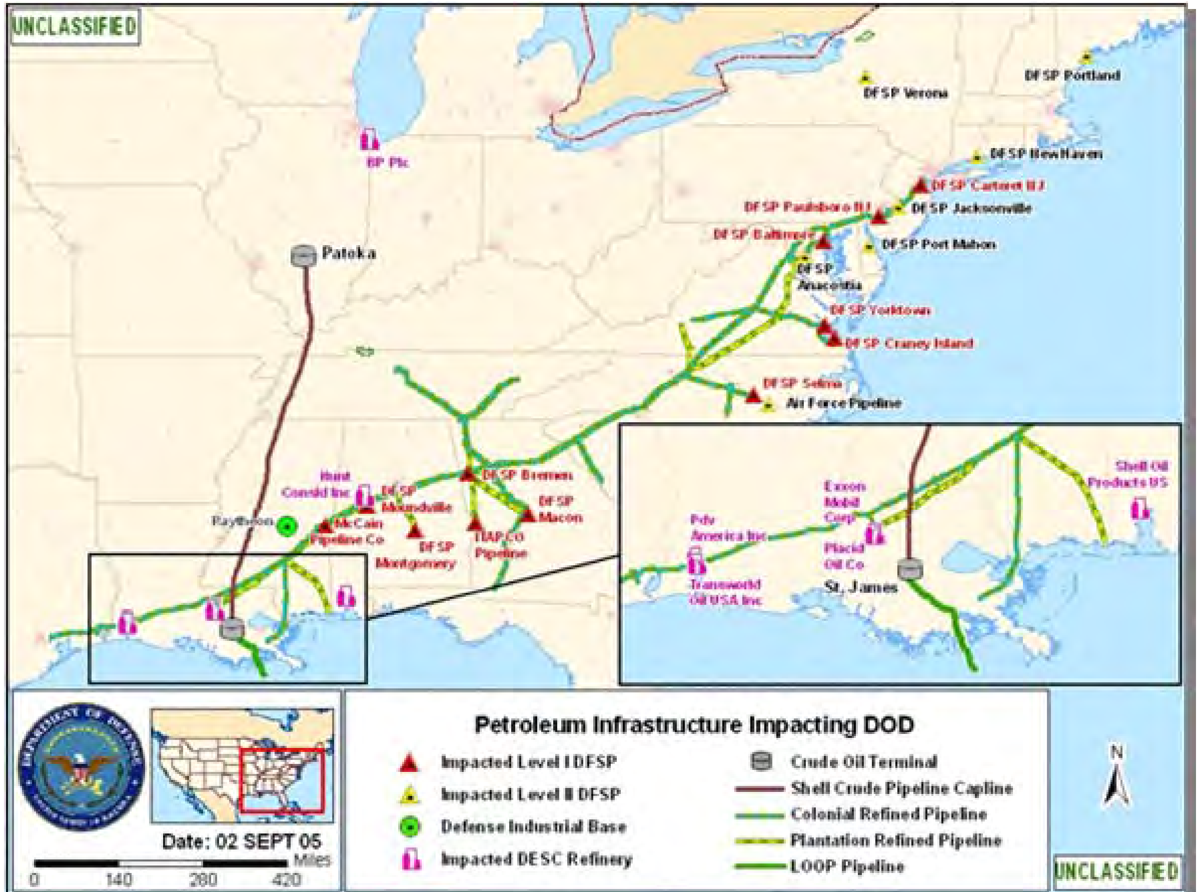
Tools for Analysts & Users







Interdependency Analysis

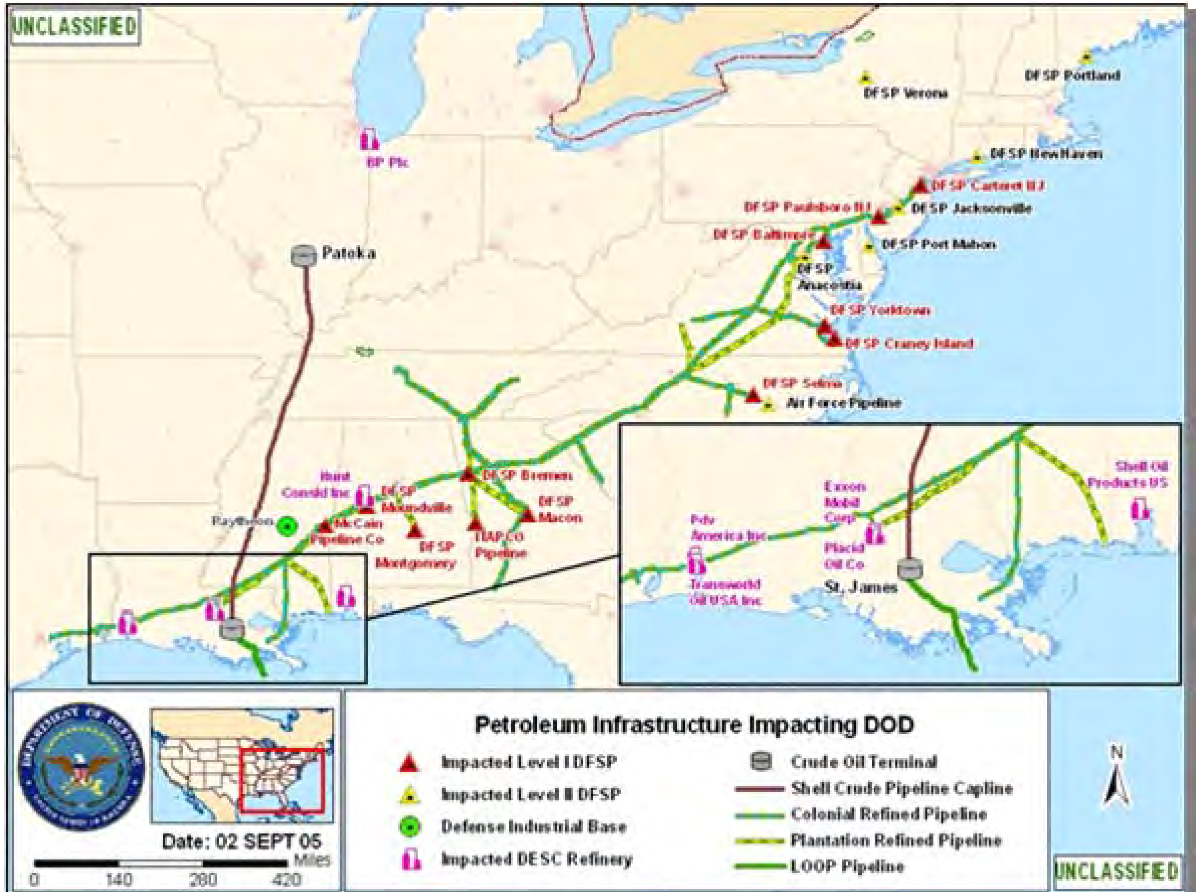


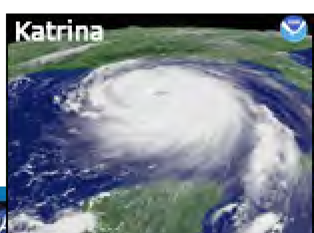
Analysis – Supply to End Users:

- Available networks
- Logistics
- Impact magnitude

Katrina/Rita Effect:

Interdependency Analysis





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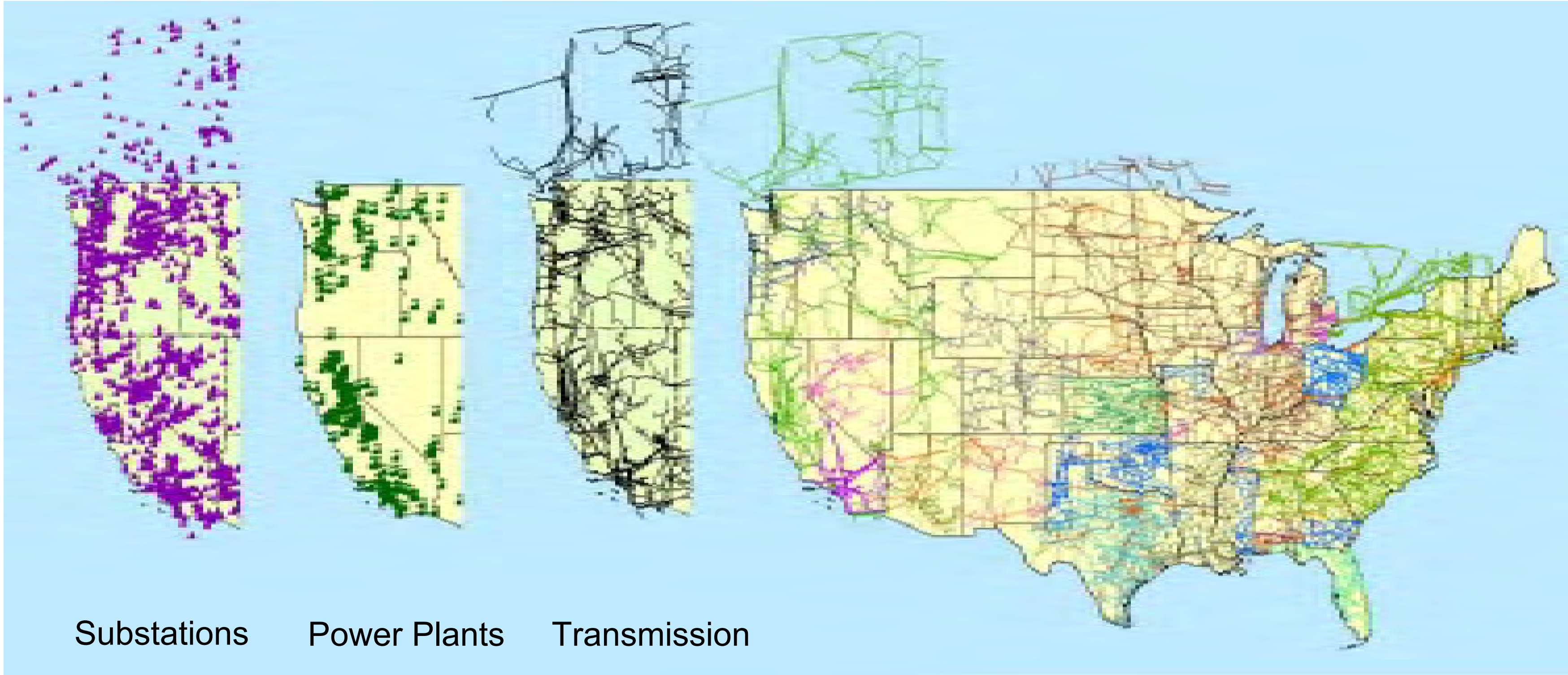
CONUS Electric Power Dataset



Data Build-out Example

CONUS Electric Power Infrastructure Dataset

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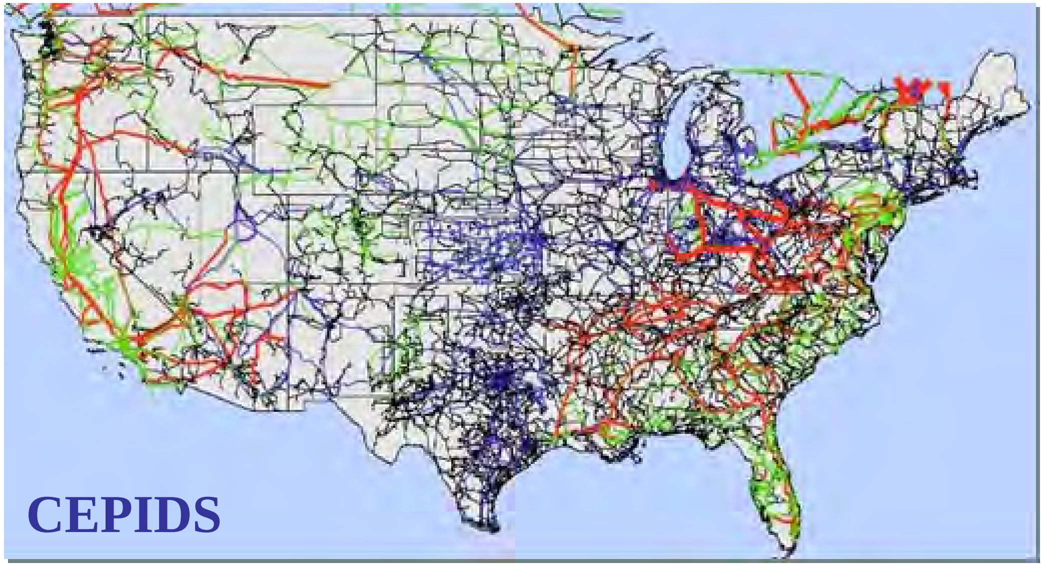

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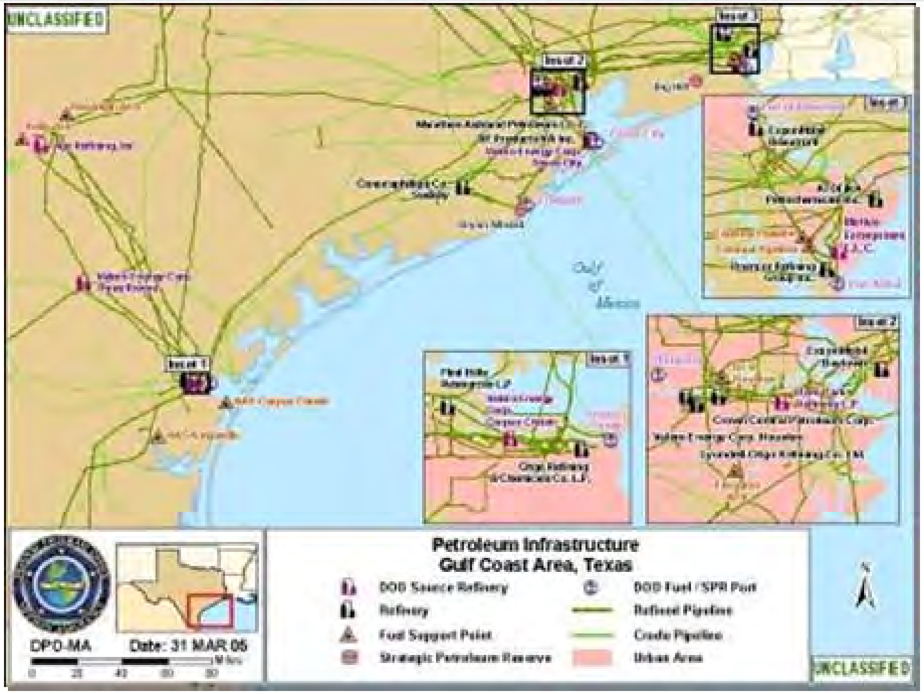

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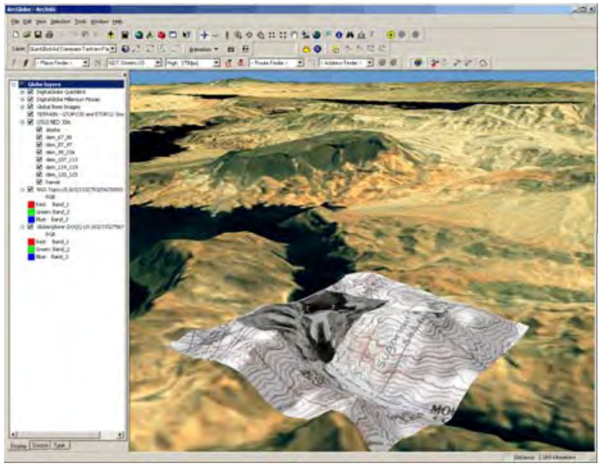

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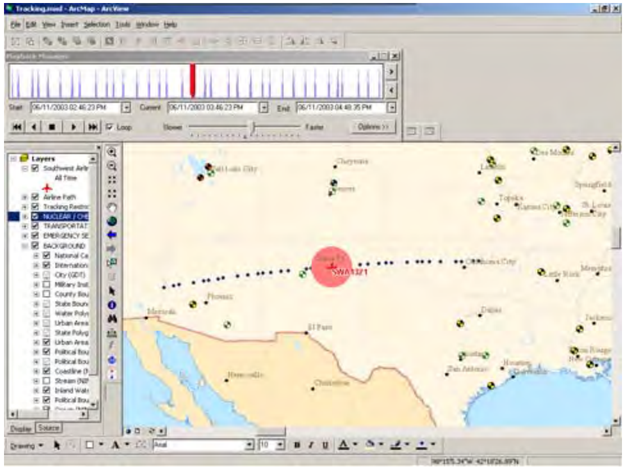

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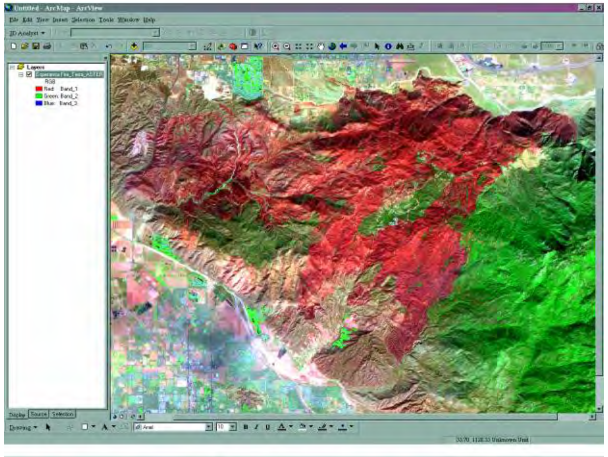

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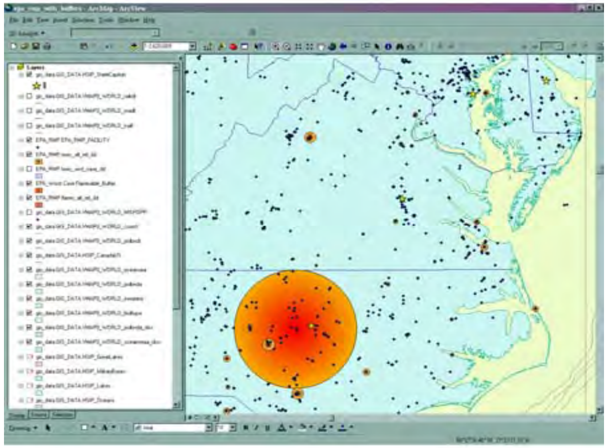
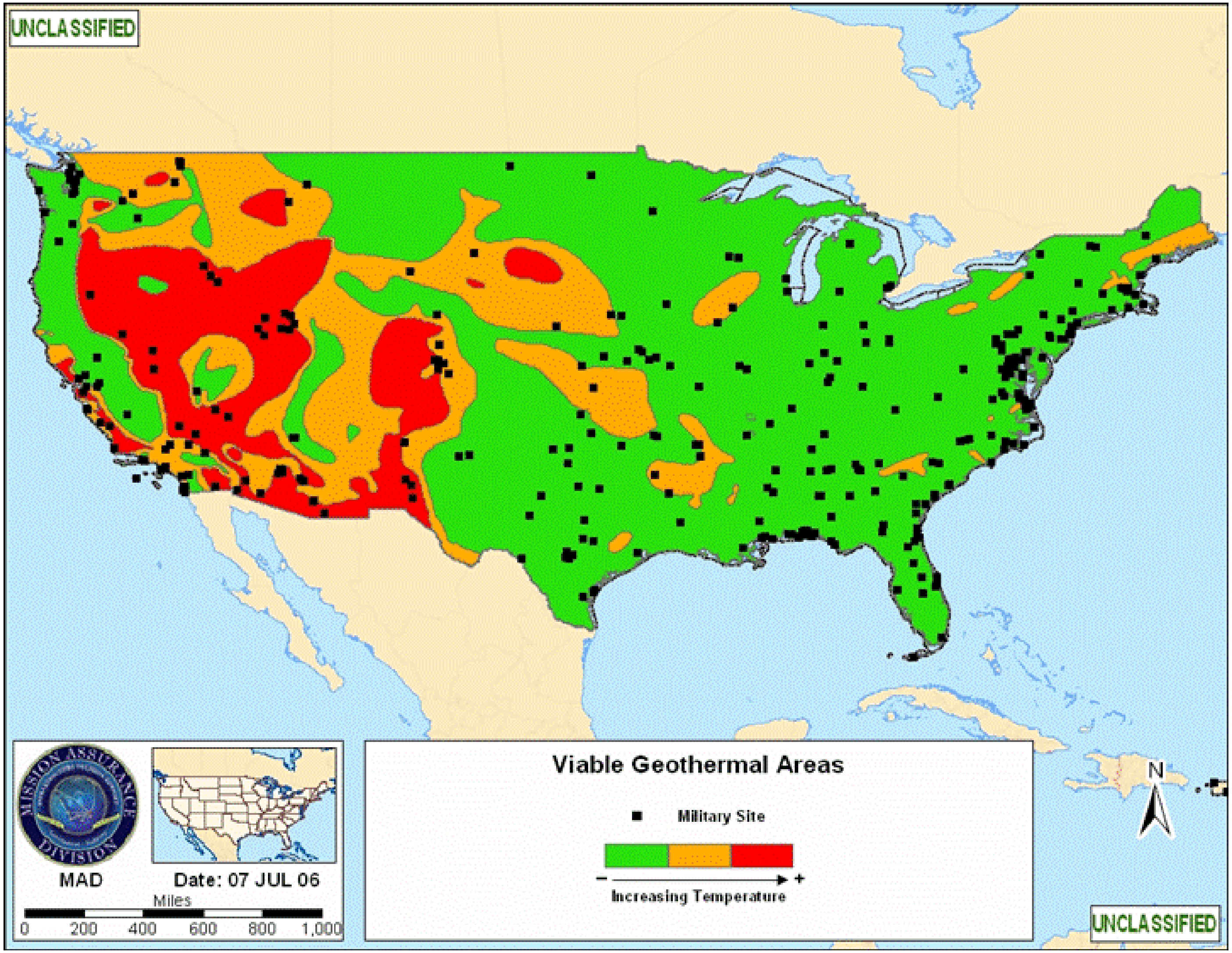
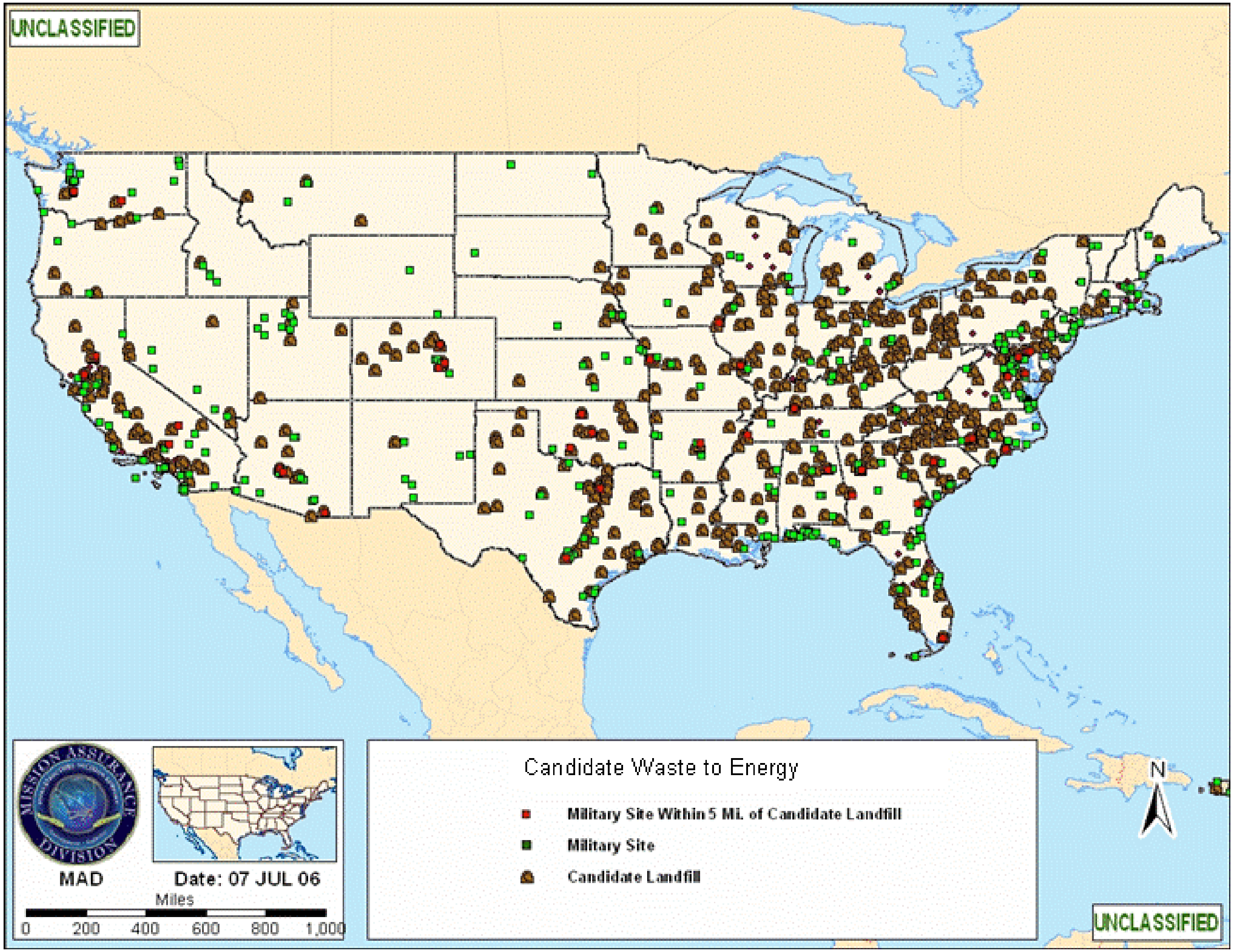


Site Selection

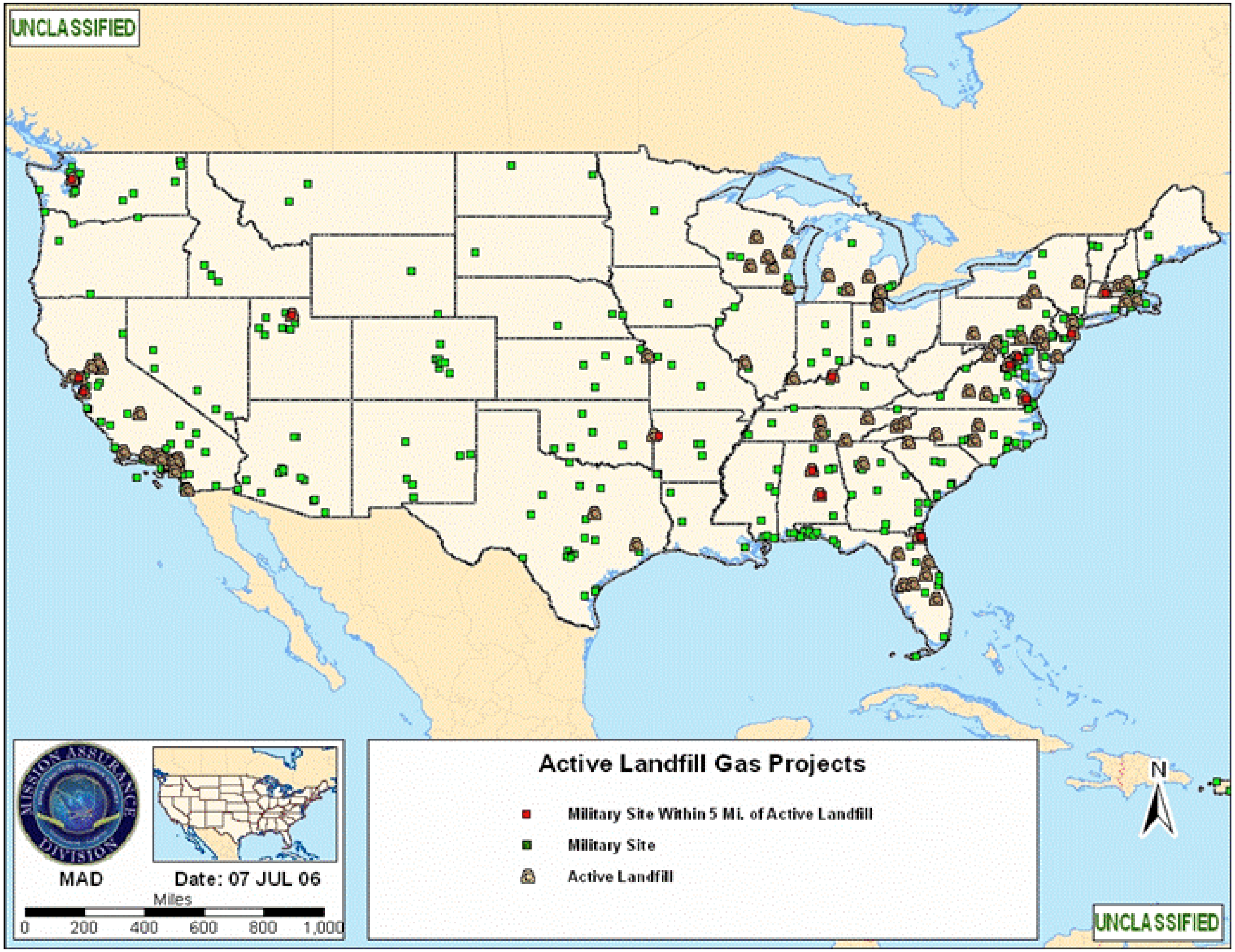
Geothermal – Optimal Locations



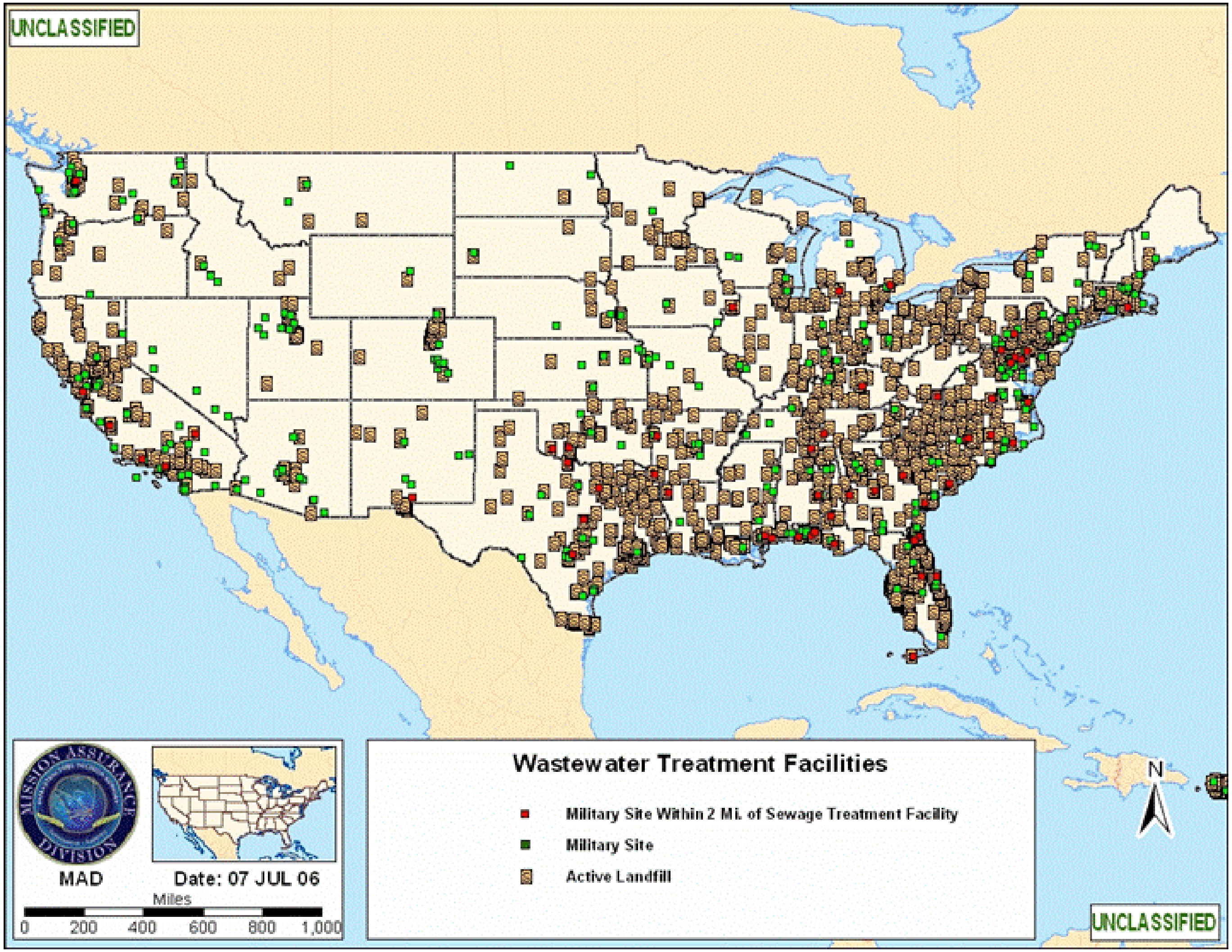
Municipal Waste – Optimal Locations



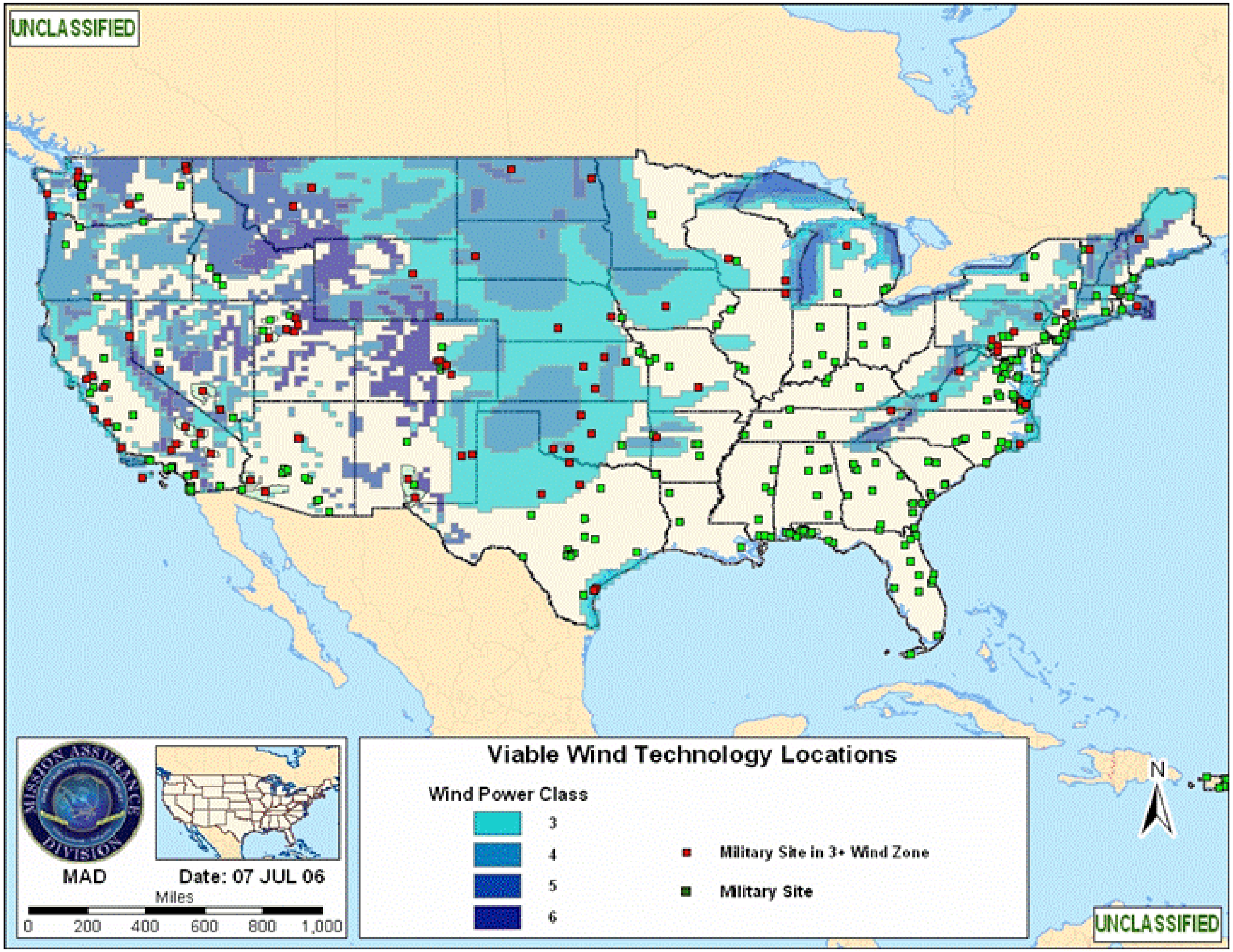
Landfill Gas – Excess Gas Projects



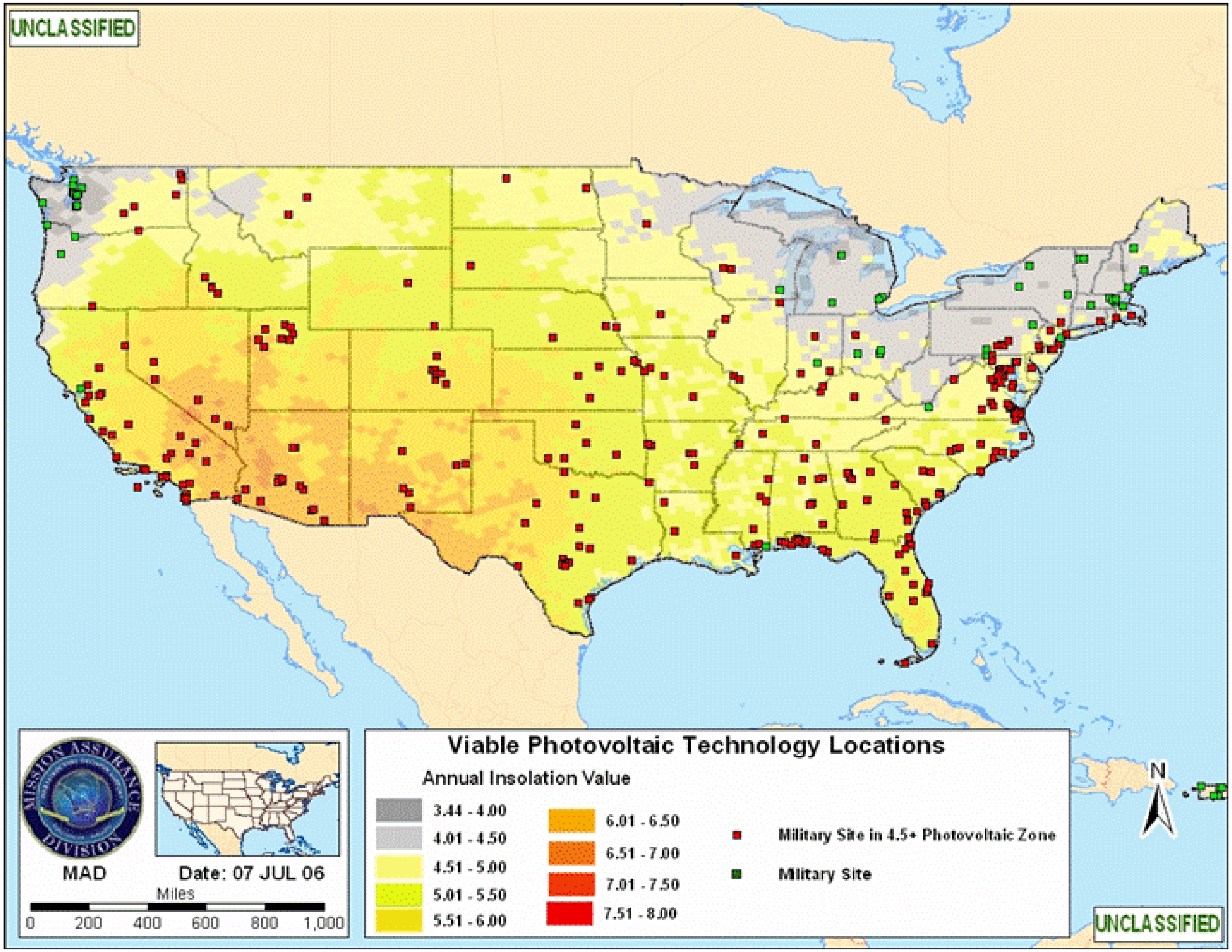
Wastewater Gas – Optimal Locations



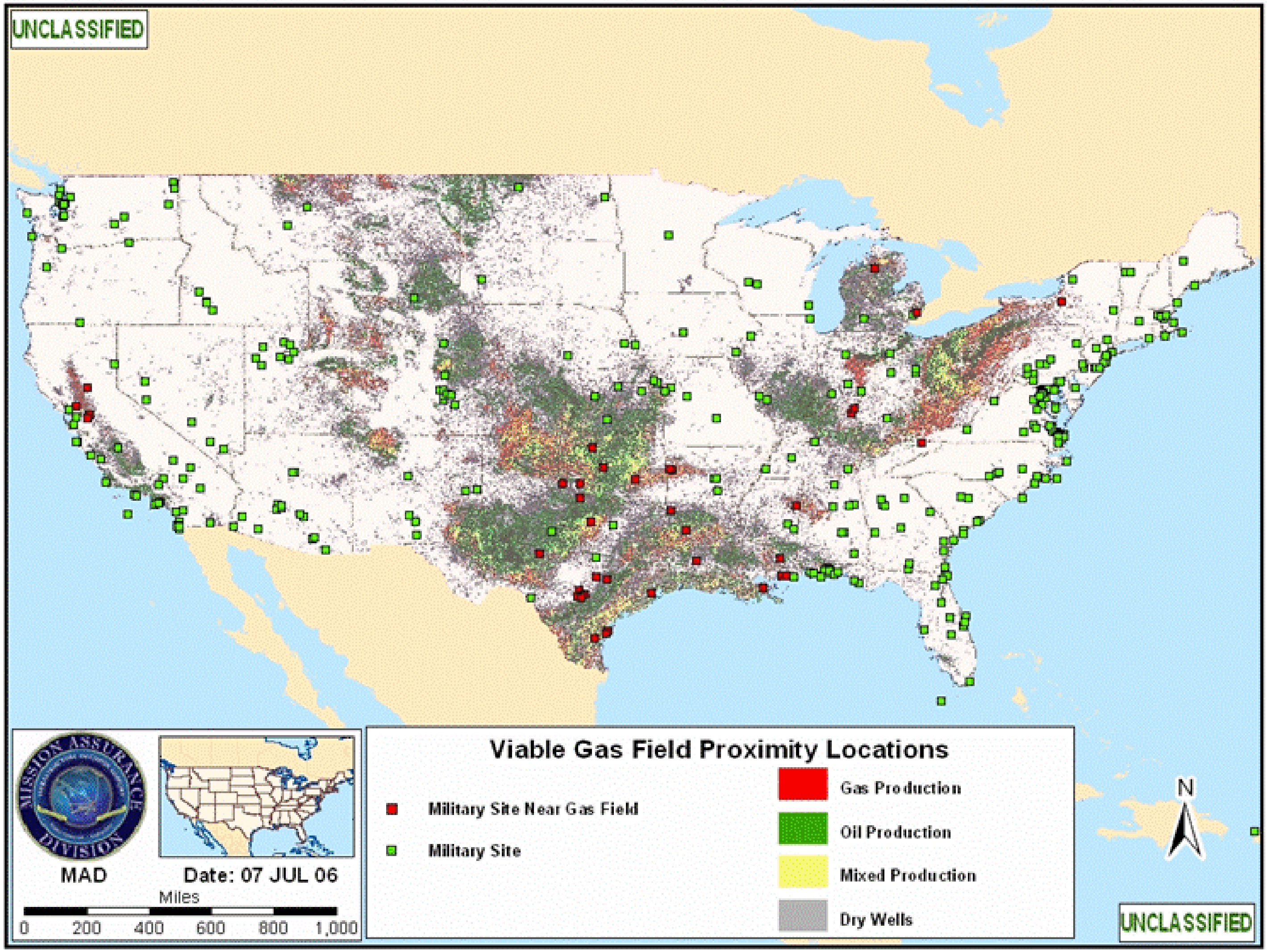
Wind – Optimal Locations



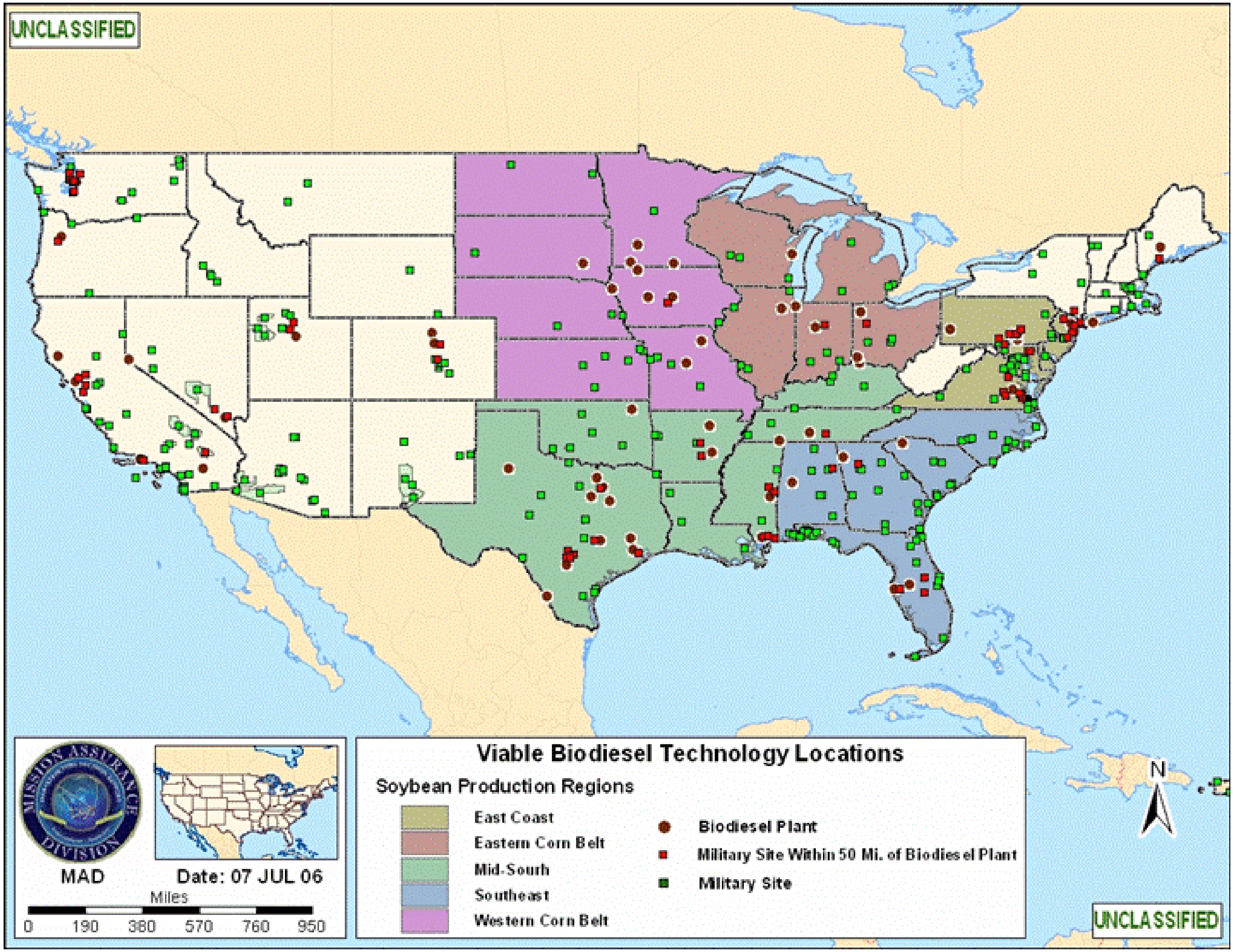
Photovoltaic – Optimal Locations



Natural Gas – Optimal Locations



Biodiesel - Optimal Locations



USMC Energy and Power Future

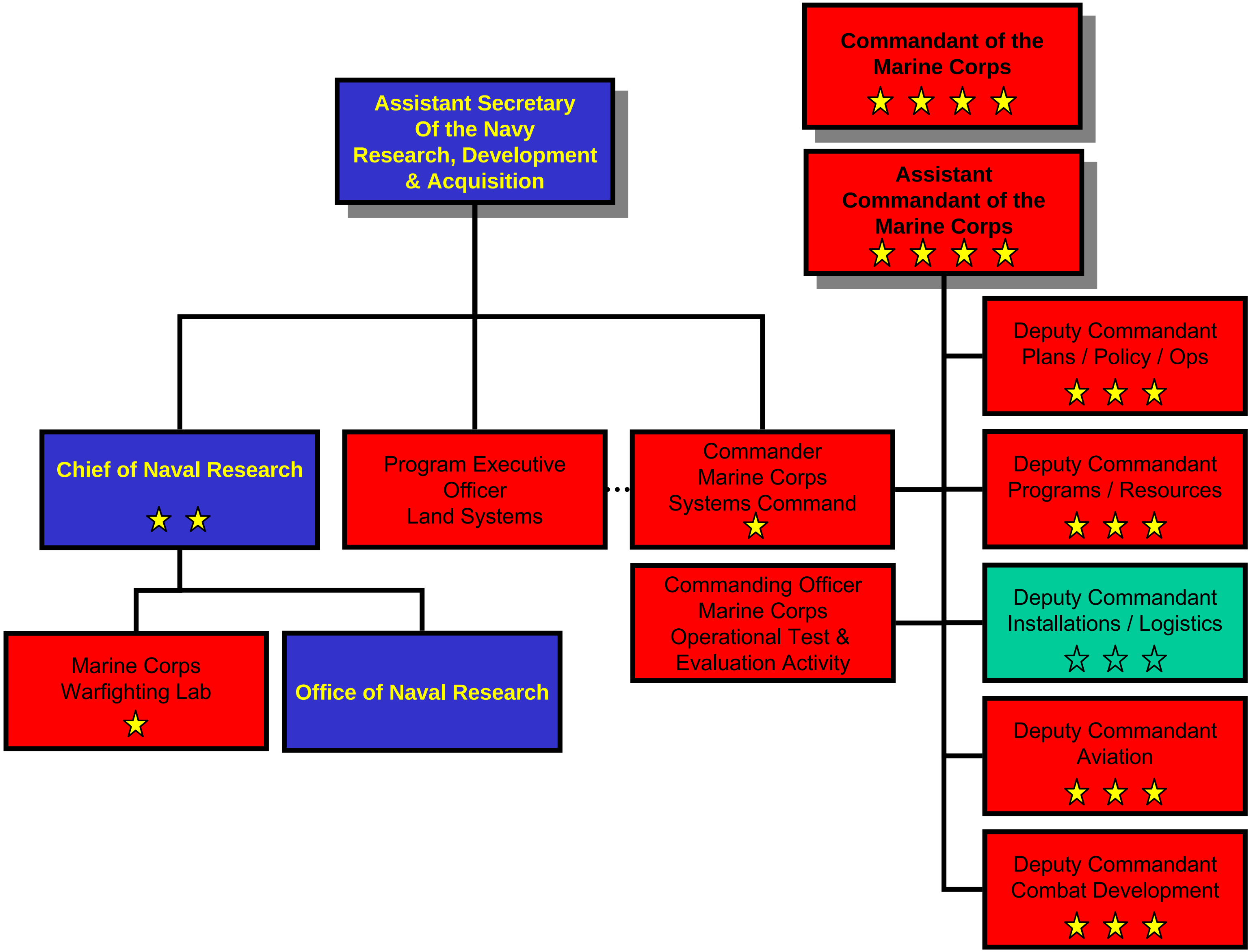
PRISON
Cook County Correctional Center

WORK
Pentagon Washington, DC

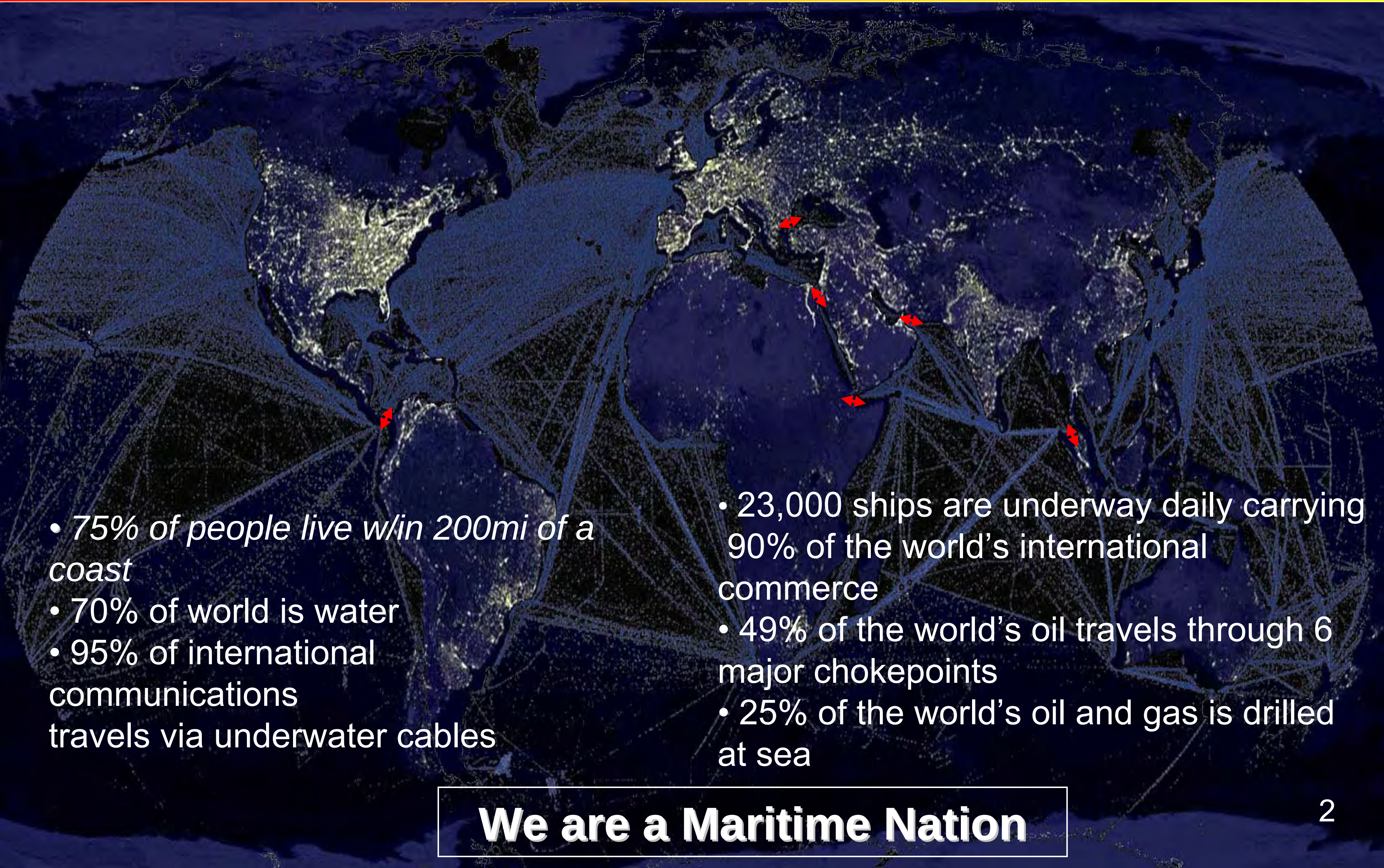
@ PRISON You spend most of your time in a 10X10 cell	@ Work - You spend most of your time in a 6X6 cubicle
@ PRISON You get three fully paid for meals a day	@ Work You get a break for one meal, and you have to pay for it
@ PRISON For good behavior, you get time off	@ Work For good behavior, you get more work
@ PRISON The guard locks and unlocks all the doors for you	@ Work You carry a security card and open all the doors yourself
@ PRISON You can watch TV and play games	@ Work You could get fired for watching TV and playing games
@ PRISON You get your own toilet	@ Work You share the toilet with people who pee on the seat
@ PRISON They allow your family and friends to visit	@ Work You aren't even supposed to speak to your family
@ PRISON All expenses are paid by the taxpayers with no work required on your part	@ Work You must pay all your expenses to go to work, and they deduct taxes from your salary to pay for prisoners
@ PRISON You spend most of your life inside bars wanting to get out	@ Work You spend most of your time wanting to get out and go inside bars
@ PRISON You must deal with sadistic wardens	@ Work They are called '"Generals and Admirals"

THERE IS SOMETHING SERIOUSLY WRONG WITH THIS PICTURE.

USMC Organizations involved in Research and Acquisition



Our Interconnected World



- *75% of people live w/in 200mi of a coast*
- 70% of world is water
- 95% of international communications travels via underwater cables

- 23,000 ships are underway daily carrying 90% of the world's international commerce
- 49% of the world's oil travels through 6 major chokepoints
- 25% of the world's oil and gas is drilled at sea

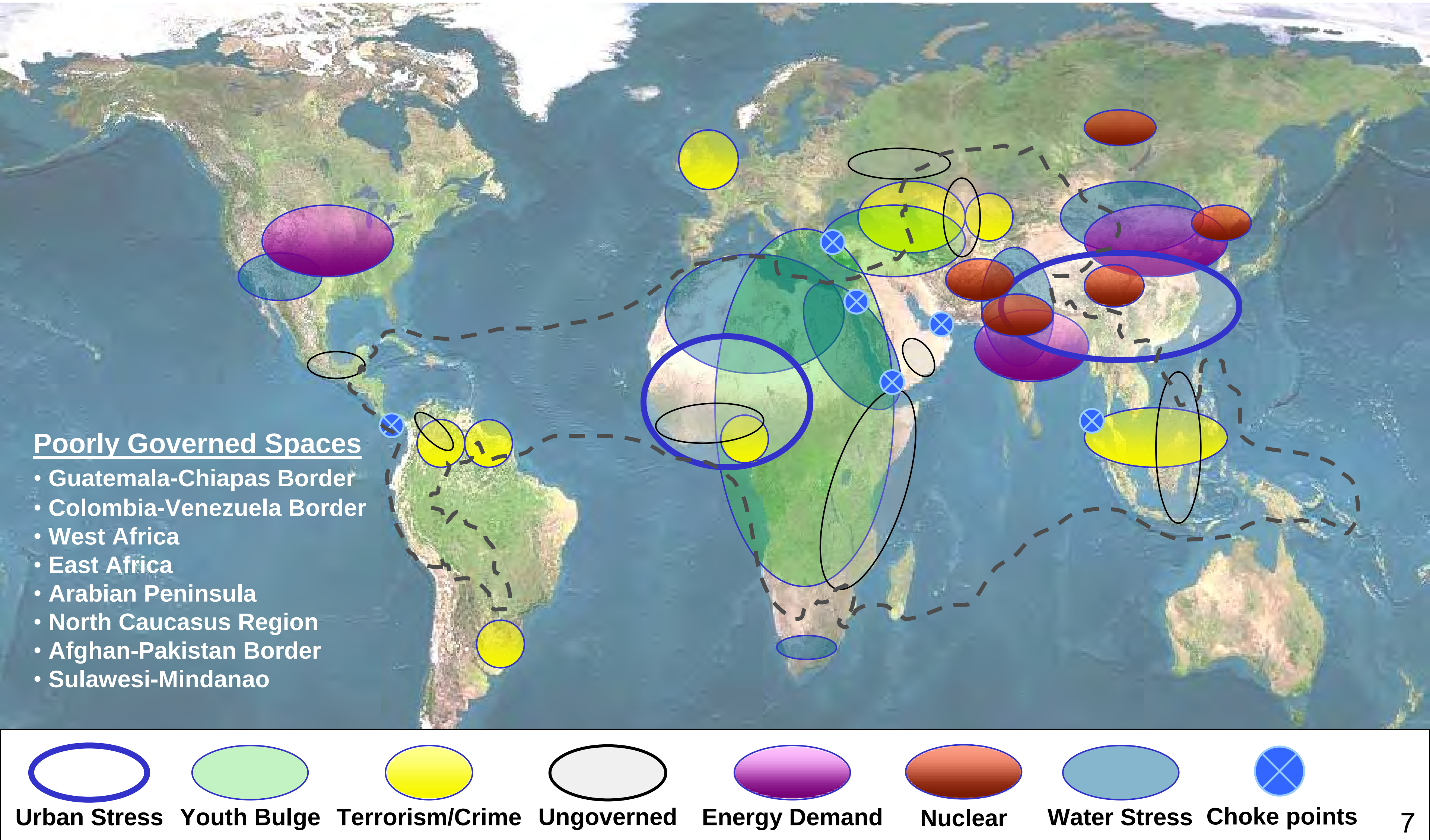
We are a Maritime Nation

Strategic Challenges

- Multipolar world
  - Economic volatility
  - Energy dependency
  - Global Commons accessibility
- Weakened states
  - Key region instability
  - Terrorist / Pirate sanctuary
  - WMD proliferation
- Transnational threats
  - Migration & Illegal immigration
  - Climate change
  - Increased competition for resources

Pirates – Argghhh!

Sources of Instability, Stress & Conflict



Hybrid threats, the blurring character of conflict,and complex environments lead to…

Wars Amongst the People

Hybrid Threat Capabilities

ARC OF INSTABILITY

- Emerging Global Powers
- Increasing Global Interdependence
- "Haves" vs "Have Nots"
- Anti-West attitudes

- Terrorism/Crime
- Significant Drug Regions
- Ungoverned Spaces
- Nuclear Armed States
- Anti-access Weapons

Access challenges…

Largely in the Littorals

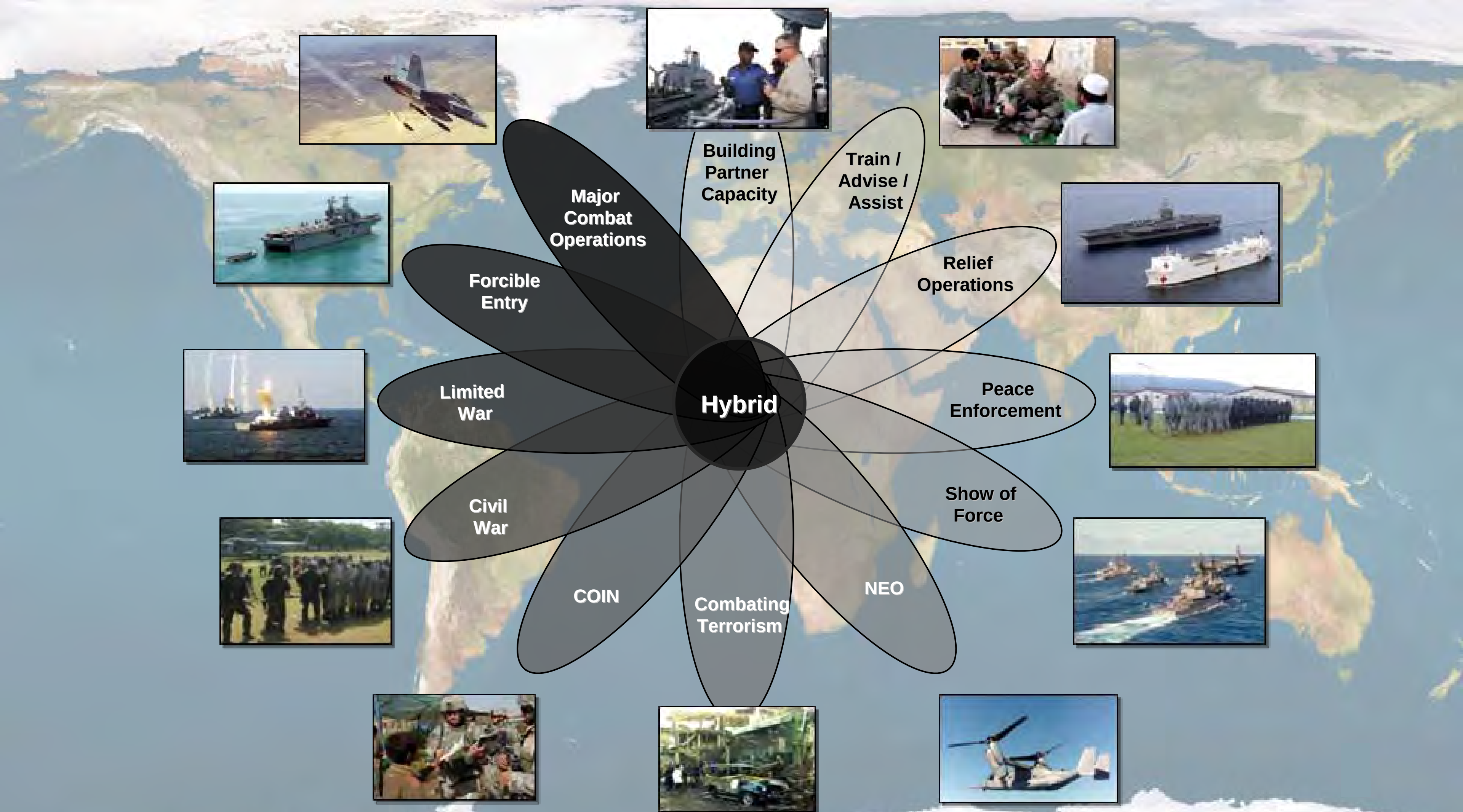
Complex Terrain

- Urbanization
- High Earthquake Risk Areas
- Famine and Disease
- Top Ten Oil Reserves

Information Environment

The "asymmetrical kind of war" we face today will last at least two decades…

…thriving in an uncertain world



Conflict is not "irregular" or "conventional"

Requires "Smart Power" - combines soft and hard power

We <u>are</u> the Nation's Expeditionary Force

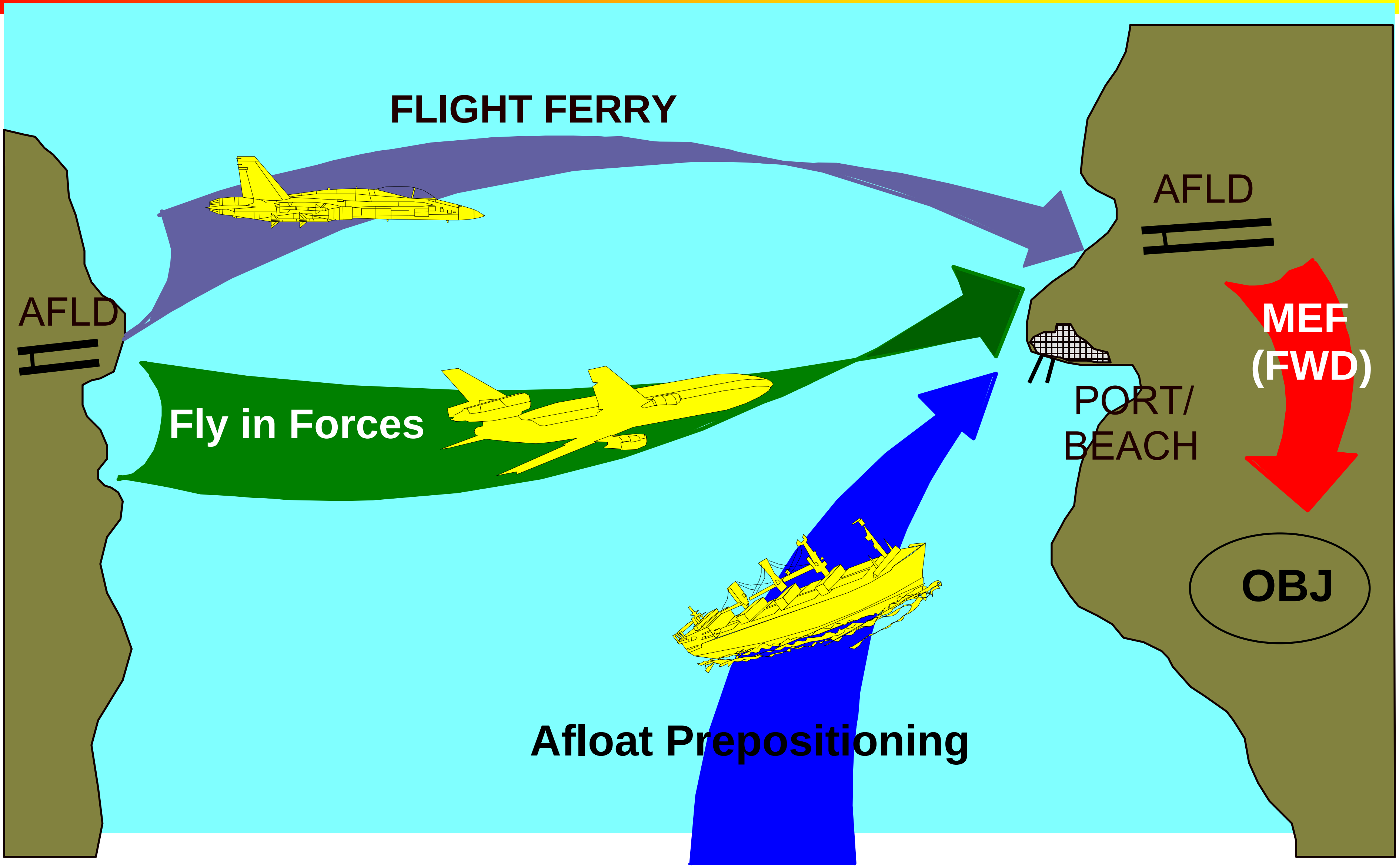
Certain Capabilities for an Uncertain World

USMC Energy Challenges

Philosophical Challenges

- Plan for Worst Case
  - "The Marine Corps will be ready when the rest of the Country is not"
- Evolving scale of Warfare
- Success on the side of Bigger Battalions
- Cost – Effectiveness vs ROI

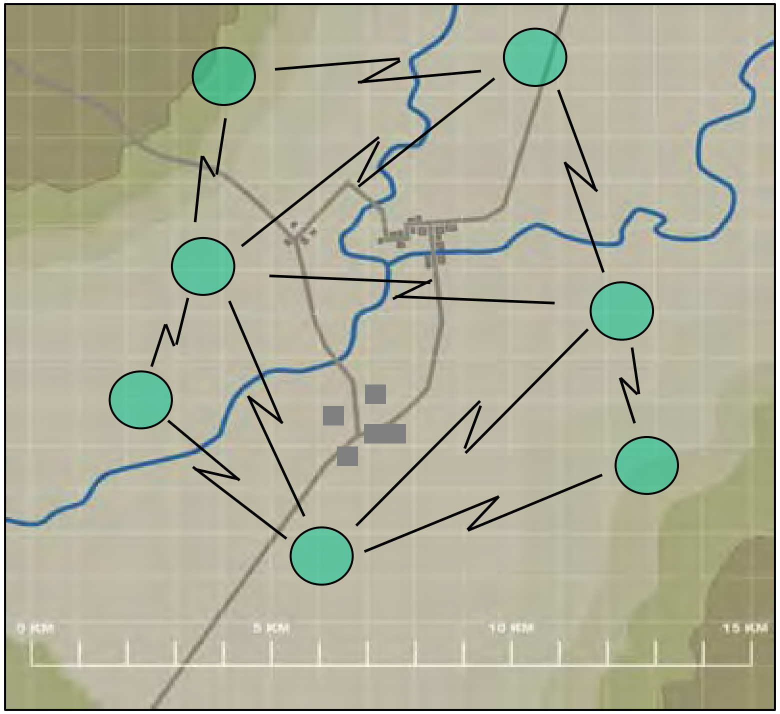
Current Deployment Concept



Future Seabasing and Expeditionary Maneuver Warfare
A Faster More Lethal Force

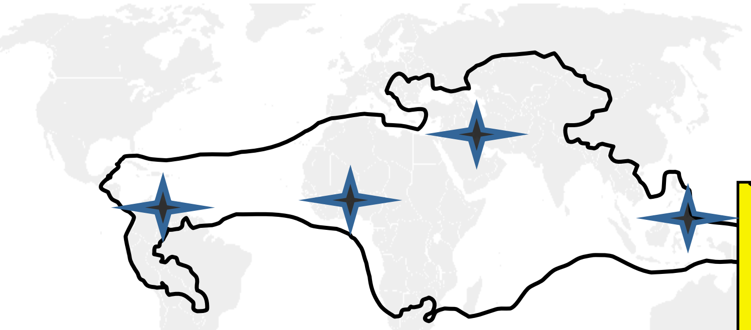
New Capabilities ... New Way to Fight

Distributed Operations



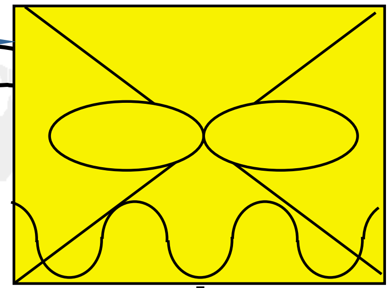
Security Cooperation MAGTF

Task organized to meet specific requirements



KEY to increasing forward presence and engagement

SC MAGTF



Additional capabilities / attachments as required:

- Interagency Representatives
- Navy Expeditionary Combat Command
- U.S. Coast Guard
- Allies
- Info Operations / Civil Affairs
- Veterinary capabilities
- Band
- Others as needed

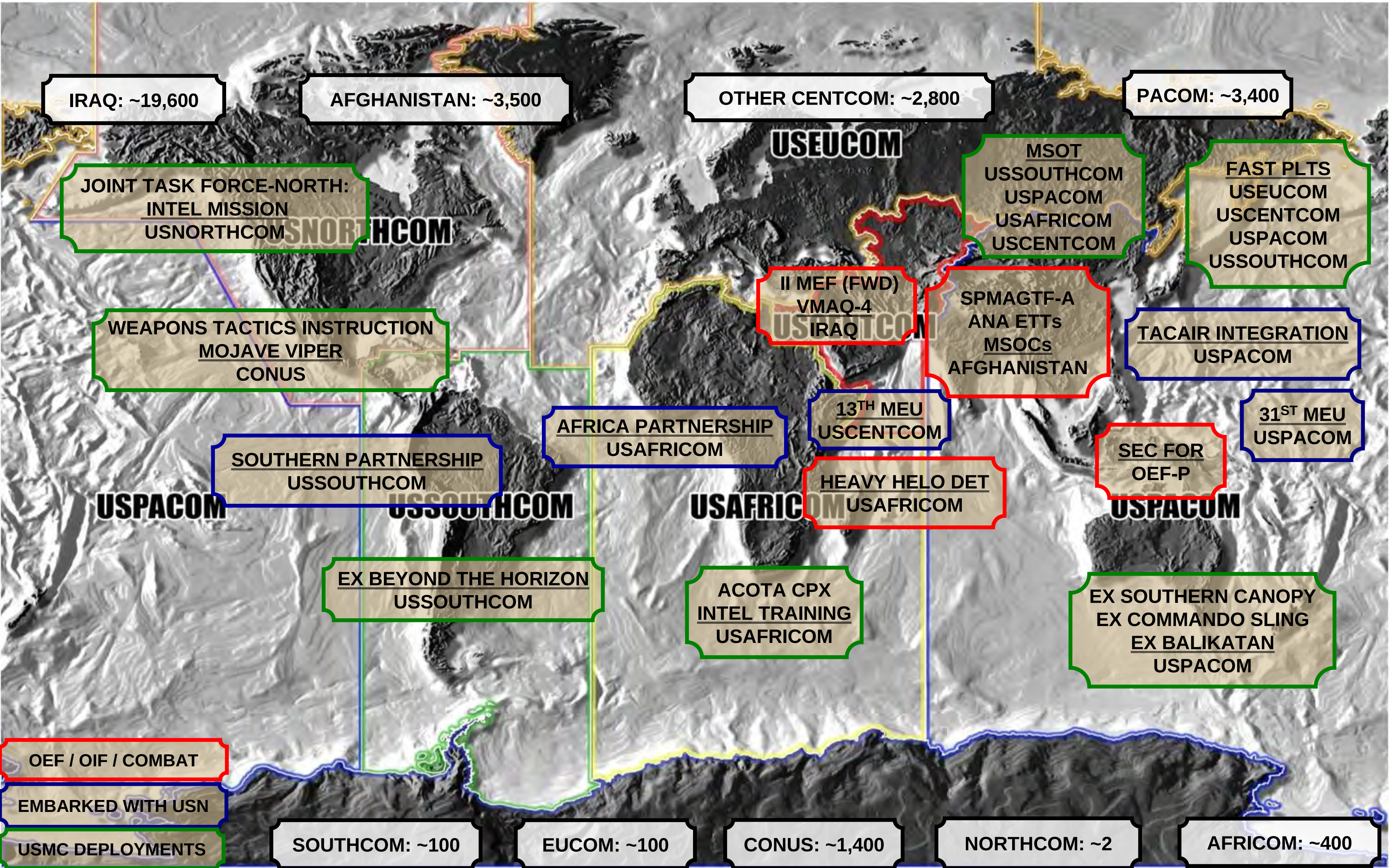
Reinforced Infantry Battalion

Task Organized Aviation Detachment

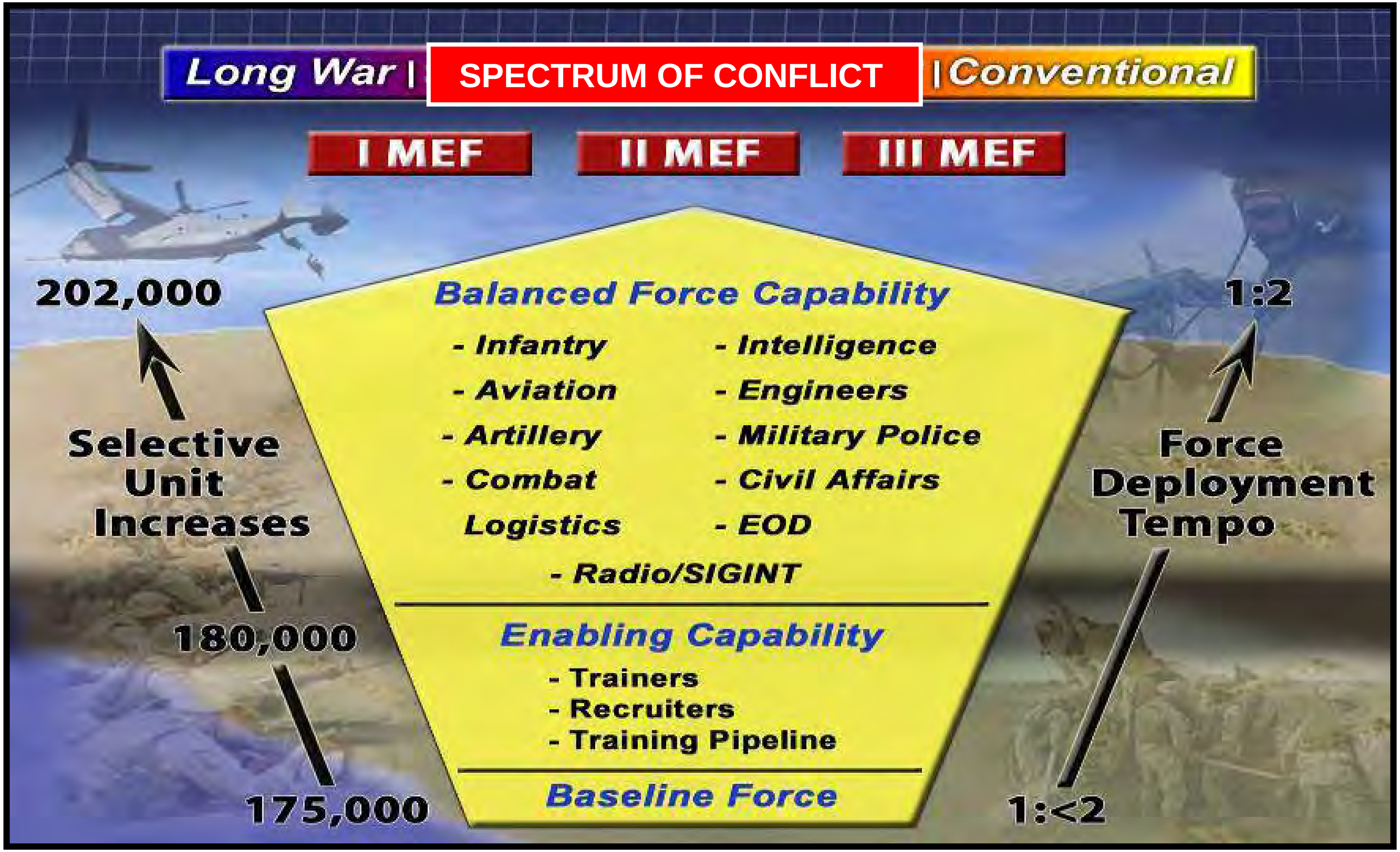
Task Organized Combat Logistics Element

Other Detachments

Current Global Force Disposition



Balanced Expeditionary Capability



Bigger Organizations

Sept 11th 2001	Iraq / Afghanistan	2006
Traditionally Focused	In Theatre	Distributed Operations Enabled
Table of Equipment	Table of Equipment	Table of Equipment

Radio Density

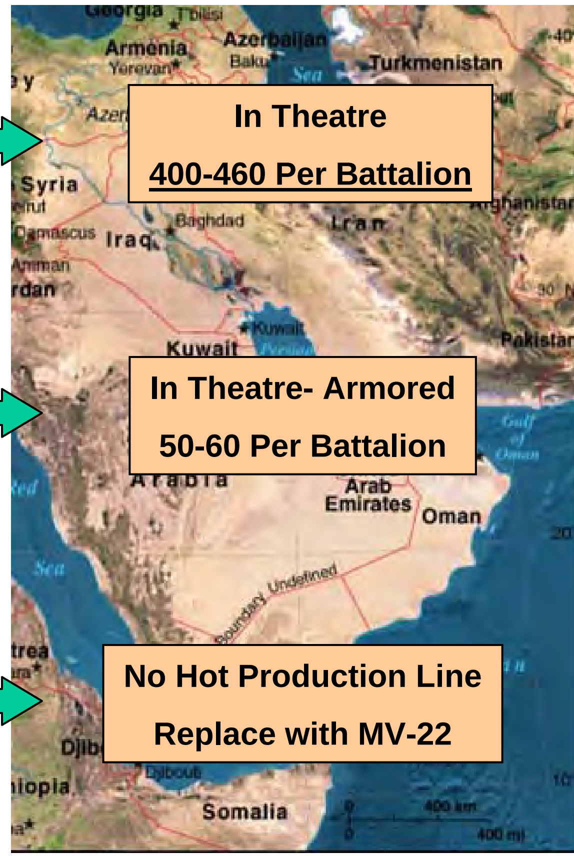
175 Per Battalion

HMMWV Not Armored

32 Per Battalion

CH-46

12 Per Squadron



In Theatre

400-460 Per Battalion

In Theatre- Armored

50-60 Per Battalion

No Hot Production Line

Replace with MV-22

Radio Density

1220 Per Battalion

HMMWV Armored

55 Per Battalion

MV-22

12 Per Squadron

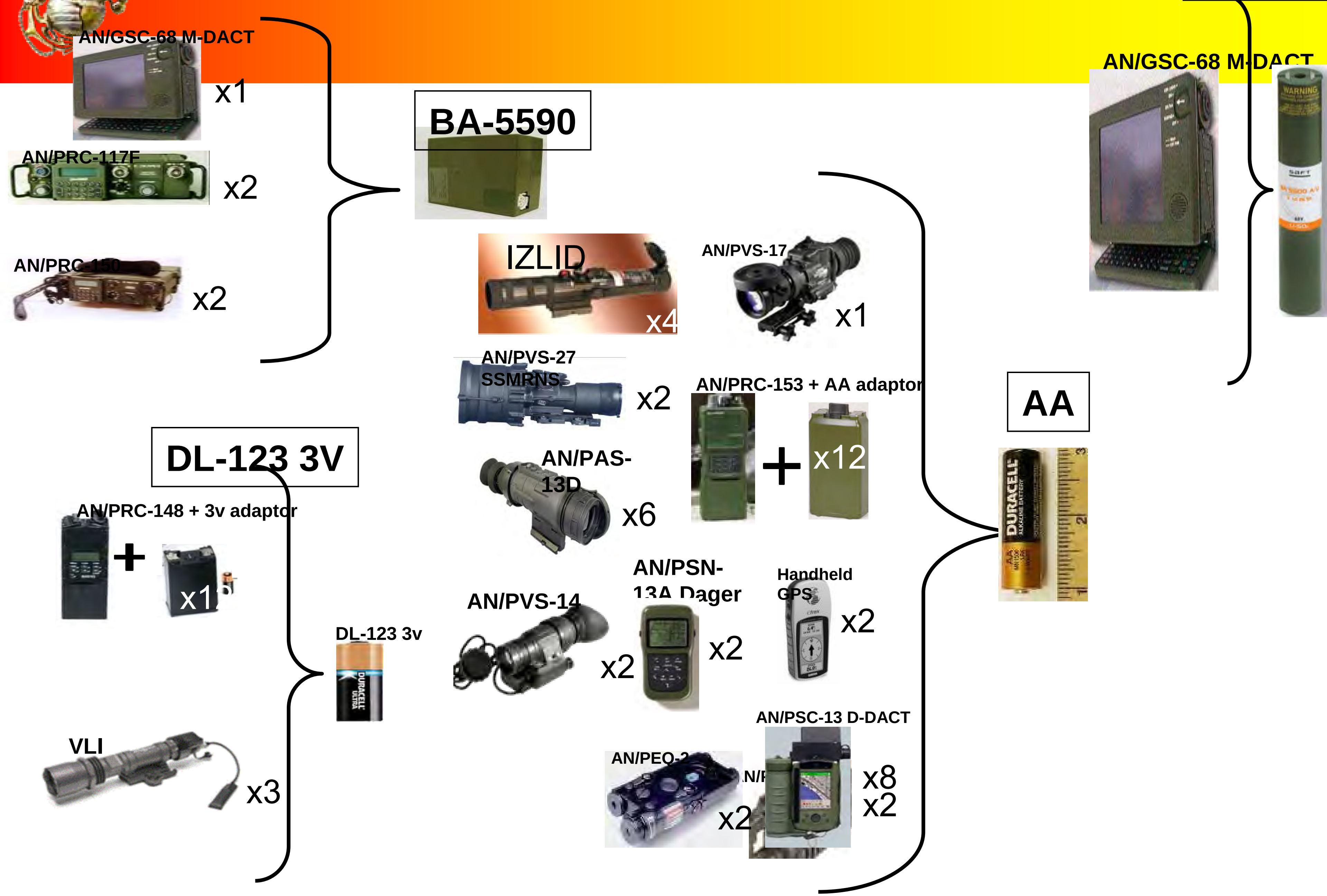
Meeting Theatre Demands, Responding to Lessons Learned & Replacing Destroyed Equipment with 2006 Technology

Infantry Squad Communication in the Old Days

AN/PRC-88 x 1

BB588/U x 1

Modern Infantry Squad Requirements



Squad Systems Requiring Non-Compatible Rechargeable Lithium Batteries

AN/PRC-153 IISR

AN/PSC-13 D-DACT

MSIDS

AN/VSQ-2C EPLRS

Squad Digital Camera

Tactical Computer

Health and Comfort Issues

No Problem in the Assault

But Austerity Goes Only So Far

Capability vs Affordability

DoD **USMC**

2002 HMMWV Business Case

	Stock **HMMVV**	**Hybrid HMMVV**
Top speed (mph)	70	85
Acceleration(0-50) (sec)	14	7
Fuel economy (mpg)	8	16
Range (miles)	275	380
Power Gen Source	None	55KW
Cost	***$50K***	***$200K***

Hybrid HMMWV 200% more fuel efficient

Army Transformation

USAF Transformation

Navy Transformation

Providing Energy not easy

Marine Corps Energy Solutions

Marine View of Change

2002 Fuel Efficiency Policy Memorandum

- Set forth following actions:
  - Acquisition:
    - **Achieve a 10% reduction of fuel requirements in replacement platforms**
    - **Consider Fuel Efficiency as a key requirement in each acquisition milestone decision**
  - RDTE: Continue Warfighting Laboratory efforts in emerging technologies to reduce fossil fuel use
  - Bases and Stations: Prosecute an alternate fuels program in non-tactical fleet

Operational Drivers

Maj. Gen. Richard Zilmer submitted an **urgent request for renewable energy systems** due to the vulnerability of American supply lines to insurgent attack by ambush or roadside bombs. The request said "**reducing the military's dependence on fuel for power generation could reduce the number of road-bound convoys**." …'Without this solution, personnel loss rates are likely to continue at their current rate. Continued casualty accumulation exhibits potential to jeopardize mission success…'"

Defense News, August 2006

Strategy and Vision 2025
January 2009

- Improve aggressive research, development, acquisition, fielding and sustainment of equipment that;
- Has inherent force protection capability,
- **Is lighter, easier to maintain, and promotes energy efficiency, and**
- Ensure interoperability with and between naval platforms and joint systems.

Changes in Equipment Fuel Efficiency

Old **New**










Platform Old/ New	(Yr)	(Mi/Gal)	Cargo max (tons)	baseline Mi-Tons/Gal	Fuel Eff Incr %
HMMWV	1984	13	2.5	33	
JLTV	2015	17	2.5	43	25%
M813	1982	4.3	5	21.5	
MTVR	2002	4.5	7.1	32	50%
LVS	1990	2	12.5	25	
LVSR	2010	2.6	16	42.9	42%
CH46	1963	0.605	2	1.211	
MV22	2006	0.605	5	3.029	61%
F18/AV8B	1988	996 Gal/Hr	2	NA	
JSF	2012	794 Gal/Hr	2	NA	21%

Equipment Scalability Concept

D9

D8

D7

Multi-Terrain Loader

Skid Steer Loader

Water Purifier

LWP (125 gph)

TWPS (1500 gph)

Fuel Distribution

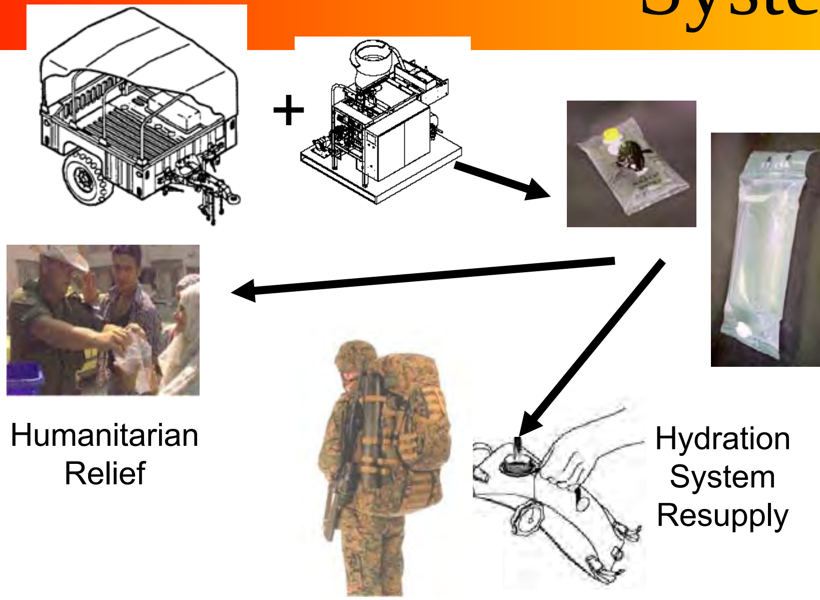
Small System with (6)
28 Gal Bladders

Medium System with (4)
155 Gal Bladders

DESCRIPTION

- Ground Expedient Refueling Systems (GERS) - fuel distribution equipment procured in two sizes (small – 168 gallons; medium – 620 gallons).
- Uses an electric air compressor vice liquid pumps to dispense fuel.
- Transportable by any vehicle (HMMWV or larger), incidental operators, easily set-up and operated.
- Capability to be “tailored” to use various logistics platforms as a fuel distribution vehicle, or as a range-extension capability for units possessing GERS.

Expeditionary Water Packaging System (E-WPS)



Description

- E-WPS places potable water into bags ranging from 1 to 3 liters.
- Serve as source of resupply for the existing Marine-on-the-move hydration system or stand alone packaged water for relief missions. Note: The E-WPS bag is not intended for replacement of the hydration system bladder, but to serve as a source of water to refill the bladder.
- Rugged, automated, and skid mounted so that it can be integrated on a standard M1102H HMMWV trailer without exceeding the towing capacity of the HMMWV

Foam for tents and Relocatable Buildings

End View

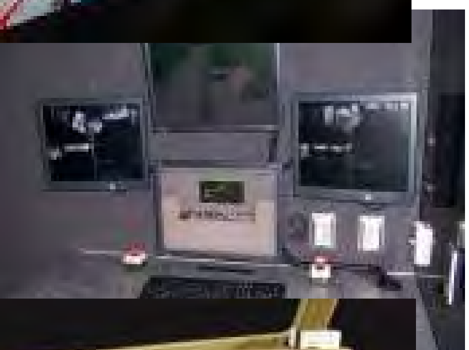
2-3”

Texture

Profile view

60-75% power requirement reduction to cool or heat

Increased Simulator Use



Research Development Testing and Evaluation (RDTE) Initiatives

- Inserted three Initiatives into POM08 ($15M)
- FY09 Plus-up Funding ($10M)
- Nominated five initiatives for Economic Stimulus Funding ($10M)

Participation in Joint Efforts

- Joint Staff Functional Capabilities Integration Board
  - Develop Joint Standards on   Feeding/ Water/ Billeting/Hygiene
- Joint Expeditionary Base Working Group
  - Develop Joint Standards for Tent Camps between Army and Air Force
    - Energy Efficiency
    - Joint Interoperability/commonality of parts and maintenance and savings in costs

How much will be enough?

- Initiated studies on
  - Future of Bulk Fuel Consumption
  - Power
  - Equipment to maintainer Ratio

Navy Energy Strategy Efforts

Expeditionary Working Group
2020 Goals

Reduce operational energy consumption by 15%

Increase operational energy efficiency up by 15%

Increase use of non-petroleum fuel to 25-40% of operational energy generation

Fuels Working Group Efforts

Objective: Produce a JP-8 surrogate to reduce DoD dependence on petroleum-based fuels

Approach:

- Develop and demonstrate an affordable, highly efficient process for converting crop oils to JP-8
- Submit a final bio-derived JP-8 sample for government testing and evaluation
- Diversify portfolio of agricultural / aquacultural source feedstock to avoid competition with current crop oil / food markets

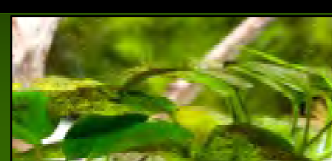
Highly-efficient conversion process to JP-8 from long chain oils

"Build-down" process:
cracking/isomerization of C12-C16 to JP-8

Highly-efficient conversion process to JP-8 from short chain biomass waste

"Build-up" process:
oligomerization of C2-C6 to JP-8

Highly-efficient system for cellulosic feedstocks and low-cost algal oil production and conversion to JP-8



Maximize algal oil production and process algal oil to JP-8

Finding the Marine Corps Way Ahead

- Include fuel effectiveness/efficiency in all requirements and acquisition processes.
- Aggressively explore/pursue alternative and renewable fuels and power technologies.
  - Commercial application efficiency improvements will benefit tactical applications
- Continue to leverage other Services and Commercial Sector Capabilities and efforts

...A Thought....A Goal??

....By 20XX, the Pentagon will be a NET ZERO PLUS installation.

"Hell is paved with good intentions, roofed in with lost opportunities."

- ***Portuguese Proverb***


OUR.MARINES.COM

Oshkosh Corporation
MTVR On Board Vehicle Power Program Update

May 5, 2009

Built Strong.
Building for the Future.






Outline

- ONR OBVP Program Review
- Vehicle Design
- Aberdeen Testing Results
- Program Milestones & Transition to LRIP
- OBVP Applications

MTVR OBVP Technical Specifications

- Exportable Power
  - 120 kW Stationary export power
  - 21 kW Power on the move
  - 208 Volt, 3 Phase, 60 Hz
- Vehicle Performance
  - Oshkosh TK-4™ Independent Suspension
  - 70% Off-road Mission Profile
  - 6.1 ton payload cross country
  - 14 ton payload primary and secondary roads
  - Central tire inflation
- Variants
  - 14′ and 20′ cargo OBVP variants
  - Available with and without SRW

ONR OBVP Program Objective

- Provide a vehicle integrated power supply
  - Eliminates need for ground forces to carry trailer mounted generator sets
    - OBVP provides greater mobility compared to a MTVR trailered generator
    - Reduced logistics footprint
      - Estimated 6,000 lb weight reduction compared to towed 100 kW TQG with trailer
      - Estimated 100 ft^2 footprint reduction compared to 100 kW TQG with trailer
      - Fuel usage during export power similar to 100 and 200 kW TQG
  - Mobile power
    - Power on the Move (POTM) allows mission critical systems to continue operation while driving
  - Flexible architecture
    - Allows OBVP to be configured to meet specific application requirements

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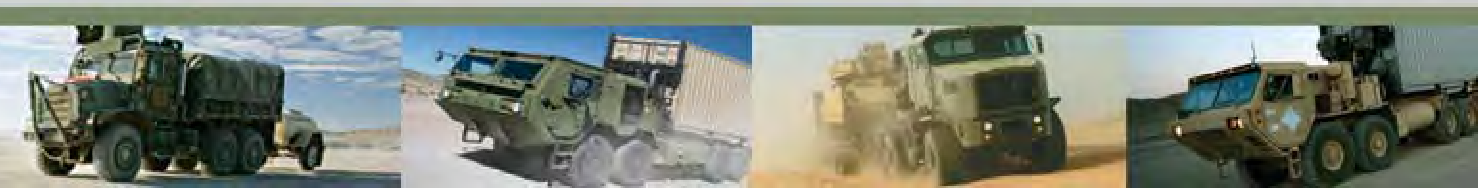
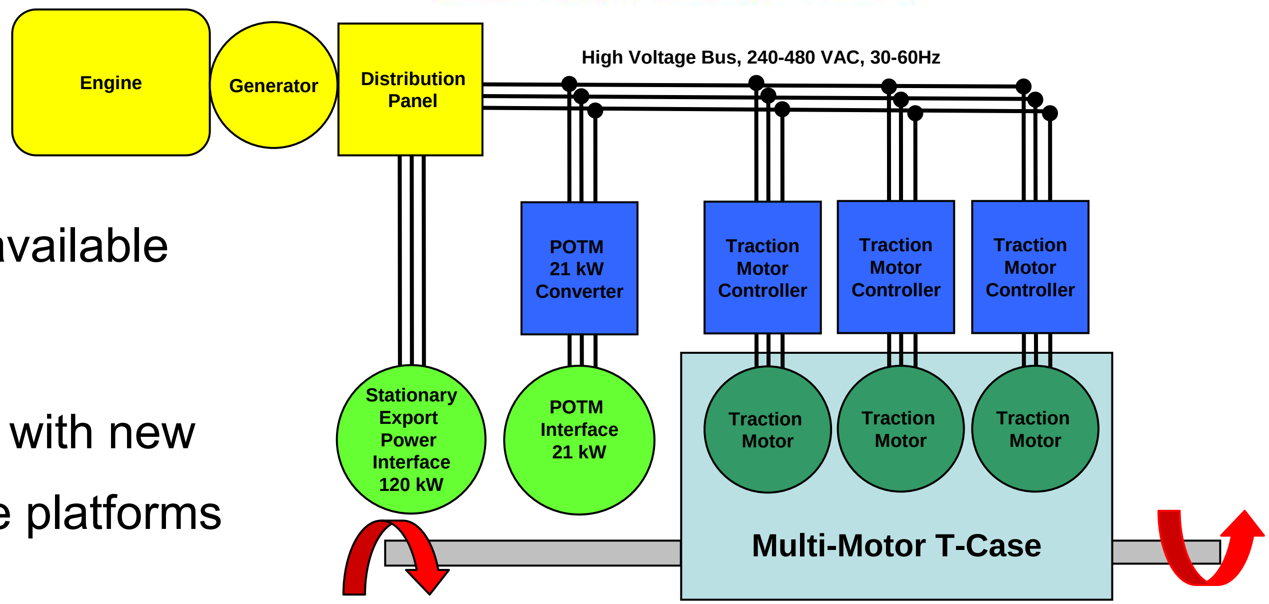
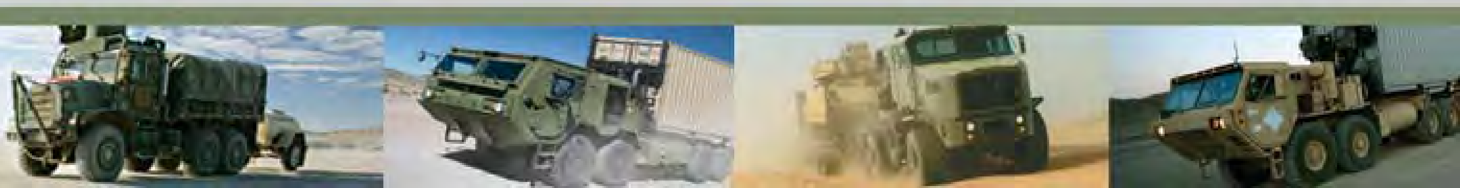


Oshkosh OBVP System Architecture

- System Architecture For OBVP
  - Oshkosh proprietary system of electric drive components and controls
  - Configurable architecture
    - Series hybrid
    - Diesel electric
  - Large amounts of available export power
  - Flexible integration with new and existing vehicle platforms

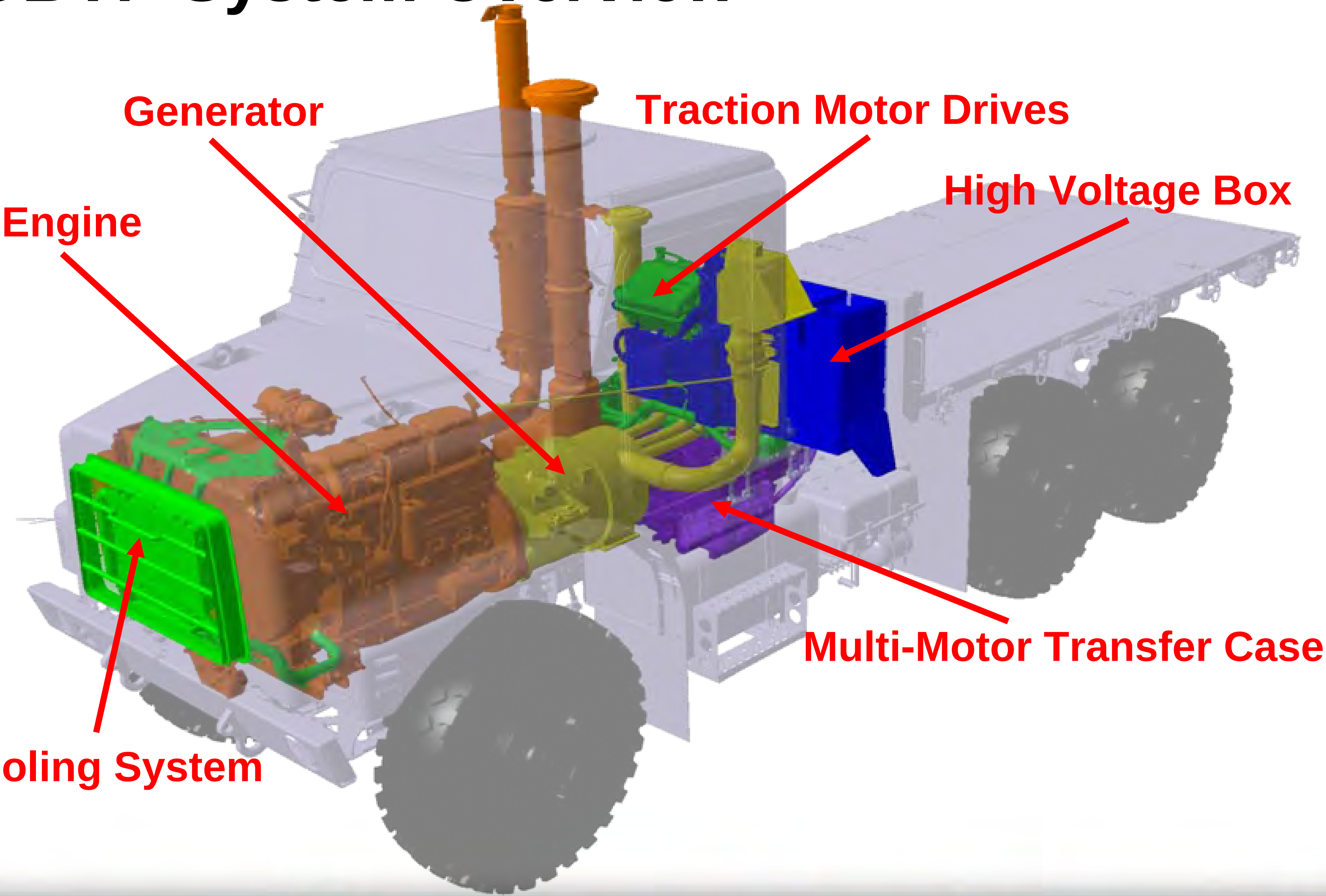
PROPULSE®





OSHKOSH

OBVP System Overview



Oshkosh OBVP Performance Testing

14 Inch Cross-Articulation

60% Grade Ability

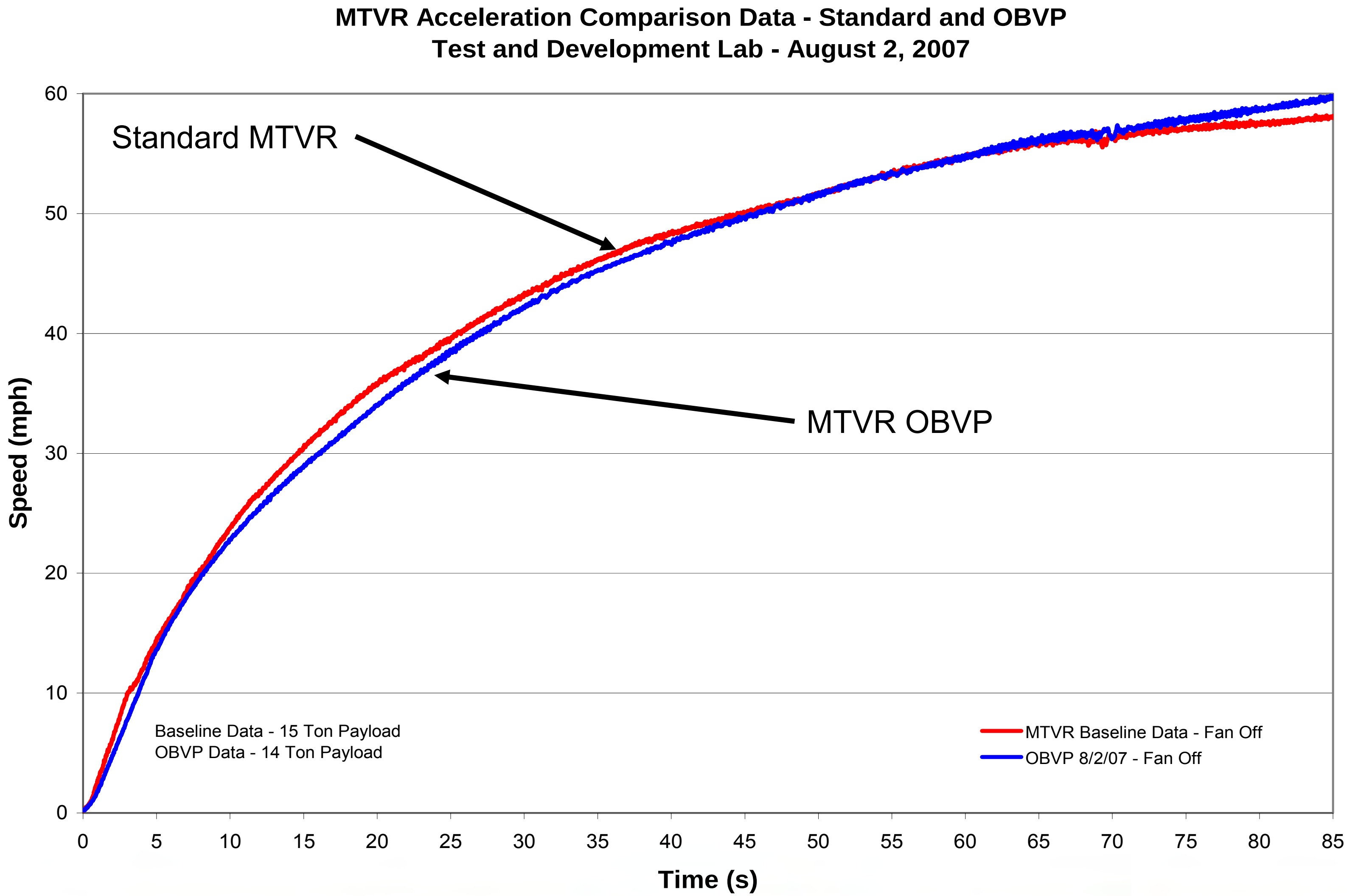
Export Power Performance

Roll Stability

24 Inch Vertical Step

System Durability Testing

Acceleration



Project Status - Aberdeen Testing

- OBVP is undergoing evaluation at Aberdeen Test Center
  - Completion of Aberdeen test last technical milestone in OBVP project
- Tests completed to date
  - Voltage and frequency performance per Mil-Std-705C Method 608.1 and 608.2
  - Maximum power per MIL-STD-705C Method 640.1
  - Voltage waveform per MIL-STD-1332B
  - Stationary export power fuel consumption
  - Low temperature storage and operation (-25°F)
    - Export power performance tests repeated
  - High temperature storage and operation (+125°F)
    - Export power performance tests repeated
  - Road shock and vibration
  - Gradeability and slopes (20,30,40,50,and 60%)
  - Static rollover / lateral stability
  - Roadway simulator
- Remaining tests
  - Off-road endurance
  - Blowing rain
  - Stationary export power audio noise level testing per MIL-STD-1474D

Roadway Simulator Testing at Aberdeen

OBVP Power Quality Test Results

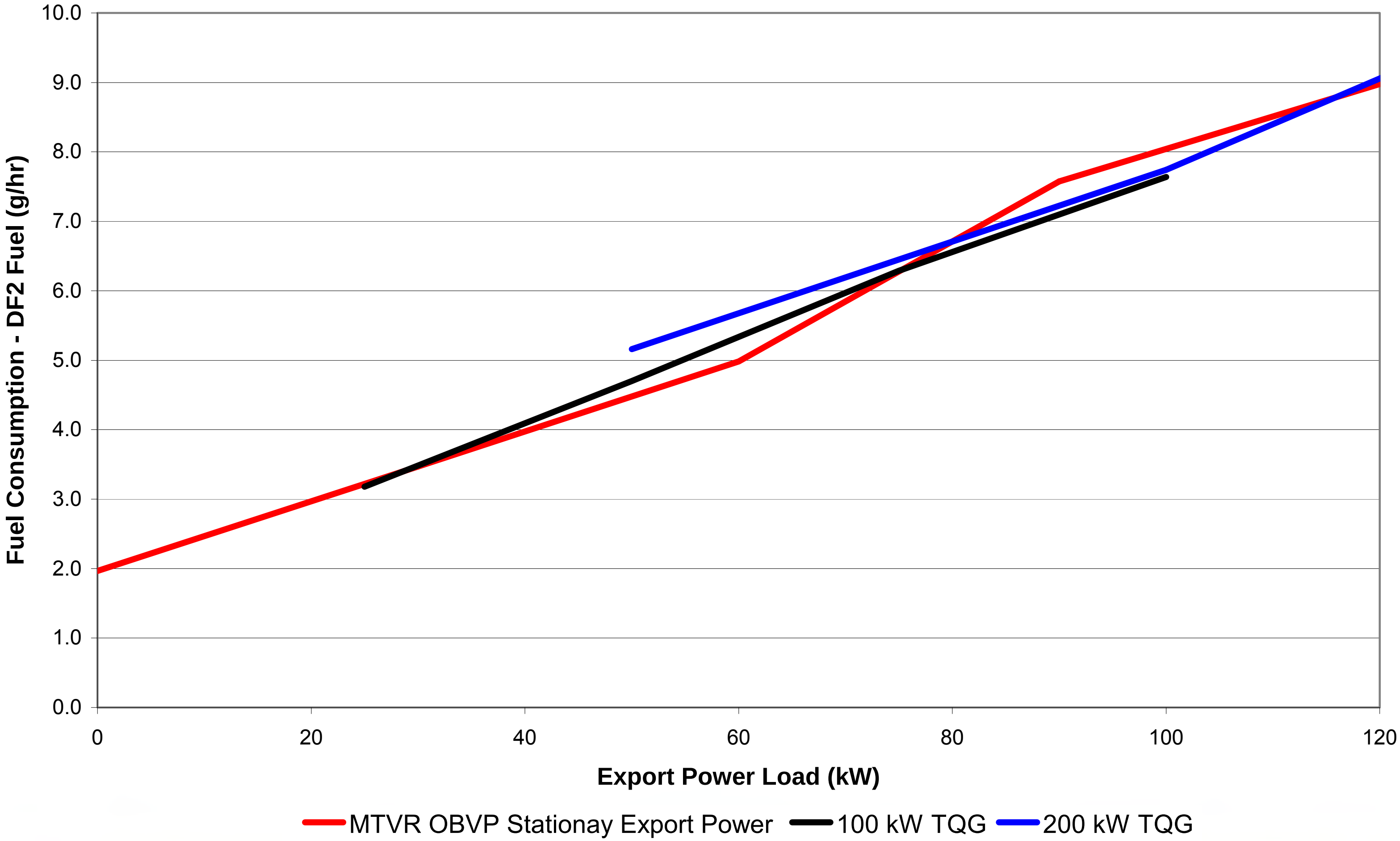
ATC OBVP Export Power Quality Results Summary June 20, 2008				
PARAMETER		REQUIREMENT [1]	POWER ON THE MOVE [2]	STATIONARY EXPORT POWER [2]
VOLTAGE	Regulation (%)	3.0	1.9	0.8
	Stability (%)	2.0	0.1	1.1
	No Load to Load Transient (%)	20.0	2.3	19.2
	Load to No Load Transient (%)	30.0	2.2	19.8
	No Load to Load Recovery Time (sec)	3.0	0.2	2.6
	Load to No Load Recovery Time (sec)	3.0	0.1	2.7
FREQUENCY	Regulation (%)	3.0	0.0	0.0
	Stability (%)	2.0	0.0	0.4
	No Load to Load Transient (%)	4.0	0.0	2.2
	Load to No Load Transient (%)	4.0	0.0	3.0
	No Load to Load Recovery Time (sec)	4.0	0.0	0.8
	Load to No Load Recovery Time (sec)	4.0	0.0	0.5

[1] Requirements Per 100 kW Tactical Quiet Generator Requirements and Per MIL-STD-1332B Class 2B Utility Grade Power

[2] Results Tested Per MIL-STD-705C Test Method 608.1B

OBVP Fuel Usage Comparison

Export Power Fuel Usage Comparison
Aberdeen Test Center, Preliminary Results - January 23, 2009



MTVR OBVP: From Prototype to Production

Aberdeen Testing of ONR OBVP Prototype

MTVR OBVP Design Updated

Aberdeen Production Unit Qualification Testing

2006 2007 2008 2009 2010 2011

ONR OBVP Prototype Contract Award

USMC LRIP OBVP Contract Award

Fielded Production OBVP Integrated Applications

Oshkosh ProPulse® System Flexibility

MTVR OBVP
- 120 kW of export power stationary
- 21kW power on the move
- Diesel electric solution

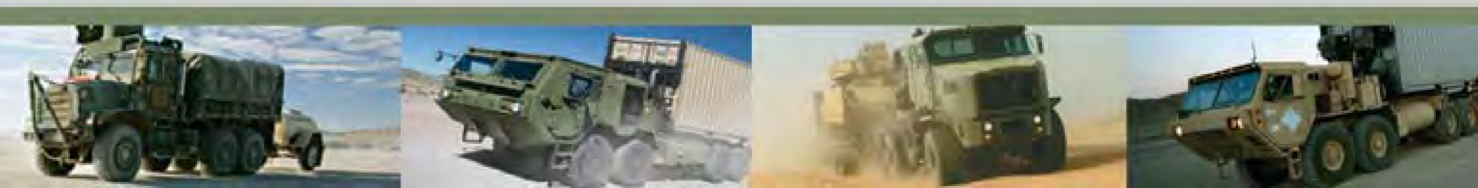
Heavy Hybrid Propulsion System
- DOE / NREL 3 yr program
- Target 2x fuel economy
- Validation vehicle / Waste Management

OSHKOSH®

ProPulse® Implementation

HEMTT A3
- Hybrid w/ capacitor based energy storage
- 100 kW of export power

Future Programs
- Marine Corps LVSR
- JLTV, MRAP, LAV
- Others…



OBVP Application Flexibility

- OBVP architecture allows for export power to be tailored as required for specific applications
  - Power On The Move (POTM)
    - Current capability 21 kW AC
    - Could be increased to as much as 200 kW AC
      - POTM pulled directly from generator run at synchronous speed
      - Ideal for applications that require large amounts of power while moving such as IED defeat devices
  - Voltage levels available
    - Configured to export 208 V, 3 phase, 60 Hz
    - Other voltages / frequencies available
      - 480 VAC
      - 416 / 240 VAC
      - 208 / 120 VAC
      - 50, 60 Hz available
      - DC power through simple rectification
  - Pulse power applications through addition of energy storage

OBVP Applications

- Mobile radar systems
  - G/ATOR (Ground/Air Task Orientated Radar)
  - TPS-59, TPS-77 radars
  - 3DELRR radar
- Command Operation Centers (COCs)
- Marine Expeditionary Units (MEUs)
- Other applications
  - IED defeat and neutralizing devices
  - Mobile weapons systems
    - Directed energy
    - Raytheon Centurion
  - Emergency backup power
    - Disaster relief
    - Primary generating system failure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Department of Defense
Project Manager Mobile Electric Power (PM MEP)

Tactical Electric Power

Now and for the Future

Mr. Michael Padden
Project Manager

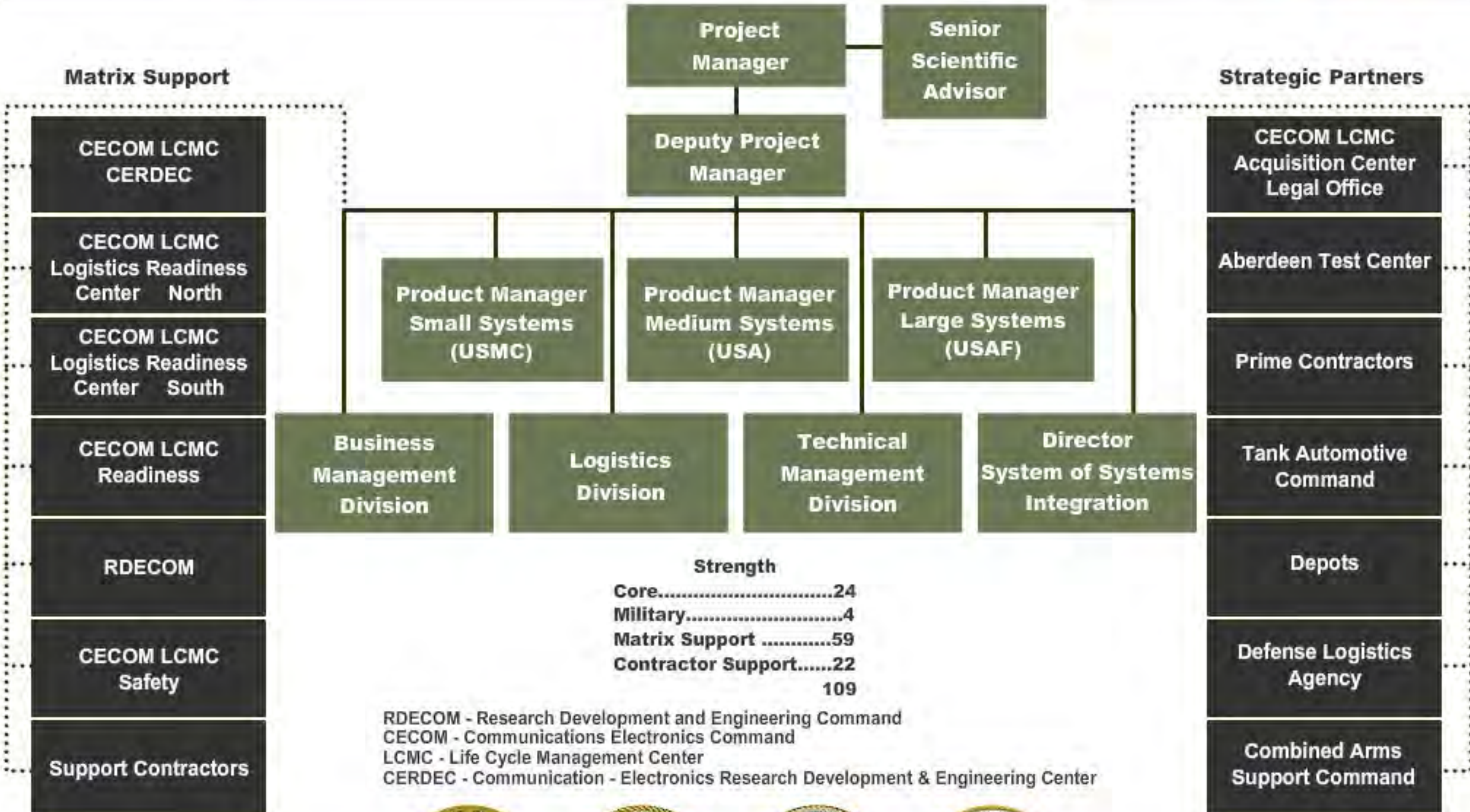
2009 Joint Service Power Expo
May 5-7, 2009
New Orleans, LA

Tactical Electric Power

Now…

Powering the Force

TEAM MEP



Strength

Core...........................24
Military..........................4
Matrix Support 59
Contractor Support......22
109

RDECOM - Research Development and Engineering Command
CECOM - Communications Electronics Command
LCMC - Life Cycle Management Center
CERDEC - Communication - Electronics Research Development & Engineering Center

PM MEP Strategic Framework

- Values
  - Integrity – Quality - Innovation
- Mission
  - Provide standardized tactical electric power and environmental control capabilities to the Department of Defense in support of National Security
- Vision
  - Recognized as the Department of Defense leader for innovative power and environmental control solutions; known for the quality of our products and the excellence of our people

PM MEP Executive Agent Mission

Standardization

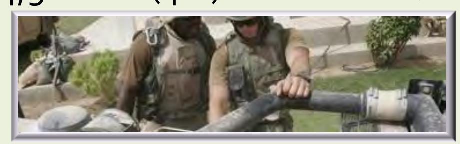
Deputy Under Secretary of Defense (Logistics and Material Readiness)

Program Execution

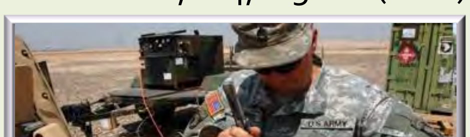
Assistant Secretary of the Army (Acquisition, Logistics and Technology)

Marine Corps
7,698 Gen Sets (6%)
179,802 kW (9%)

Navy
1,594 Gen Sets (1%)
84,588 kW (4%)



Army
102,493 Gen Sets (82%)
1,264,105 kW (60%)



DOD Total Requirements

125,125 Generator Sets
2,104,952 kilowatts (kW)

Air Force
13,340 Gen Sets (11%)
576,547 kW (27%)

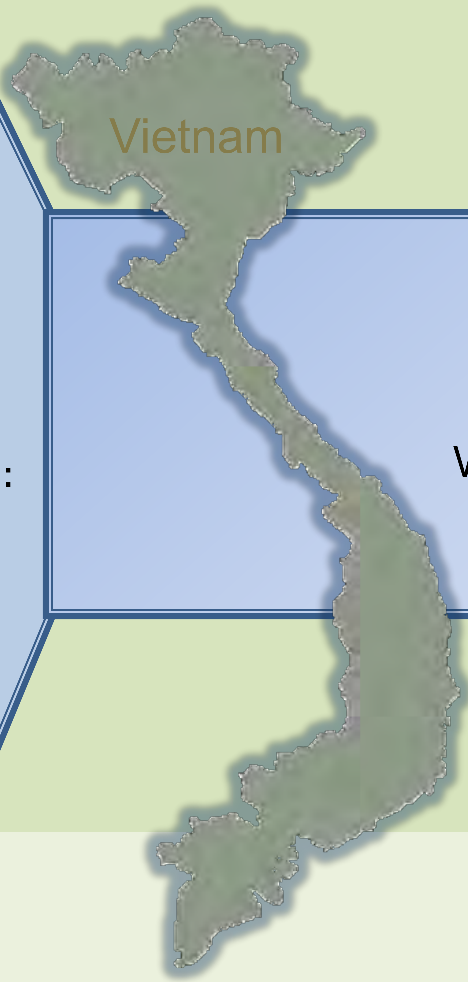
Mobile Electric Power Program History

1965
Southeast Asia

Exorbitant Demand for Electrical Power

Excessive Proliferation: 2,000 different makes, models, and sizes

Ineffective Logistical Support



1967
DOD Ad Hoc Working Group Established

- Identified need for a Department of Defense Standard Family of Mobile Electric Power Generating Sources
- US Army designated as lead standardization activity
- Established Project Manager Mobile Electric Power to execute mission
- Codified in Department of Defense Directive and Joint Operating Procedures

Meeting Operational Needs

- Operation in harsh environments
  - High and low ambient temperatures
  - Dust
  - Reduced acoustic and thermal signatures
  - Low noise

- High performance, rugged systems
  - EMI/EMC/EMP
  - Shock resistance
  - Noise and vibration
  - Resistant to nuclear, biological, and chemical (NBC)

- Deployability and flexibility
  - Interoperability with NATO equipment
  - Fully transportable and mobile
  - Reliability and maintainability

- Advanced control systems and human-machine interfaces
  - Prognostics and diagnostics
  - Automatic sequencing and paralleling

Power Generation and Distribution Programs

2kW

3kW

5kW

10kW

15kW

30kW

60kW

100kW

200kW

Military Tactical Generator

Tactical Quiet Generators

Deployable Power Generation & Distribution System (DPGDS)

840kW

Power Units/Power Plants (PU/PP)

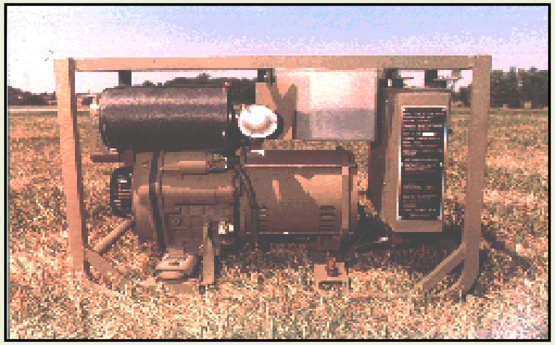
Power Distribution Illumination System Electrical (PDISE)

Small 2kW Military Tactical Generator

CHARACTERISTICS/PERFORMANCE:

Fuel	Diesel/JP-8
Noise	79 dBA
Reliability	500 hrs MTBF
Weight (Wet)	138 lbs DC / 158 lbs AC
Size	5.95 cu ft
Operating Temp	-50° to +120°F
Altitude	2kW @ 4000ft/120 F de-rated up to 8000ft
Fuel Capacity	4 hours @ 100% Load
Fuel Consumption	.33gal/hr

ORD –LT2kW 14 Jul 1992



EQUIPMENT USES:

- Modern Burner Unit, Mobile Kitchen Trailer (MKT)
- RQ-7A Tactical Unmanned Aerial Vehicle (TUAV)
- Enhanced Position Location Reporting System (EPLRS)
- High Mobility Artillery Rocket System (HIMARS)
- Assault Hose System (AHS)
- Woodworking Set
- M77A2 155mm Howitzer

CONTRACTOR:

Dewey Electronics, Oakland, NJ

Small 3kW Tactical Quiet Generator

CHARACTERISTICS/PERFORMANCE:

Fuel	Diesel/JP-8
Noise	70 dBA @ 7m
Reliability	>560 hrs MTBOMF
Weight (Wet)	326 lbs
Size	15.05 cu ft
Operating Temp	-25^o to $+120^o$F
Altitude	3kW @ 1000ft/107 F de-rated up to 8000ft
Fuel Capacity	8 hours + Auxiliary
Fuel Consumption	.33gal/hr

ORD – CGSA ROC w/Revision 1995

EQUIPMENT USES:

- Mobile Subscriber Equipment (MSE)
- Joint Biological Point Detection System (JBPDS)
- Patriot/Terminal High-Altitude Area Defense (THAAD)
- Lightweight Water Purification (LWP) System
- Maintenance tent lights and battery charging system

CONTRACTOR:

DRS Fermont, Bridgeport, CT

Medium (5-60kW) Tactical Quiet Generators (TQG)

CHARACTERISTICS/PERFORMANCE:

Decreased weight and cube
Improved mobility/transportability
Improved survivability
Single fuel on the battlefield (diesel/JP-8)
Reduced fuel consumption
Increased interoperability
Increased reliability
Improved ease of operation/maintenance/repair
Stringent power quality
Sustained power output in extreme climatic and environmental conditions

Compared to MIL\STD generator sets which TQGs replace

EQUIPMENT USES:

- Command Posts
- Weapon Systems
- Aviation Ground Support
- Water Purification Systems
- Laundry Units
- Bakery Plant
- Printing Plant
- Refrigeration Systems

CONTRACTOR:

DRS Fermont, Bridgeport, CT

L-3, Tulsa, OK

Large 100/200kW Tactical Quiet Generator

CHARACTERISTICS/PERFORMANCE:

	100 kW	200kW
Fuel	Diesel/JP-8	Diesel/JP-8
Fuel Tank Capacity (gal)	66	128
Fuel Consumption (gal/hr)	7.8	13.9
Oil Capacity (quarts)	30	36
Dimensions (L-W-H)	106" - 40" - 65"	114" - 50" - 75"
Size (Cu ft.)	160	250
Weight (lbs)	6100	9300
Noise	74 dbA@7m	78 dbA@7m
Voltage	120/208V Three Phase	120/208V Three Phase
	240/416V Three Phase	240/416V Three Phase
Frequency	50/60 Hz	50/60 Hz
Reliability	1250 hrs MTBF	600 hrs MTBF
Operating Temp	-25°F to +120°F	-25°F to +120°F
Altitude	Rated power to 4000ft/95°F	Rated power to 4000ft/95°F

Automatic Paralleling Between Sets

EQUIPMENT USES:

- Medical Facilities
- COSCOMs
- Hospitals
- Homeland Defense
- Military Intelligence
- Special Operations Command
- IBCT

CONTRACTOR:

DRS Fermont, Bridgeport CT

MTBF – Mean Time Between Failure
COSCOM – Corps Support Command
IBCT – Infantry Brigade Combat Team

Deployable Power Generation & Distribution System (DPGDS) 840kW (Prime Power)

CHARACTERISTICS/PERFORMANCE:

Fuel	Diesel/JP-8
Fuel Tank Capacity (gal)	120
Fuel Consumption (gal/hr)	60
Oil Capacity (gal)	13
Dimensions (L-W-H)	277" – 98" – 122"
Size (Cu ft.)	1920
Weight (lbs)	30000
Noise	85 dbA@7m
Voltage	2400/4160V Three Phase
	2200/3800V Three Phase
Frequency	50/60 Hz
Reliability	950 MTBF
Operating Temp	-25°F to +125°F
Altitude	Rated power to 4000ft/95°F

EQUIPMENT USES:

- Prime Power (249th EN BN)
- Forward Operating Bases
- THAADS
- JLENS
- AVCRAD
- MUSE

CONTRACTOR:

DRS Technical Services, Herndon VA

MTBF – Mean Time Between Failure
249th EN BN – 249th Engineer Battalion (Prime Power)
THAADS – Terminal High Altitude Area Defense System
JLENS – Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System
AVCRAD – Aviation Classification and Repair Depot
MUSE – Mobile Utilities Support Equipment

Power Units/Power Plants (PU/PP)

PU/PP PRODUCT DESIGN

- Power Unit (PU)
  - One generator set mounted on one trailer
  - 5kW, 10kW, 15kW, 30kW, and 60kW TQGs mounted on 1T, 2 ½T, or 5T trailer, towed by HMMWV, 2 ½T, or 5T truck
  - 20 separate models
- Power Plant (PP)
  - Two generator sets with switchbox and ancillary equipment mounted on one or two trailers (depending on generator set size and weight)
  - 3kW, 5kW, 10kW, 15kW, 30kW, 60kW and 100kW TQGs mounted on 1T, 1 ½T, 2 ½T or 5T trailer, towed by HMMWV, 2 ½T, or 5T truck
  - 14 separate models

TQG = Tactical Quiet Generator
HMT = High Mobility Trailer
HMMWV = High Mobility Multi-purpose Wheeled Vehicle

Power Distribution Illumination System Electrical (PDISE)

CHARACTERISTICS/PERFORMANCE:

Two feeder systems (M200 & M100)
Two distribution systems (M40 & M60)
Utility receptacle and lighting system (M46)
Operating Temp -25 F to +140 F

	M200	M100	M40	M60	M46 Utility Kit
Weight (lbs)	140	77	55	45	85

Line distance from generator to load is 300 ft (91.4m) at maximum load.

EQUIPMENT USES:

– Used extensively throughout the Army

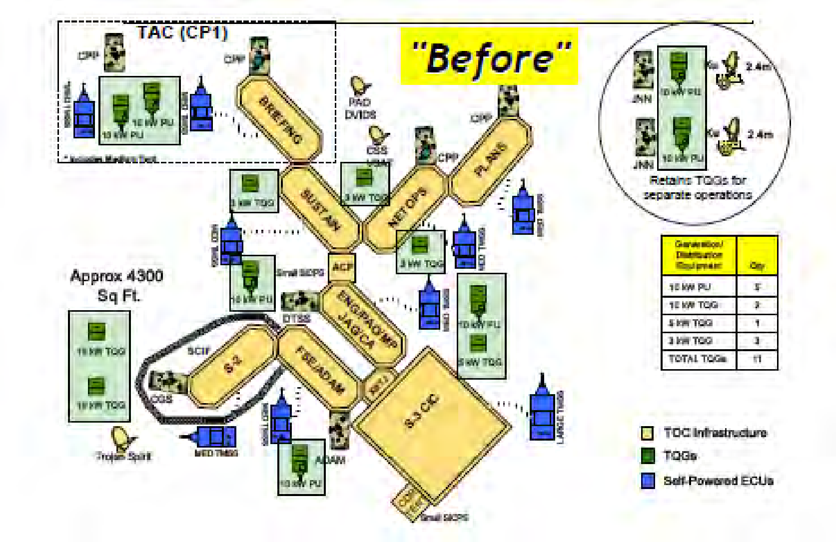
CONTRACTOR:

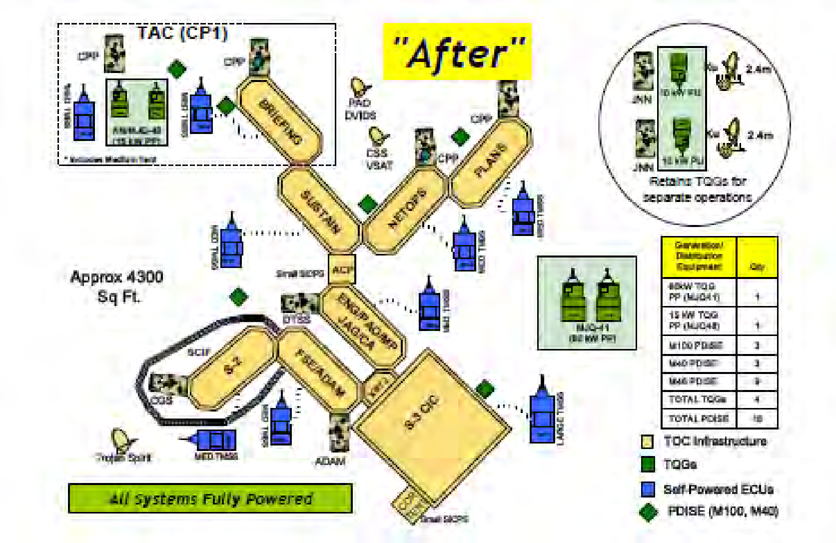
Fidelity Technology Corporation, Reading PA

Command Post Central Power

Benefits and Savings

- Soldier Safety
- 24/7 operation of mission-critical equipment
- Reduction in spare parts, maintenance, fuel consumption
- Organically supported
- Reduce Division fuel consumption by 275k gallons per year
- Reduce Division maintenance by 71k hours per year
- Reduce carbon dioxide emissions by 2400 tons per year





Total Net Present Value Savings

- $5 million: 15 year peacetime scenario
  - $150 million: 10 year peacetime/5 year low intensity conflict
    - $200-250 million: 10 year peacetime/5 year high intensity conflict

Department of Defense Project Manager Mobile Electric Power

2008 Accomplishments

- Produced 9,923 generators
- Issued 11,577 generators
  - Fielded 130 Units with 1,798 generators
  - Completed 562 supply transactions with 5,674 generators
- Filled 274 customer orders with 4,105 generators
  - Other Services - 189 orders with 2,818 generators
  - Foreign Military Support – 16 orders with 163 generators
  - Other Army – 69 orders with 1,124 generators
- Trained 298 maintainers and 321 operators

Power and Environmental Control Migration

Past	Present	Future

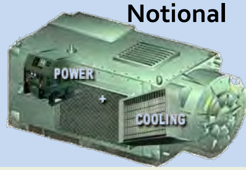
Environmental Control Units

Military Standard Environmental Control Units


Improved Environmental Control Units

Central Cooling Solution

Notional



Co-Generation

Electric Power Generation

Military Standard Generators

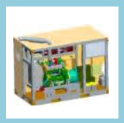
Tactical Quiet Generators



Next Generation Power Sources

- AMMPS
- LAMPS
- STEP

Notional




Alternative/Hybrid Energy

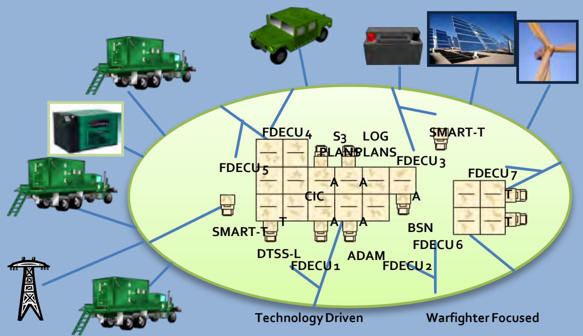
Electric Power Distribution

Distribution Illumination Systems Electrical (DISE)

Power Distribution Illumination Systems Electric (PDISE)


Central Power Solution

Intelligent Power Distribution



Tactical Electric Power

...the Future

Powering the Force

Hierarchy of Tactical Electric Power Requirements

WARFIGHTER REQUIREMENTS

Future Years Defense Plan FY 12-17

Future Concepts FY 17>

DOTLMPF Solutions (Programs of Record)

Joint/Army Concepts

Capability Needs Analysis

Future Operational Capabilities

Development Programs

AMMPS
LAMPS
STEP

S&T Programs

Concept Demonstrations
University Research
ATO/SBIR

DOTLMPF: Doctrine, Organizations, Training, Leader Development, Materiel, Personnel and Facilities
AMMPS: Advanced Medium Mobile Power Sources
LAMPS: Large Advanced Mobile Power Sources
STEP: Small Tactical Electric Power

S&T: Science and Technology
ATO: Army Technology Objective
SBIR: Small Business Innovation Research

Advanced Medium Mobile Power Sources (AMMPS)

- Third generation of Mobile Electric Power Generating Sources
- Replaces Tactical Quiet Generators (TQG)
- Employs advanced technologies to enhance power generation capability, improve engine control to achieve improved fuel efficiency, increase system reliability, reduce system size and weight, increase survivability for military applications, and reduce total ownership

- 5kW-60kW
- Multi-fuel (JP-8, JP-4, DF-1, DF-2, DF-A)
- Reduced noise and IR signature
- More reliable
- Less weight
- HAEMP protected
- Total package fielding (logistically supportable
- Power Units/Power Plants
- Less cost (procurement, support cost)
- Transportable (External Airlift Transport [EAT], 5 & 10kW air drop)

Improved Environmental Control Units (IECU)

- Form, fit and function replacement of MIL-STD ECUs
- Use R-410A refrigerant, the commercial industry's standard
- Fully operable up to 125 ˚F
- Ruggedized for military environments
- Reduced power consumption up to 25%
- Reduced weight up to 30%
- Increased reliability 200% over current MIL-STD ECUs
- Soft start, limited inrush current
- NBC compatible and EMI protected
- Embedded diagnostics

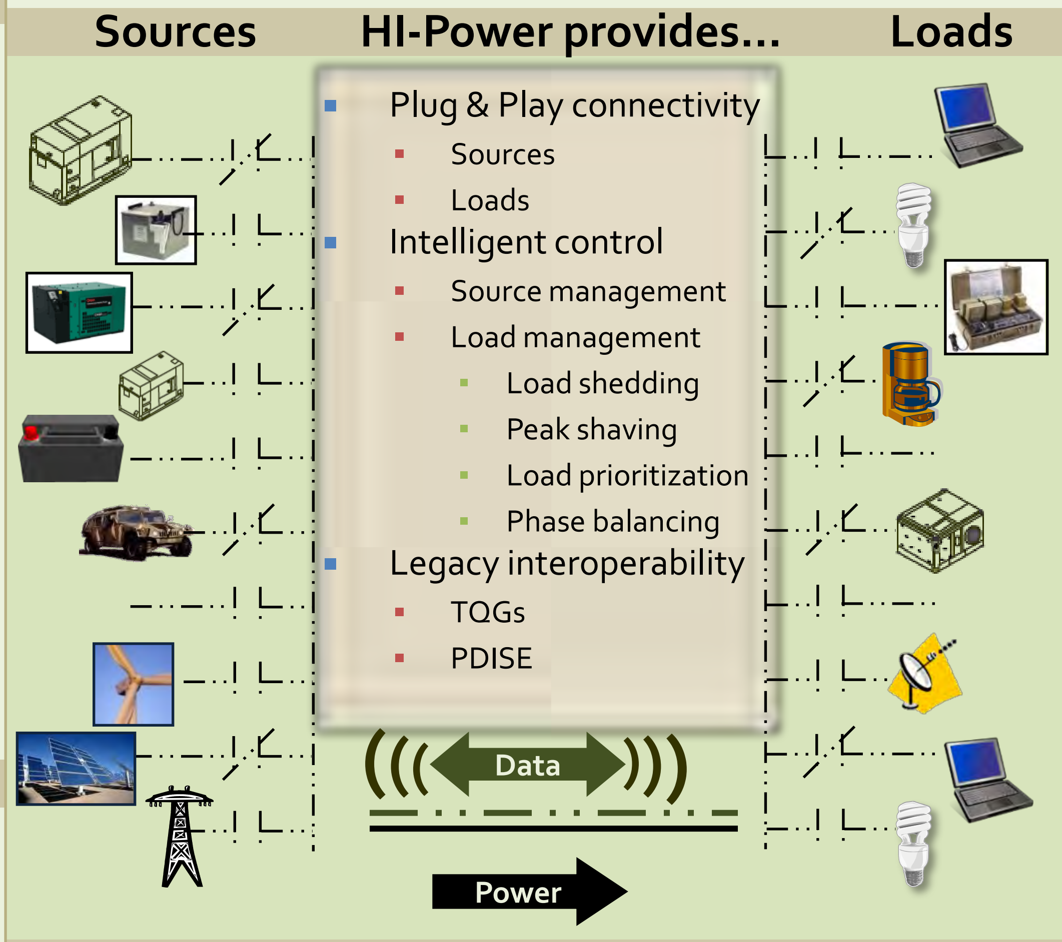
Hybrid Intelligent Power (HI-Power)

Project Objective:

- To develop a general Hybrid Intelligent Power Management architecture that demonstrates
  - Feasibility of Autonomous source and load side management
  - Compatible interface and operation with legacy equipment
  - Reduction in fuel consumption by >25%
  - Fault tolerance and ability to handle transient events
  - Ability to automatically parallel multiple sources
  - Scalability/Flexibility from 2kW – 200kW
  - Plug and Play Capability

Project Execution:

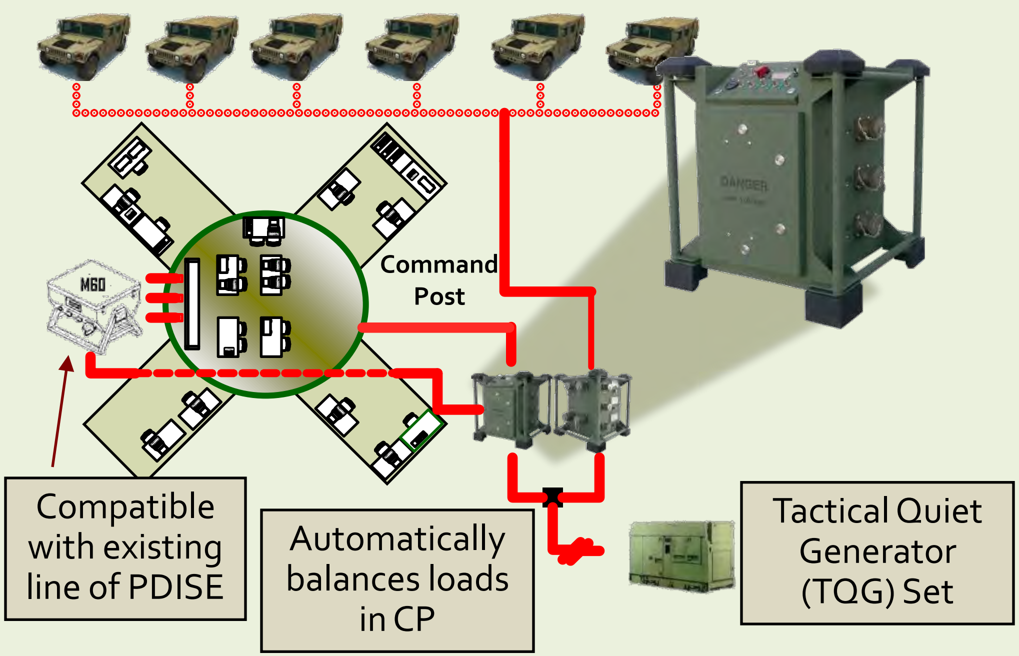
- OSD funded
- PM MEP Program Lead
- CERDEC Technology Lead
- Support contracts
  - Electricore, Inc.
  - I-Power Energy Systems, LCC



OSD – Office of the Secretary of Defense
CERDEC – Communications and Electronics Research Development and Engineering Center
TQG – Tactical Quiet Generator
PDISE – Power Distribution Illumination System Electric

Intelligent Power Management

Vehicles: *Connect as Mission Requires*



Project Objective:

- Power management for Command Posts
- Reduced training needed to establish and maintain an effective power grid
- Improved utilization of power assets
- Reduced fuel consumption
- Compatibility with current line of PDISE power distribution equipment
- Automatic Phase Load Balance
- Input Qualification & Power Management
- Rugged Design for Environmental Survivability

Project Execution:

- Defense Acquisition Challenge Program co-funded by PM-MEP
- PM MEP will transition to production and fielding in 2011.

Net Zero Plus (NZ+)
Joint Capabilities Technology Demonstration

Project Objective: Demonstrate a Forward Operating Base operating on reduced energy consumption.

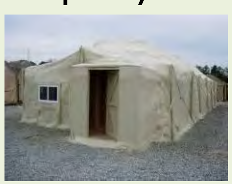
DEMAND

Enduring energy efficient structures and technologies reduce energy consumption through minimized air infiltration, low power devices, and efficient environmental control.

ENDURING ENERGY EFFICIENT STRUCTURES

External Insulation for Temporary Structures

Monolithic Domes



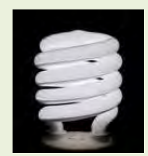
Project Execution:

- Operational Manager: CENTCOM
- Technical Manager: OSD PSTF
- Transition Manager: PM MEP

INFRASTRUCTURE

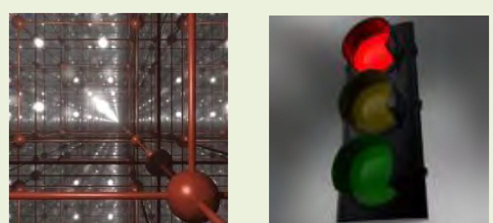
A system of distribution that precisely measures, analyzes, and connects the flow of power between energy consuming and producing devices

DISTRIBUTE, MANAGE, MONITOR, STORE, METER



Utility Survey

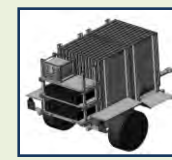
Remote Metering/Assessment

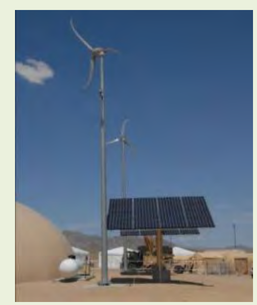


Intelligent Power Management

SUPPLY

Reduces fuel consumption by generating power through a combination of renewable, traditional and alternative power generation





Renewable/Hybrid Power

Enhanced-Tactical Hybrid Electric Power System (eTHEPS)

Project Execution:

- Project Manager, Mobile Electric Power Initiative with Department of Energy National Renewable Energy Lab
- "Power Block" based on advanced power electronic interfaces
- Follow-on to initial THEPS effort by the Rapid Equipping Force and leveraging microgrid efforts underway at TARDEC, Corps of Engineers, and Defense Logistics Agency

Project Objective:

- Single Point-Source System, but can interface with other sources
- Hybrid Capability
- Plug &Play connectivity
  - Sources
  - Loads
- Intelligent control
  - Source management
  - Load management
    - Load shedding
    - Peak shaving
    - Load prioritization
    - Phase balancing
- Phase balancing
- Legacy interoperability

eTHEPS: enhanced Tactical Hybrid Electrical System

Tactical Intelligent Power System (TIPS)

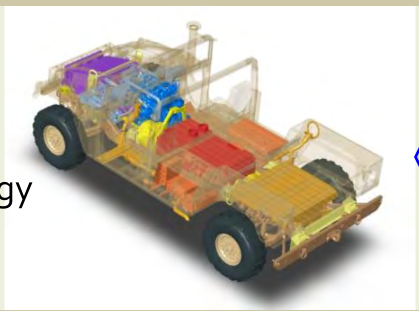
Project Execution:

- Cooperative Research and Development Agreement with DRS Inc.
- Based on hybrid electric HMMWV technology
- 75kW rating with additional 18kW peak capability
- Li-ion battery backup

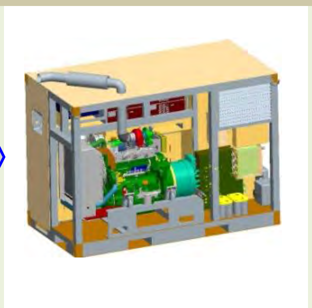
Project Objective:

- Enable full-load/high efficiency operation; engine off power at low loads
- Intelligent control system for load prioritization and source control
- System to be tested Spring 2009 to quantify benefits

Hybrid Energy HMMWV (XM1124)



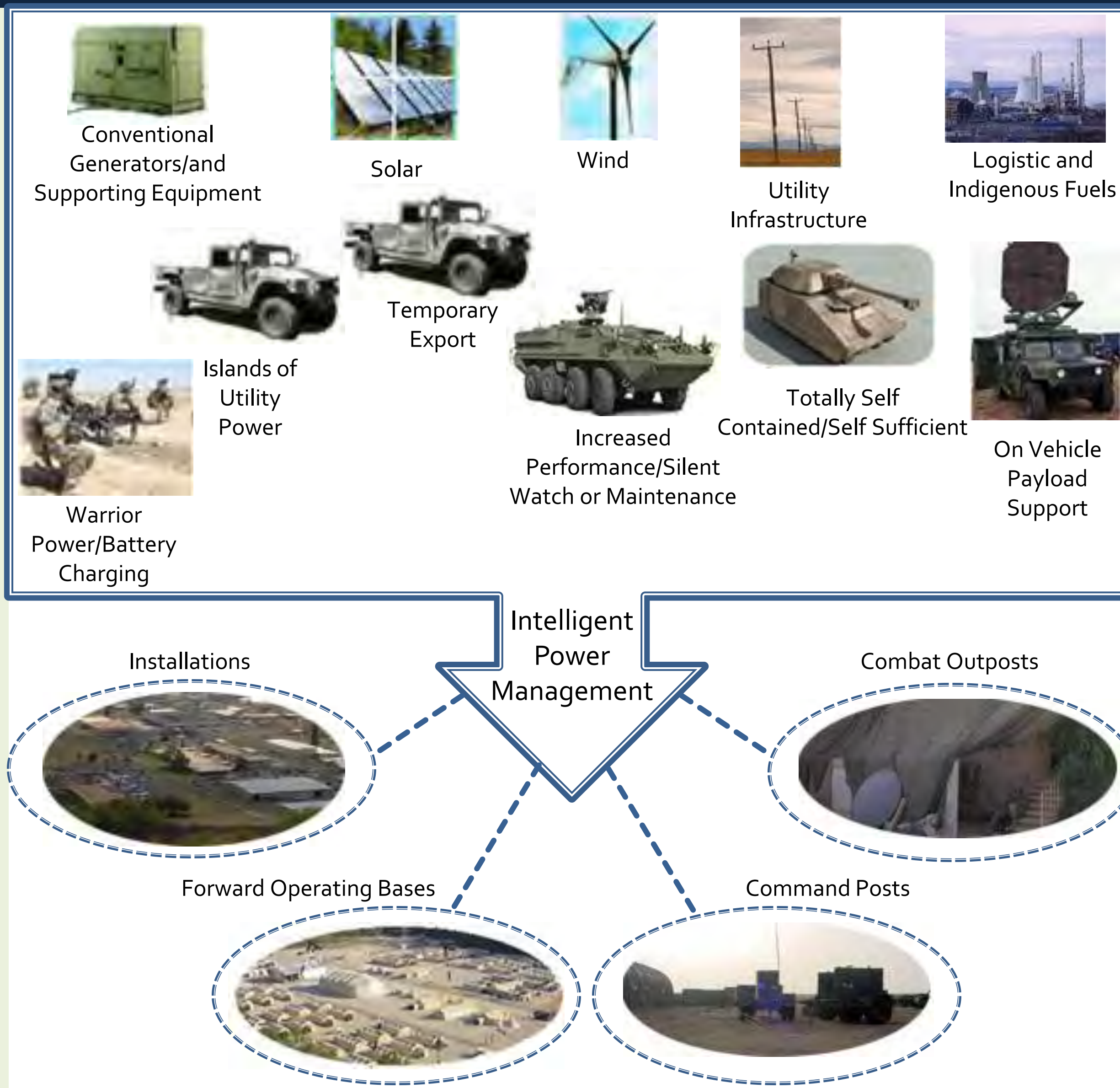
Similar Systems Approach
And Capabilities across
the Power Spectrum for Mobile
and Fixed Applications



Tactical Intelligent Power System

Battlefield Power Architecture Vision

- Approach
  - Holistic Power Architecture
  - Scalable, Integrated Micro-grids
  - Intelligent Power Management
  - Distributed Power Sources
  - Plug-and-Play Capability
- Benefits
  - Increased Capability
  - Improved Efficiency
  - Reduced Fuel Consumption
  - Smaller Logistics Footprint
  - Power Surety



Battlefield Electric Power Integration

Powering the Force

OSD Energy Strategic Objectives

- Maintain or enhance operational effectiveness while reducing total force energy demands
- Increase energy strategic resilience by developing alternative/assured fuels and energy
- Enhance operational and business effectiveness by institutionalizing energy considerations and solutions in DoD planning and business processes
- Establish and monitor Department-wide energy metrics

2006 – SECDEF creates DDRE Energy Security Task Force & directs Defense Science Board to evaluate/propose Energy Strategy

2007 – ESTF analysis results in $300M+ plus-up in Power & Energy

2008 – DSB releases Final Report on DOD Energy Strategy

2008 – Congress directs OSD establish an "energy czar" position

2008 – Army establishes Energy Security Task Force to develop way-forward

2008 – Army establishes Senior Energy Council & establishes a Senior Executive position responsible for energy activities

Battlefield Fuel Consumption

Generators are the Army's single largest user of fuel on the battlefield during wartime.*

Category	Peacetime OPTEMPO	Wartime OPTEMPO
Combat Vehicles	30	162
Combat Aircraft	140	307
Tactical Vehicles	44	173
Generators	26	357
Non-Tactical	51	51
Total	291	1040

Army Fuel consumption in peacetime and wartime (million gallons per year)

***Report of the Defense Science Board Task Force on DoD Energy Strategy**

Battlefield Electric Power Challenges

- Integrated and Intelligent Battlefield Power Management
- On-board Vehicle Power (APUs, hybrids, energy storage)
- Large Power Sources
  - Forward Operating Bases/Combat Outposts
  - Prime Power/Directed Energy Weapons Systems
- Low Power Systems
  - Soldier power (battery replacements or hybrids)
  - Battery standardization
  - Unattended ground sensors power
- Fuel reduction and use of alternative renewable energies

APU – Auxiliary Power Unit

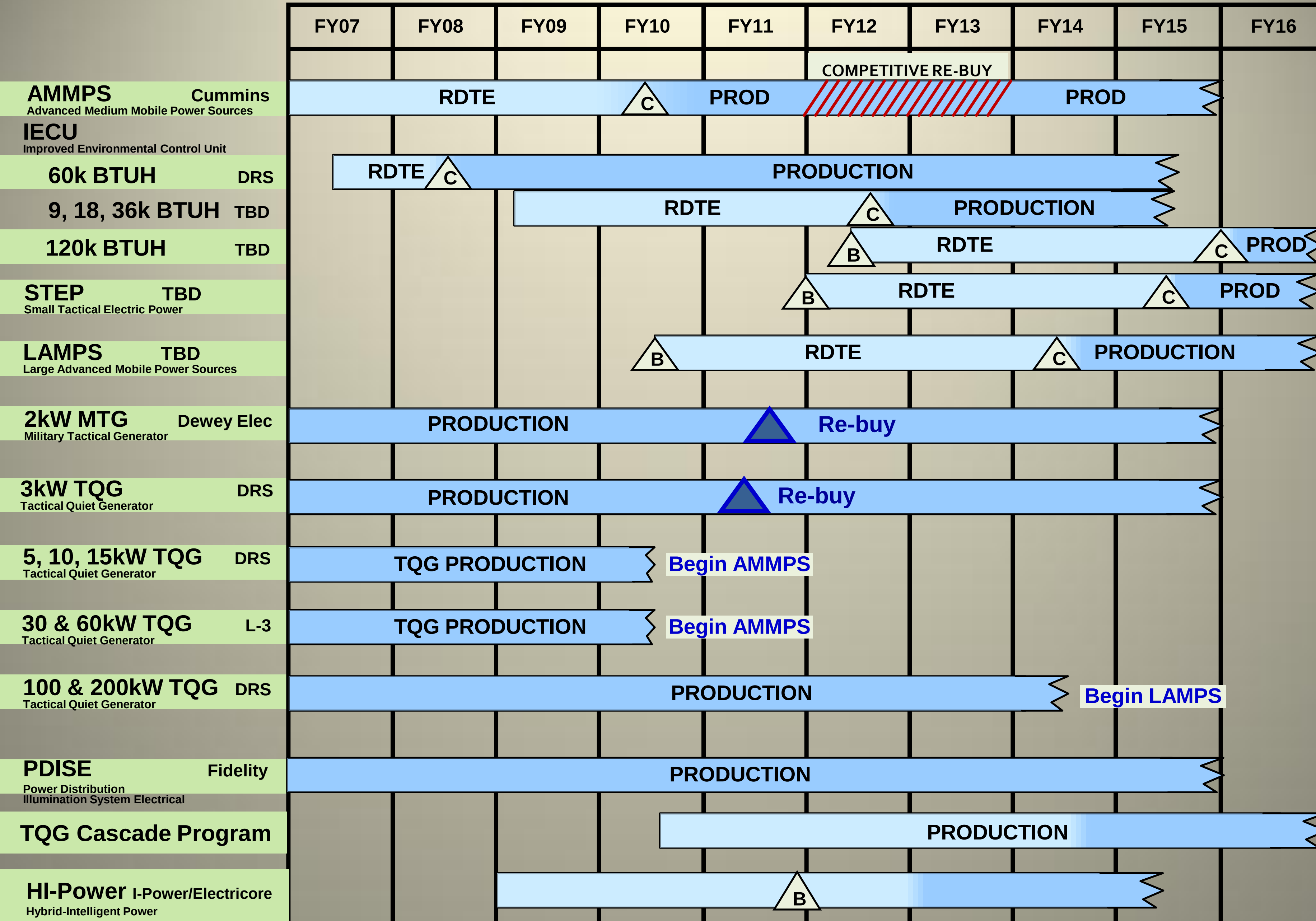
PM MEP Initiatives

- Designated as the Army's System of Systems Integrator for Battlefield Electric Power
  - Identify current and planned electric power generation/consumption requirements
  - Identify/characterize Forward Operating Base/Combat Outpost power requirements
  - Develop integrated battlefield electric power architecture
- Establishing Product Director for Batteries
  - Central authority for development and acquisition
  - Develop standard family of batteries for military application
- Developing improved Intelligent Power Management and Hybrid-Intelligent Power (HI-Power) systems architectures
- Developing Prototype Hybrid Energy Systems

Business Opportunities

Powering the Force

Tactical Electric Power and IECU Programs



Planned Upcoming Business Opportunities

- 120k BTUH Co-generation: market survey 3QFY 2009/prototype procurement 4QFY2009
- HI-Power Phase II BAA: contract awards 3QFY2009
- Tactical Quiet Generator Cascade Program: RFP 3QFY 2010/contract award 1QFY2011
- Small Power Sources Production Rebuy (2 & 3kW generators) FY2011
- Advanced Medium Mobile Power Sources (AMMPS) competitive re-buy: FY2011 or 2012
- Large Advanced Mobile Power Sources (LAMPS) development: contract award 3QFY2010
- Small Tactical Electric Power (STEP) systems development: contract award 1QFY2012

BTUH – British Thermal Units per Hour
RFI – Request for Information
BAA – Broad Area Announcement
RFP – Request for Proposal

Wrap-up

Powering the Force

Points of Contact

www.pm-mep.army.mil

- **Mr. Michael Padden**
  - Project Manager, Mobile Electric Power
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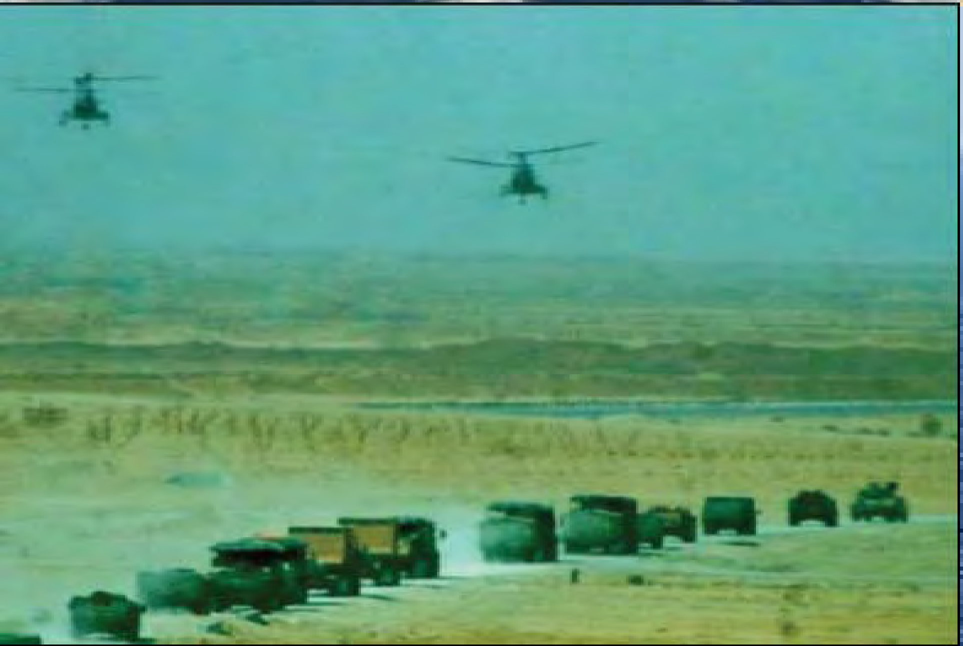
- **Lt Col Thomas Bowers (USMC)**
  - Product Manager, Small Power Systems (0.5-3kW)/Improved Environmental Control Units (IECU)
  - thomas.s.bowers@us.army.mil — 703-704-3160
- **LTC Gordon (Tim) Wallace (USA)**
  - Product Manager, Medium Power Systems (5-60kW)
  - gordon.wallace@us.army.mil — 703-704-3155
- **Lt Col Bob Thoens (USAF)**
  - Product Manager, Large Power Systems (100-920kW)/Power Distribution Illumination System Electrical (PDISE)
  - bob.thoens@us.army.mil — 703-704-0132

Energy & National Security

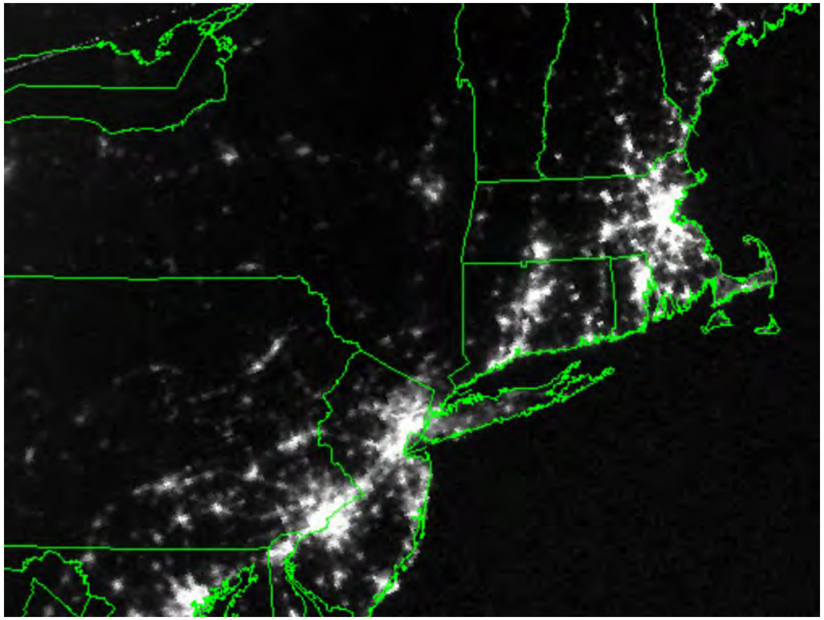
An Exploration of Threats,
Solutions and Alternative Futures

DoD Fuel Use Strategy

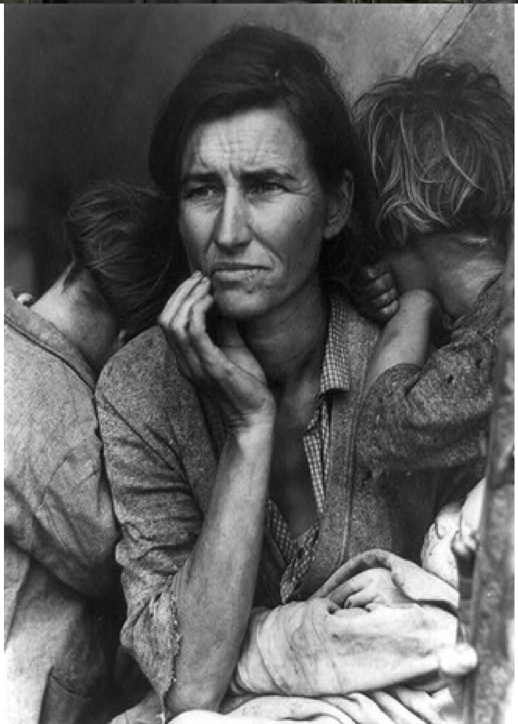





Infrastructure Vulnerability



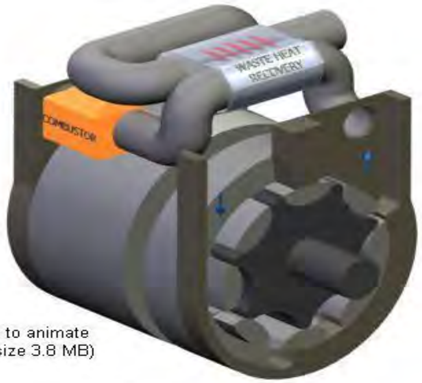
Economic Energy Security



Climate and Implications

Fuel Efficient Platform Design

Engine Efficiency



Click to animate
(file size 3.8 MB)

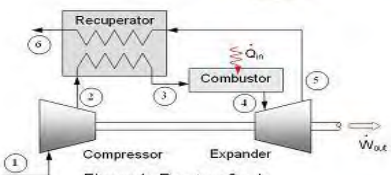
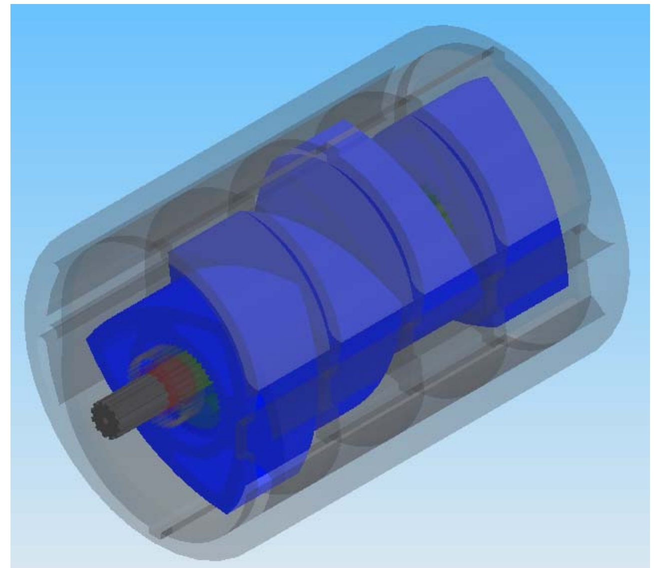
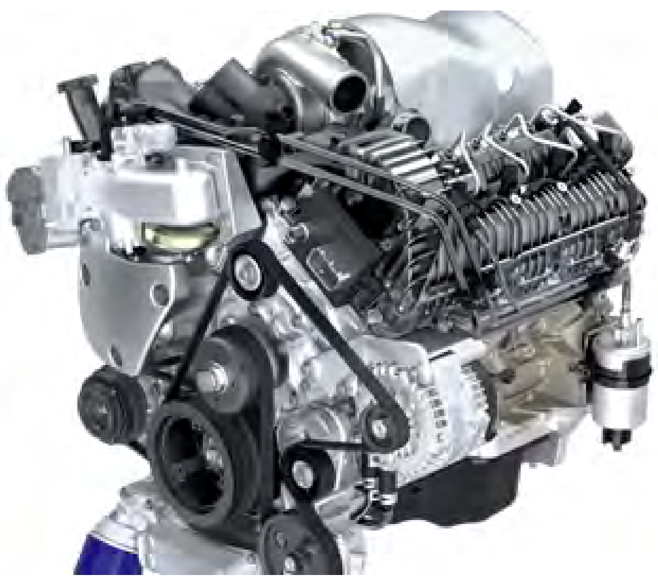
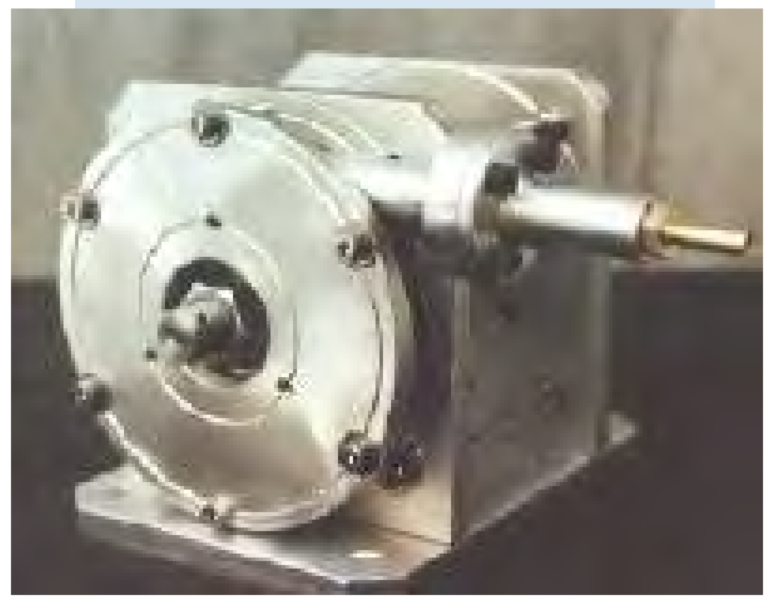


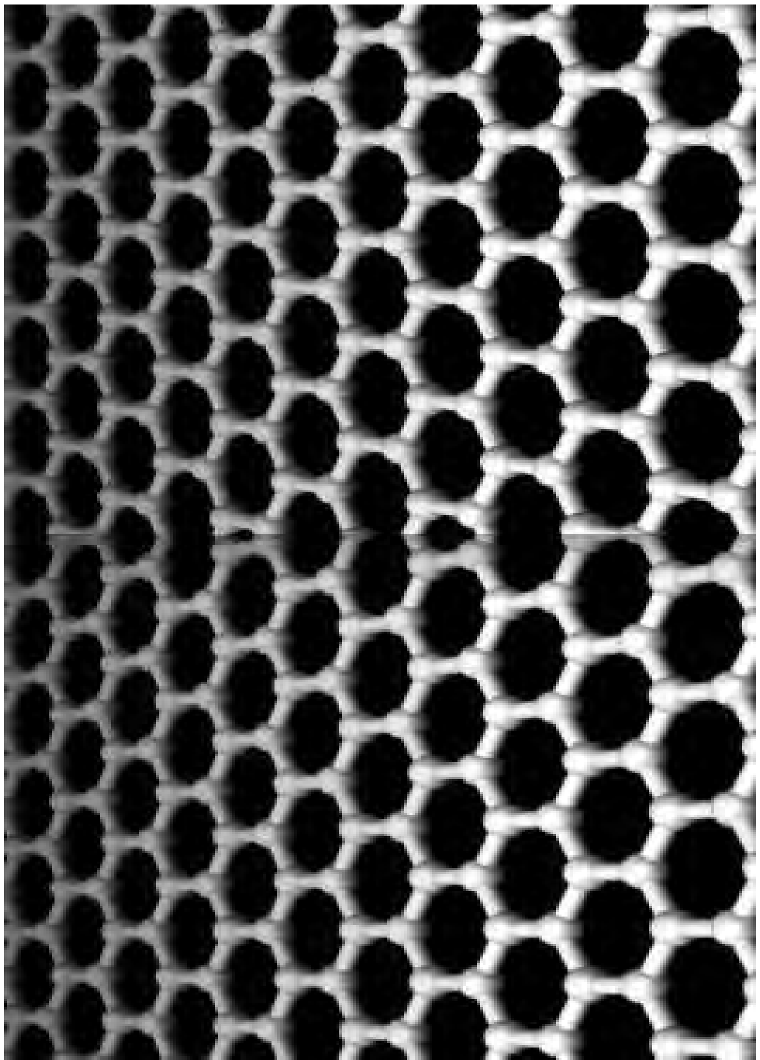
Figure 1: Brayton Cycle

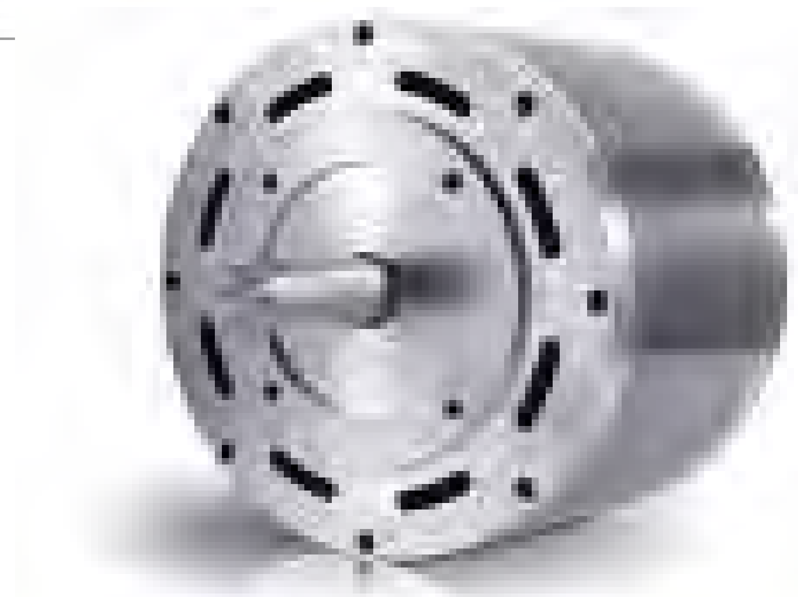




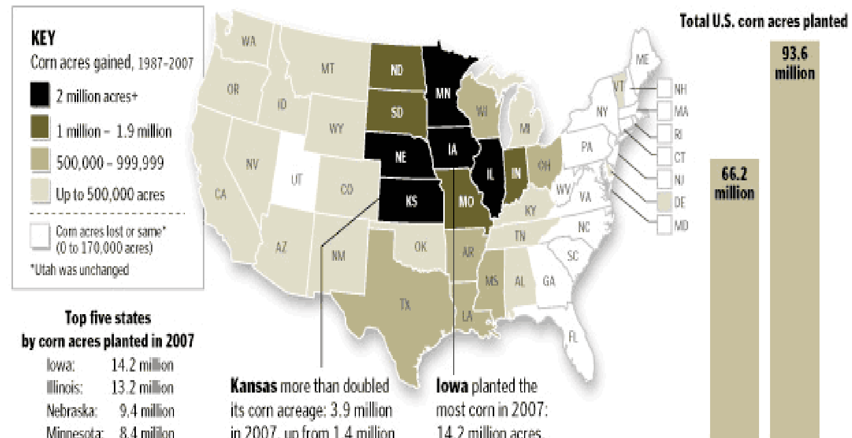


Electric Vehicle Technology





Renewable Synthetic Fuels



Alternative Power and Distribution

DefenseNews March 5, 2007

WORLD NEWS

Fighting for Fusion

Why the U.S. Isn't Funding A Promising Energy T

y WILLIAM MATTHEWS

On Nov. 11, 2005, the day his mall fusion reactor exploded in shower of sparks and metal ragments, even physicist Robert Bussard didn't know what he had chieved.

For 11 years, the U.S. Navy quietly funded Bussard's research. It vas a small project with a very arge goal: deriving usable energy rom controlled nuclear fusion.

Funding ran out at the end of 005 and Bussard was supposed o spend the tail end of the year hutting down his lab. He kept ostponing that in an effort to finish a final set of experiments.

He completed low-power tests n September and October and bean high-power testing of the reactor in November.

After four tests Nov. 9 and 10, n electromagnetic coil short-circuited as electricity surged hrough it, "vaporizing" part of his eactor, Bussard said, and bringng his tests to an end.

"The following Monday, we tarted to tear the lab down. Noody had time to reduce the data hat was stored on the computer. wasn't until early December hat we reduced the data and ooked at it and realized what we ad done," he said.

Bussard said he and his small eam of scientists had proven that uclear fusion can be harnessed s a usable source of cheap, clean nergy.

But for more than a year now, ussard has been unable to move the next step in his research. 78, he is in ill health and his cientific allies fear that the longought breakthrough he appears have achieved may fade into bscurity before it can be fully eveloped.

No small part of the problem is hat the U.S. Energy Department as a competing project, and has ent five decades and $18 billion n an as-yet-unsuccessful effort solve the fusion puzzle.

"Who would believe that a tiny ompany based on one person

BORON FUSION

U.S. physicist Robert Bussard believes that a novel form of atomic fusion based on boron could be harnessed to create electricity cheaply and cleanly, without hydrogen fusion's superhot temperatures, dangerous radiation, and enormous reactors.

Electromagnetic coils

Electron containment field

Insulating stands

Fuel: Boron and protons are injected

Yield: Helium and electricity are captured

Bussard says the boron fusion could be induced by creating an inertial electrostatic confinement machine that uses electromagnetic energy to force boron and protons together.

FUSION REACTIONS

HYDROGEN: Hot and dirty
- Powers the sun and thermonuclear bombs.
- Yields heat and neutron radiation.

Proton / Neutron

Deuterium (heavy hydrogen 2)
Tritium (heavy hydrogen 3)
Helium
Free neutron, heat and other radiation

BORON: Non-radioactive
- Could be tested in new kind of machine.
- Yields helium and electricity.

Hydrogen nucleus
Boron
Carbon
Beryllium
3 Helium atoms and electricity

SOURCE: The Advent of Clean Nuclear Fusion, Robert W. Bussard, Ph.D., Oct. 2006

DEFENSE NEWS GRAPHIC BY JOHN BRETSCHNEIDER

His idea was the basis for the

process does not produce ra-

"Who would believe that a tiny company based on one person could solve the riddle that has escaped literally thousands of researchers?"

Don Gay
Former U.S. Navy engineer

with deuterium, not boron — in November 2005 proved that the boron process will work.

The boron reactor would be similar to, but more powerful than, the reactor that blew up in 2005.

Bussard's reactor design is built upon six shiny metal rings joined to form a cube — one ring per side. Each ring, about a yard in diameter, contain copper wires wound into an electromagnet.

The reactor operates inside a vacuum chamber.

When energized, the cube of electromagnets creates a magnetic sphere into which electrons are injected. The magnetic field squeezes the electrons into a dense ball at the reactor's core, creating a highly negatively charged area.

To begin the reaction, boron-11 nuclei and protons are injected into the cube. Because of their positive charge, they accelerate to the center of the electron ball. Most of them sail through the center of the core and on toward the opposite side of the reactor. But the negative charge of the electron ball pulls them back to the center. The process repeats, perhaps thousands of times, until the boron nucleus and a proton collide with enough force to fuse.

That fusion turns boron-11 into highly energetic carbon-12, which promptly splits into a helium nucleus and a beryllium nucleus.

Quo Vadimus?




BACKUP SLIDES

Microgrid Development For Tactical Operations

LOCKHEED MARTIN
We never forget who we're working for™

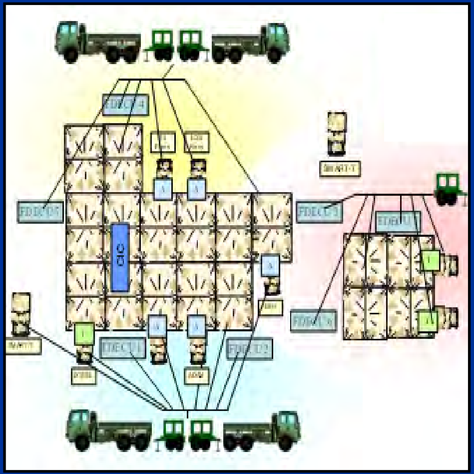
7 May 2009

Teri Hall
Electrical Engineering Staff
teri.hall@lmco.com

Current DoD Land Forces Power

Fuel Convoys

Vehicle Power



Graphics Courtesy of CERDEC

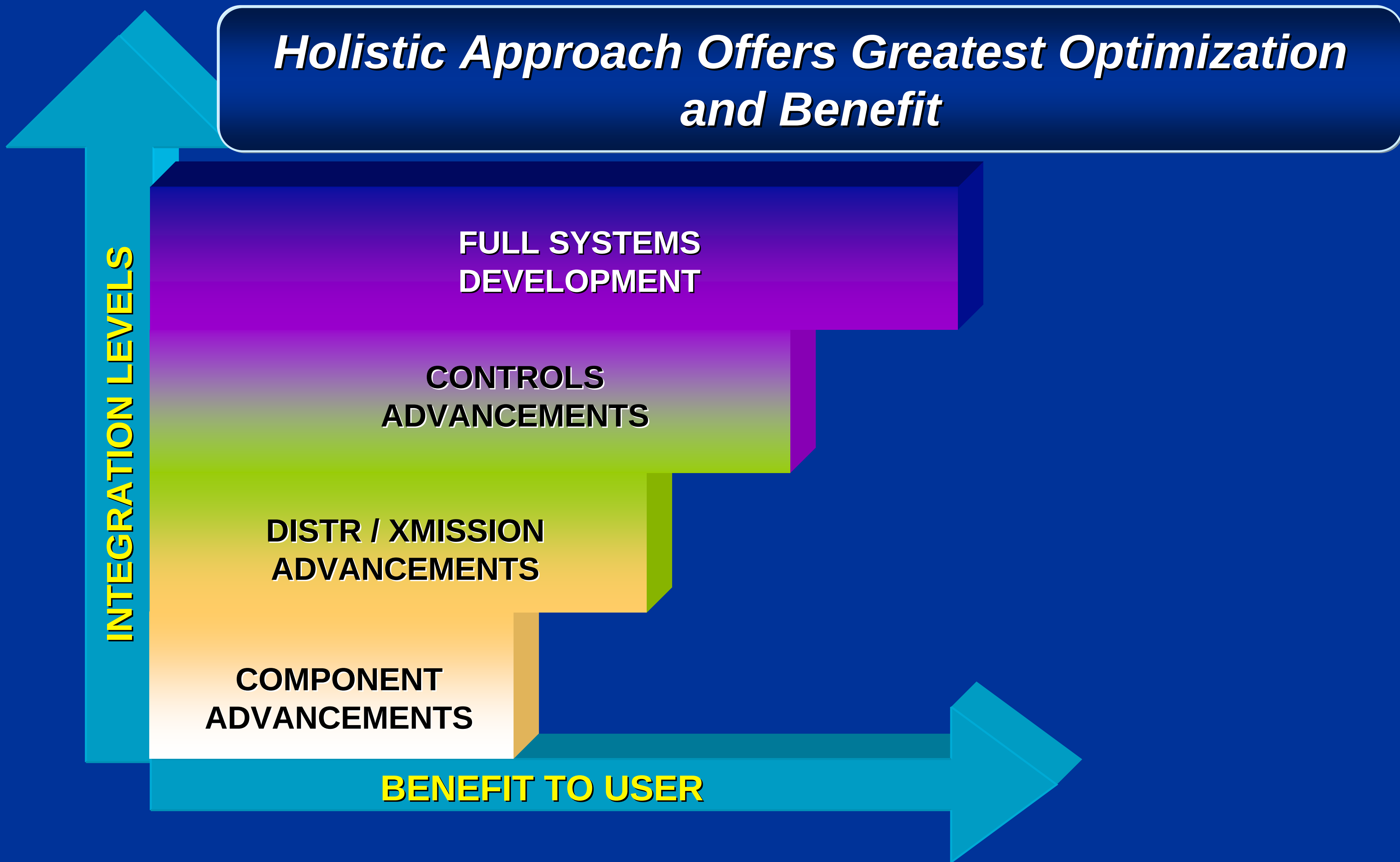
Inefficient Architecture

Capability Issues

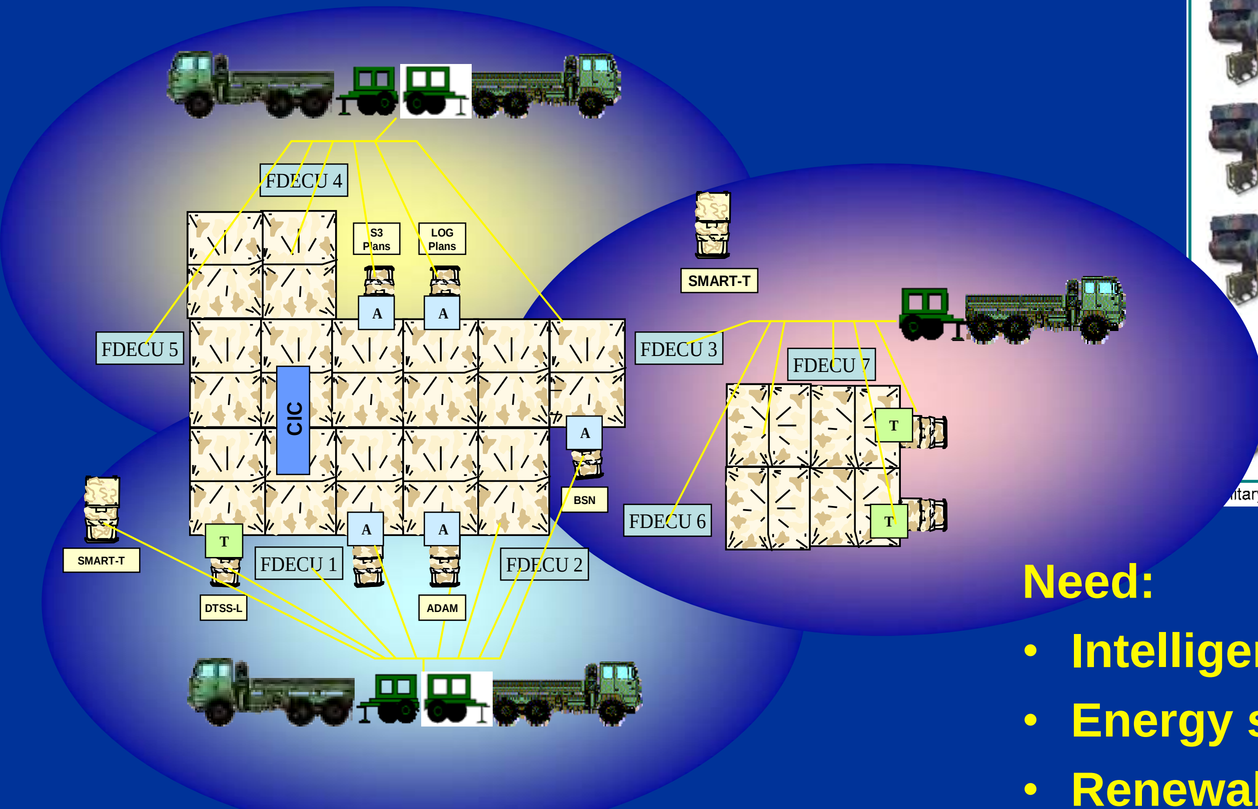
- War Fighters at Risk
- Fuel Consumption
- Non-optimum SWaPc
- High O&M Costs

Hazardous Infrastructure

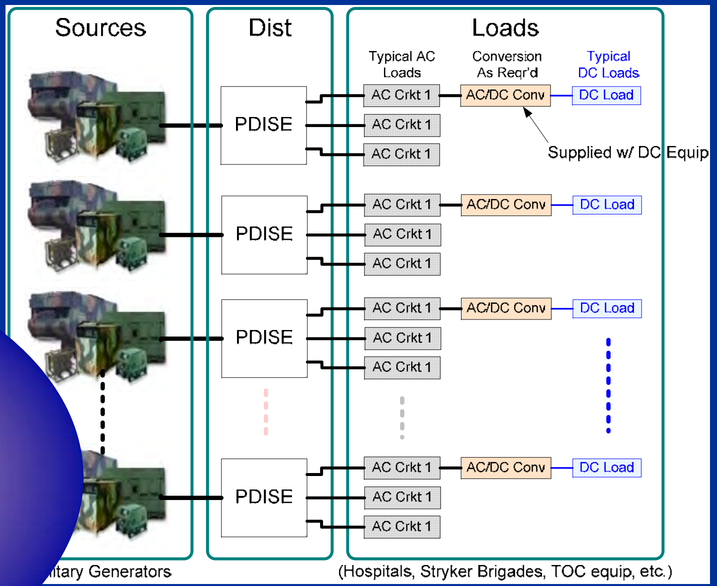
Power & Energy Integration Levels



Current Architecture



Graphics Courtesy of CERDEC

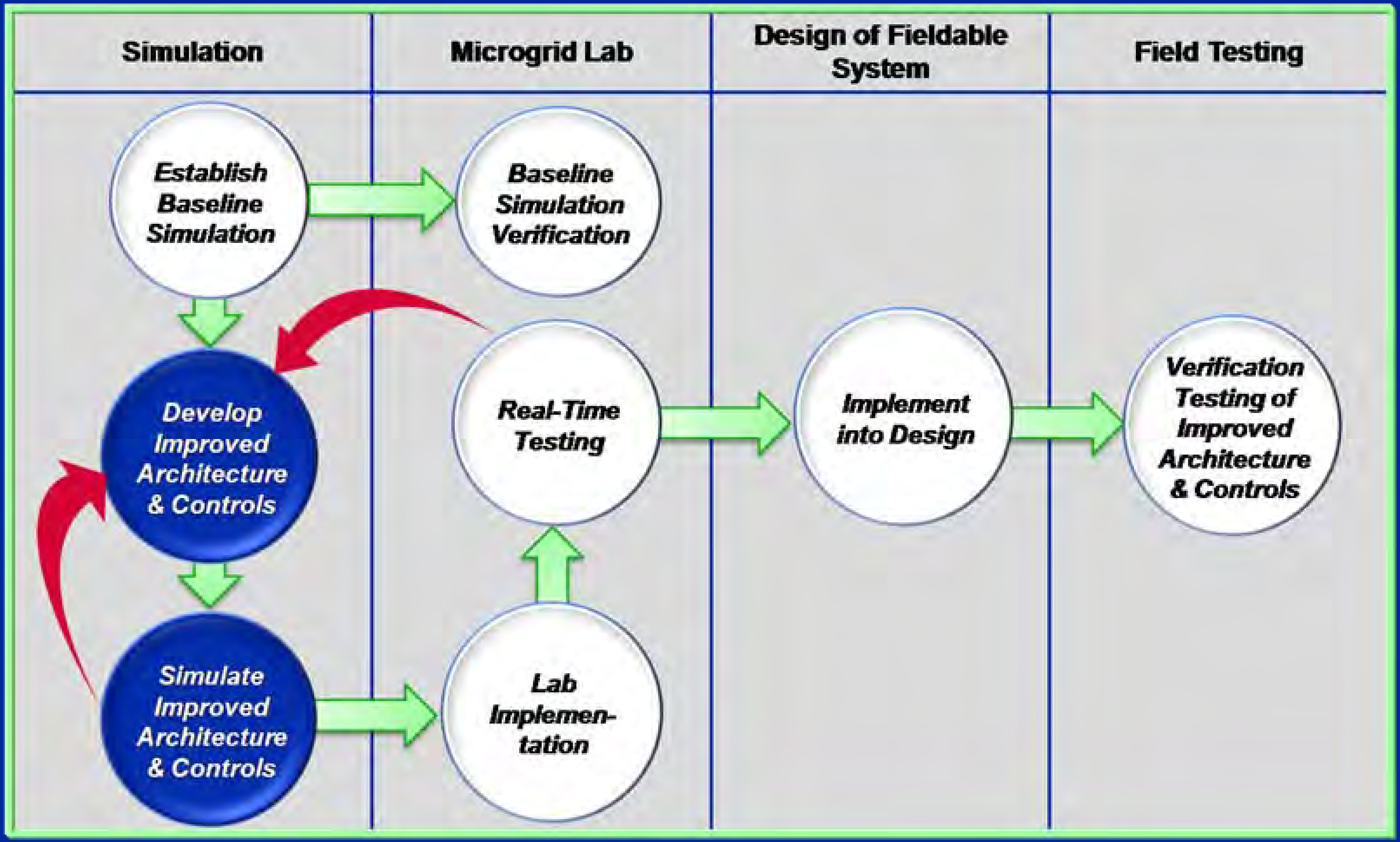


Need:

- **Intelligent distribution**
- **Energy storage**
- **Renewables**
- **Automated on/off genset and ECU control**

Remediation Requires Complex Integration and Multidiscipline Design Approach

Modeling and Simulation Approach



Simulation with Hardware Implementation Provides a Robust Design

Establish Baseline Simulation

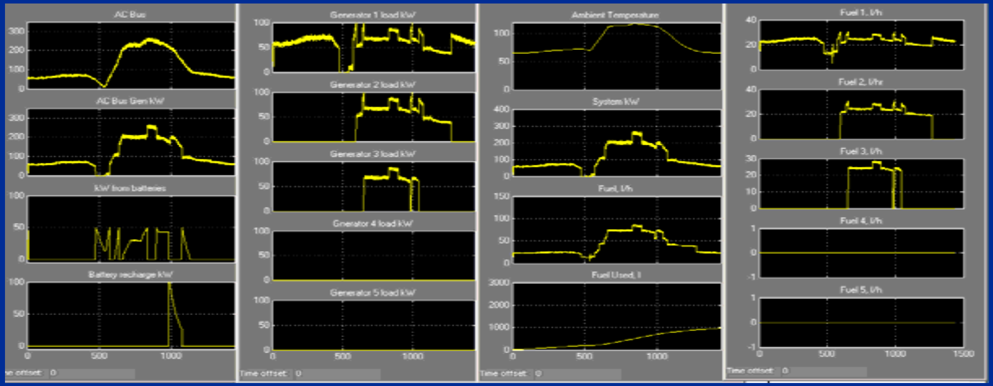
MATLAB Simulation for
TOC/FOB/ power configurations

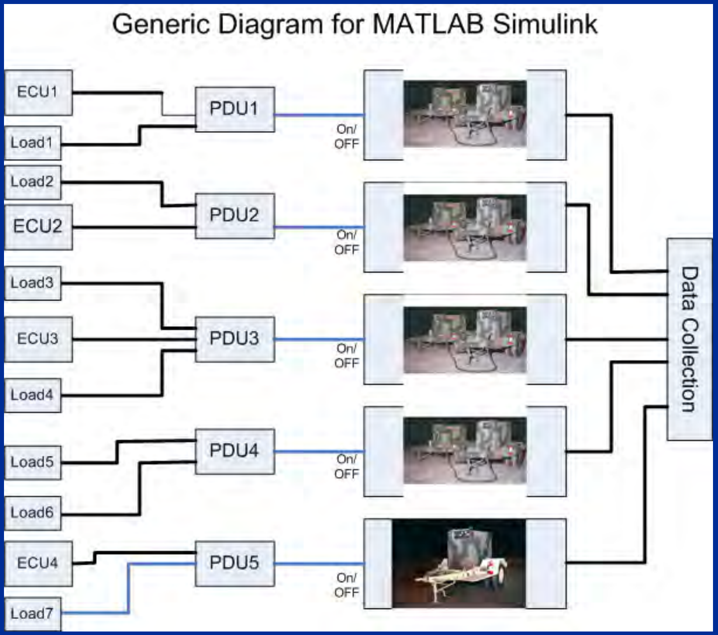
- User Load Profiles
- Establish performance char.
  - Fuel consumption
  - Generator run times
  - Load prioritization
  - Redundancy

Validation via hardware testing

Simulation Features

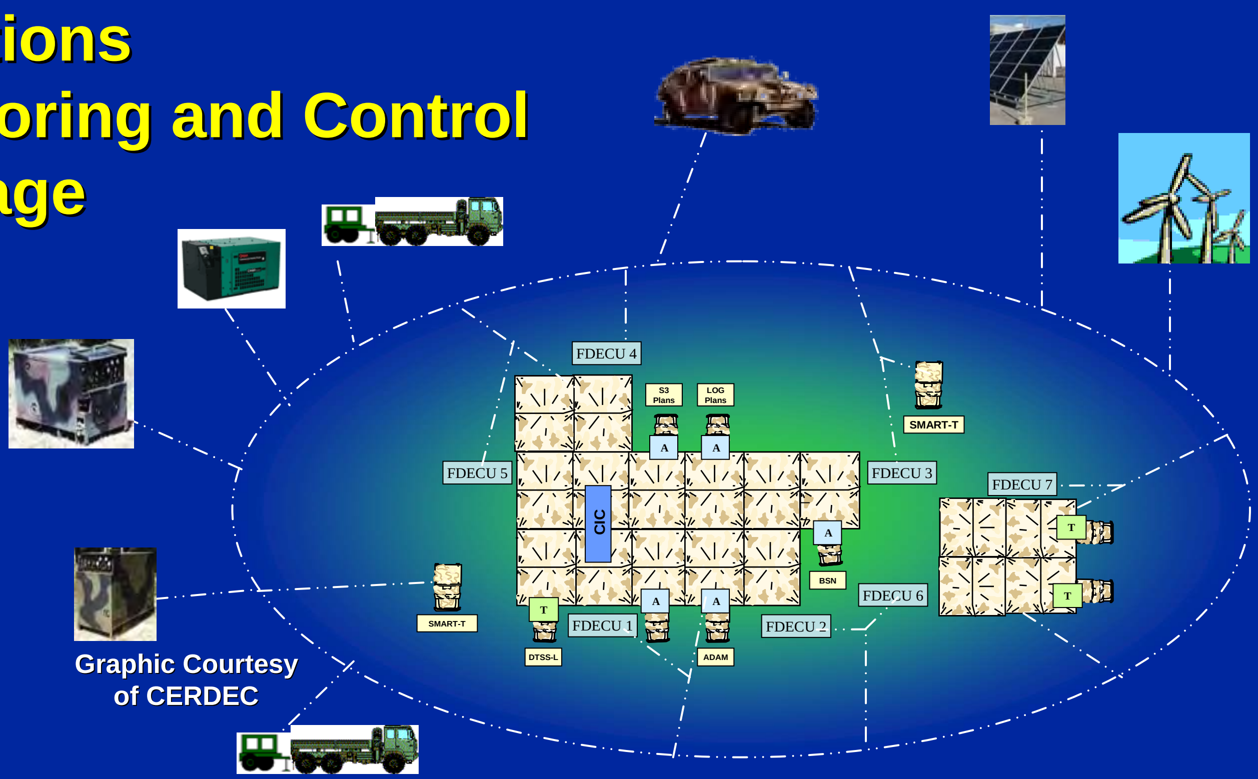
- **Low Fidelity Models**
- **High Fidelity Models**
- **Islanded Generators**





Microgrid Bus Concept

- ***Common bus design with plug and play hardware***
  - **New Power System Architecture**
  - **Advanced Power Conversion**
  - **Intelligent Bus Interconnects**
  - **Communications**
  - **Power Monitoring and Control**
  - **Energy Storage**



Graphic Courtesy of CERDEC

Improved Architecture Simulation

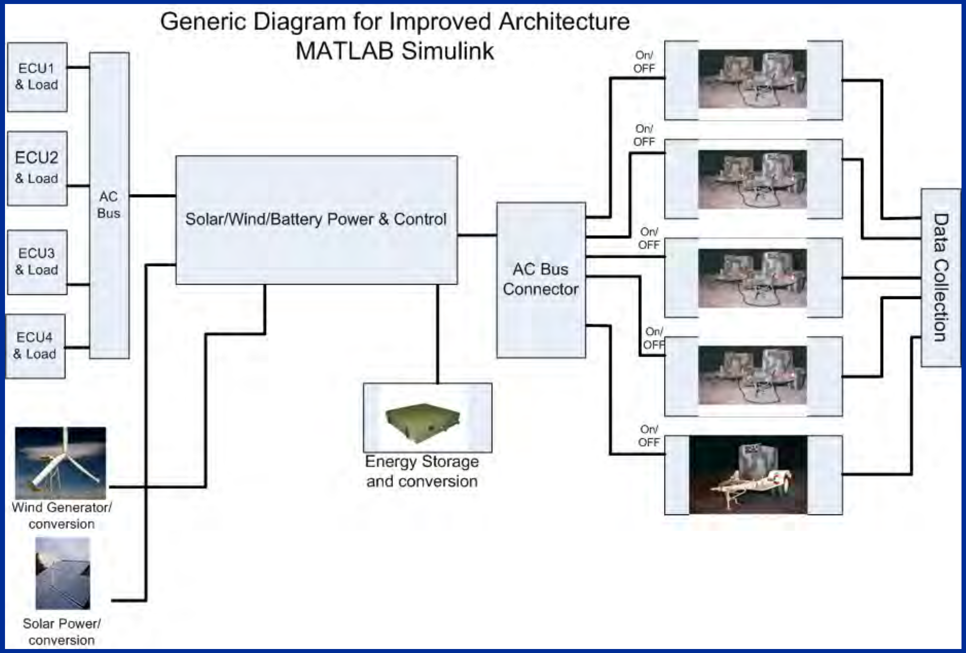
Simulations showing improved fuel consumption and increased efficiency.

- •Generators on a common bus
- •Energy Storage
- •Alternative Energy Sources

- Same user load profiles as Baseline
- Establish new performance char.
  - •Fuel consumption
  - •Generator run times
  - •Load prioritization
  - •Redundancy

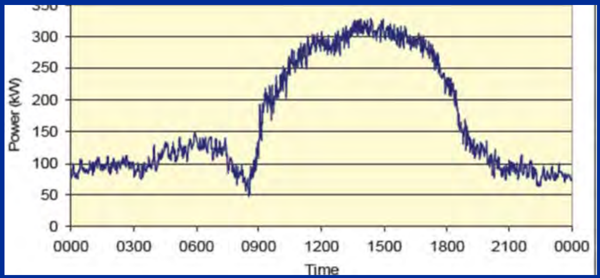
Simulation Features

- **•Low & High Fidelity Models**
- **•Common Bus**
- **•Alternative Power Sources**
  - **Wind Models**
  - **Solar Models**
  - **Fuel Cell Models**

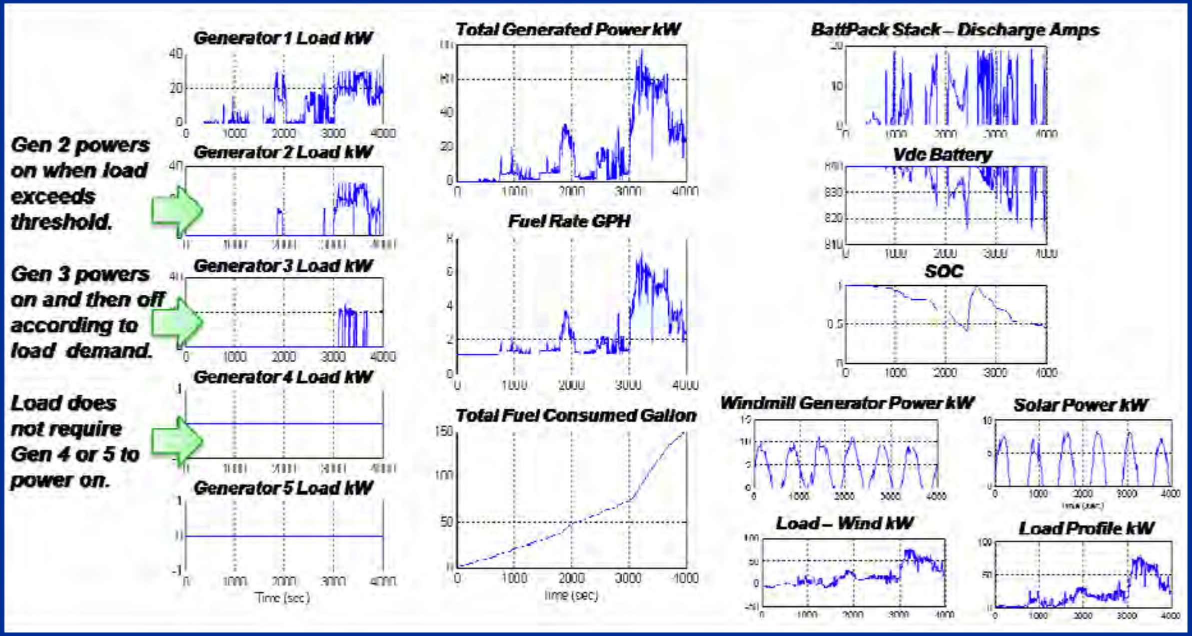


Simulation Shows Fuel Savings

- Simulation Runs with Same User Profiles
  - w/ Parallel Generators >30% fuel savings
    - Adding Energy Storage >35% savings
      - Adding Solar/Wind Power >50% additional savings.



Graphic Courtesy of CERDEC
Public Release data for Combat Support Hospital



- Fuel consumption reduced
- Reduced generator run times due to
  - Energy storage
  - Renewables

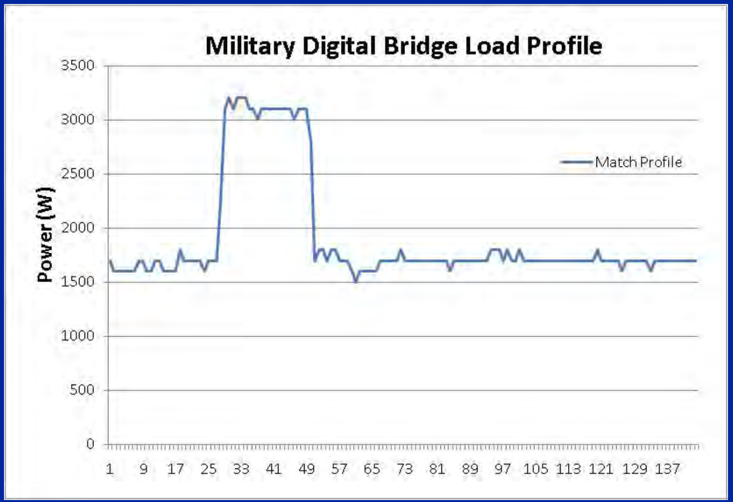
Energy/Power Management

- *Common Bus design facilitates peak load management by employing distributed energy sources.*
- *Simulations show increase in system fuel efficiency when energy storage is added to microgrids*
- *Design requires efficient power electronics*

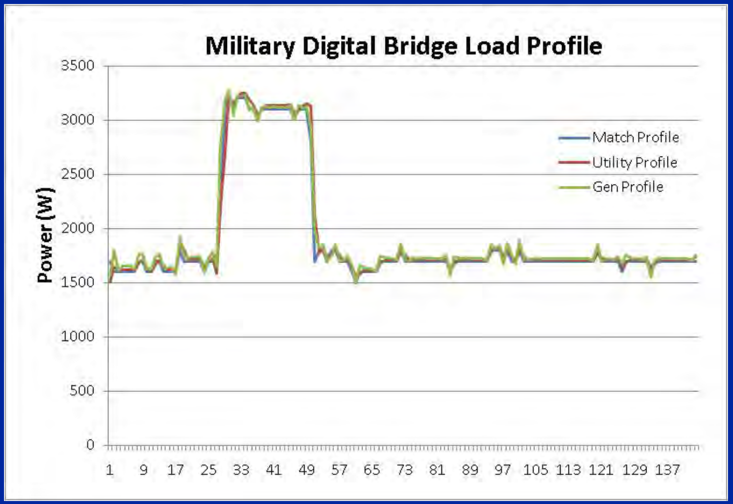
- *Implementing solutions for:*
  - *Efficient power electronics*
  - *Automatic on/off control of energy sources*
  - *Generator synchronization*

Simulation Results lead to Hardware Implementation

Hardware Implementation of Load Profiles



Public Release data for Digital Bridge Mission



- *Configure hardware to run military load profiles*
- *System controller (NI Chassis) manages operation of equipment.*
- *Run Digital Bridge profile*
  - *5KW generator*
  - *Two synchronized 2KW generators*
  - *One 2KW generator with Energy Storage*
- *Analyze and compare fuel consumption with each case.*

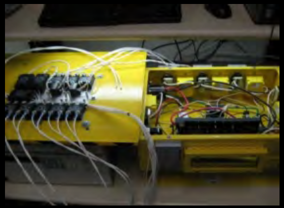
Upcoming Tasks:

Perform test with larger load profiles

Hardware Implementation-Laboratory

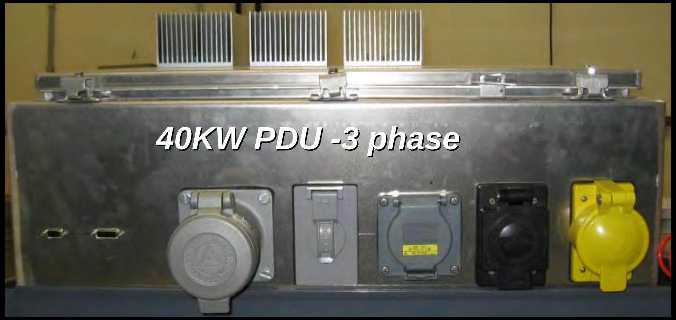
- ***Power Distribution***
- ***Power Monitoring***
  - ***Current and voltage measurements***
- ***Power Control***
  - ***High Current Relays controlled by NI Chassis***
  - ***Fault protection***

Instrumented Power Distribution



National Instruments Chassis
Voltage & Current Transducers
Power Measurement Equipment

With Power Distribution Control



Generator House

Control Center

Centralized Controller (National Instruments Lab View)

Lab Power Components

Military TQG Diesel Generators

Mil and Commercial Diesel Generators

Total power >70KW.

Wind/ Solar Power and Dedicated 3-Phase Power

Lab Loads Equipment

- Electronic DC
- AC Resistive
- Electric Motors
- Environmental Control

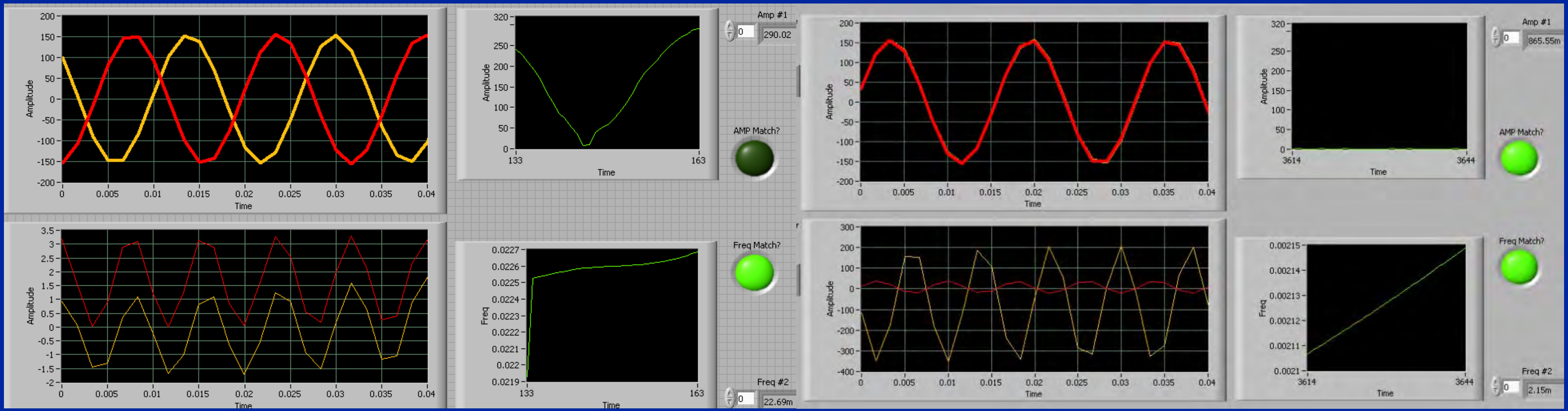
ECU –Air Rover

Energy Storage

- Li-Ion BattPacks
- Mil Batteries
- Commercial Lead Acid

AC Bus and Generator Synch

- *Using Microgrid Controller*
  - *Monitor voltage, frequency, phase of 2 or more generators*
  - *Outputs are synchronized and paralleled*



Paralleling Generators Offers Higher Efficiencies

Microgrid Lab –Alternative Energy Capabilities

- *Wind Energy - 1KW*
- *Mounted on 30 ft pole*
- *24VDC output*

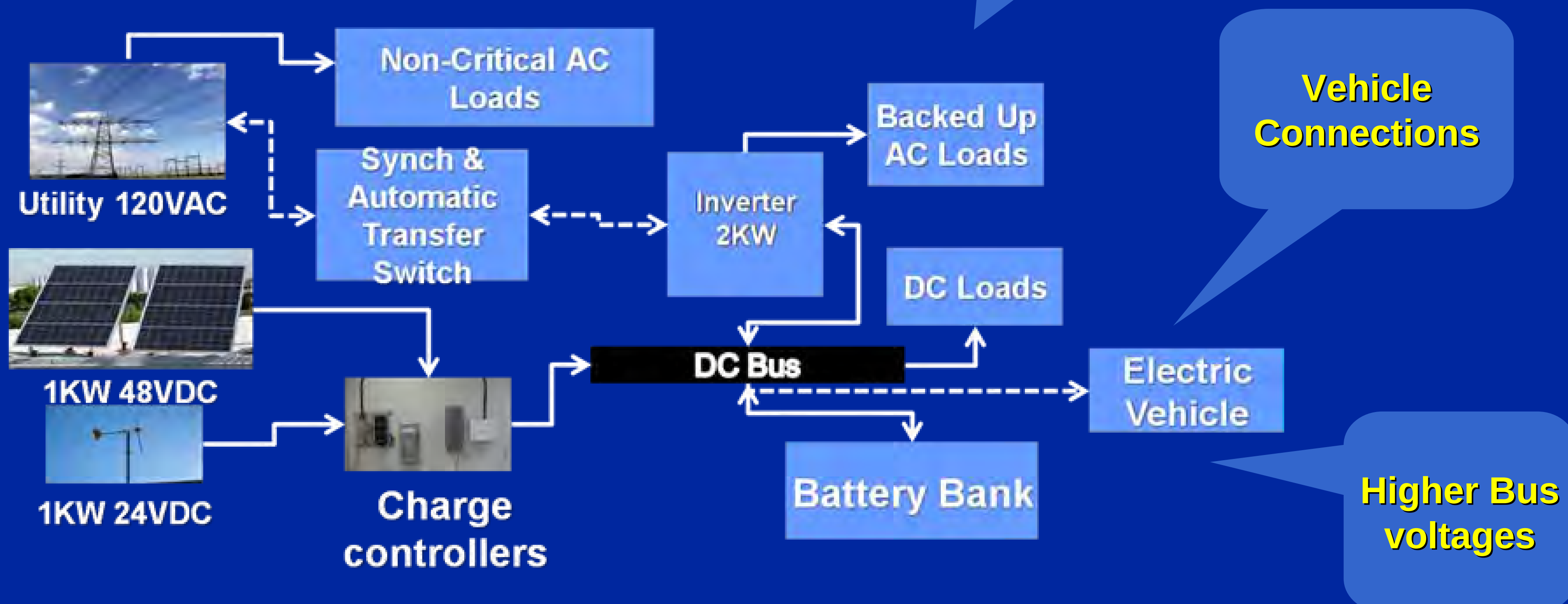
- *Solar energy - 1KW*
- *8 panels on building roof*
- *48VDC Output*

- *Charge controllers maintain battery bank at 28VDC.*
- *Integrating advanced energy storage*
- *Higher voltage buses to be evaluated*

Renewable Power within the Microgrid

- ***Initial Lab Setup for Solar/Wind Power***
- ***Test plan includes connecting electric vehicles to DC grid.***
- ***Increasing DC Bus voltage***
- ***Advanced power electronics***

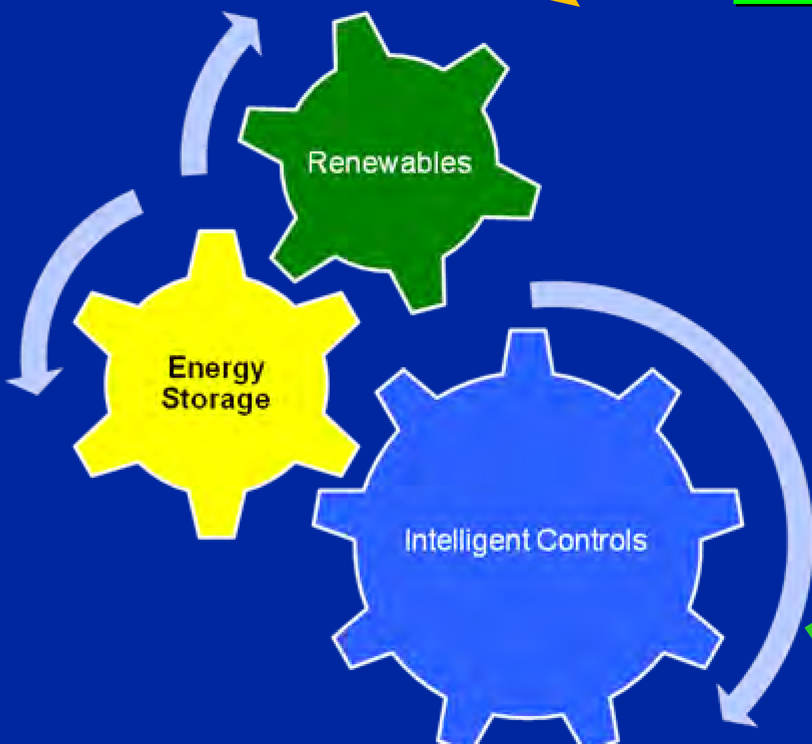
Automatic communications and controls



Development of Holistic Systems Approaches

Capability Issues

- Fuel Consumption
- Non-optimum SWaPc
- High O&M Costs



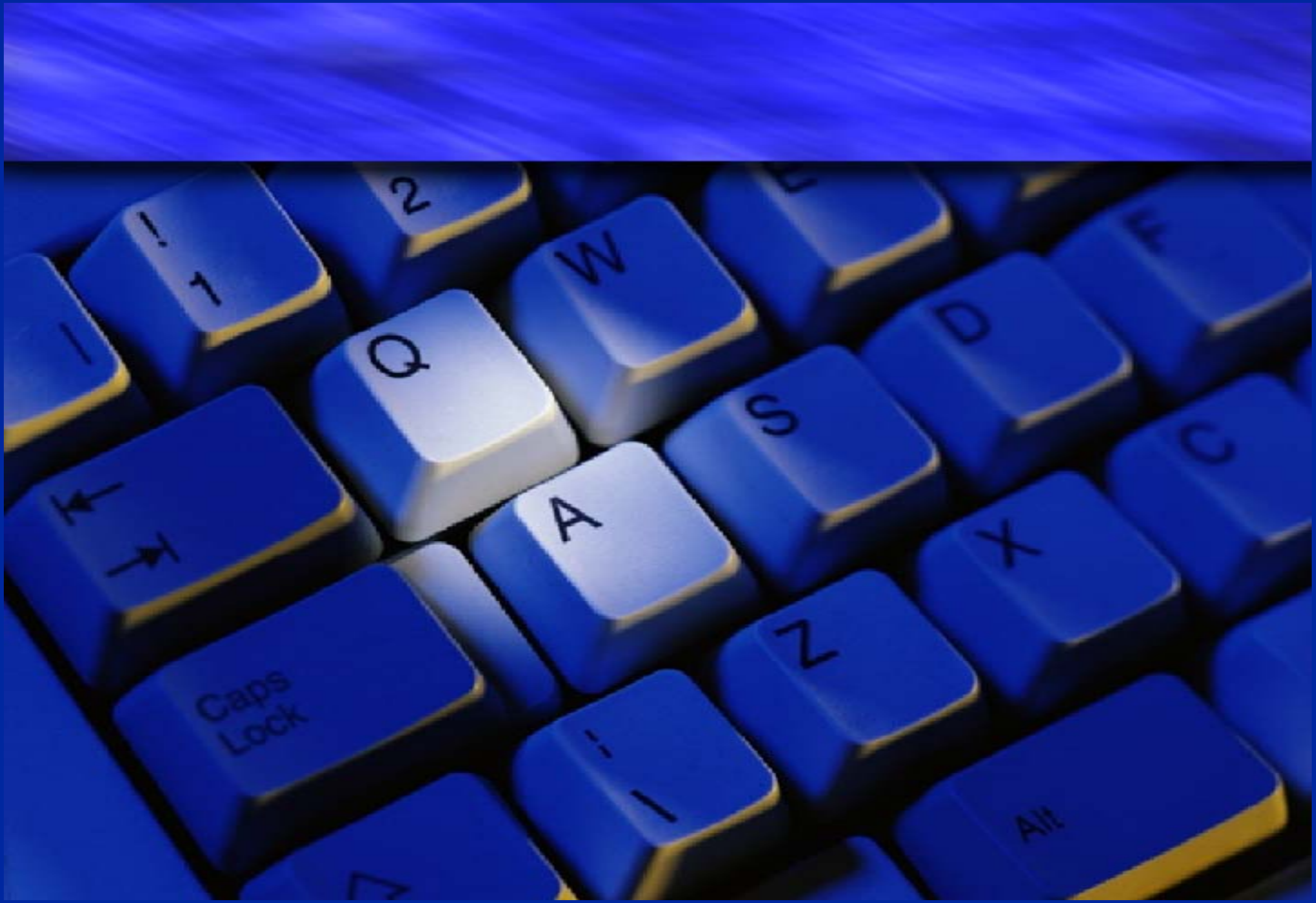
Solutions

✓ Reduce Generator Fuel Consumption

✓ Improve SWaPc with reduced number of generators

✓ Reduced O&M Costs by operating fewer generators.

QUESTIONS?



Auxiliary Power Unit (APU) for Military Vehicles

Jeff Humble

General Dynamics Land Systems
640 Seminole Rd.
Muskegon, Michigan 49441
(231)780-5609
humblej@gdls.com

APU Program Summary

- **Developed under contract to Marine Corps Systems Command in 2007. Spin-off of On Board Vehicle Power (OBVP) program for 30 kW export power and 10 kW power on the move for HMMWV1123.**
  - **OBVP system portability study to Mine Resistant Ambush Protected (MRAP) vehicles**
  - **Portability study change in scope from AC power to 28VDC power**
  - **OBVP MRAP solution evolved into the APU**
- **APU Brass Board and Pre-Production hardware fabricated and tested in 2008**
  - **Brass Board accumulated 144 hours run time**
  - **APU Pre-Production hardware government testing is ongoing**

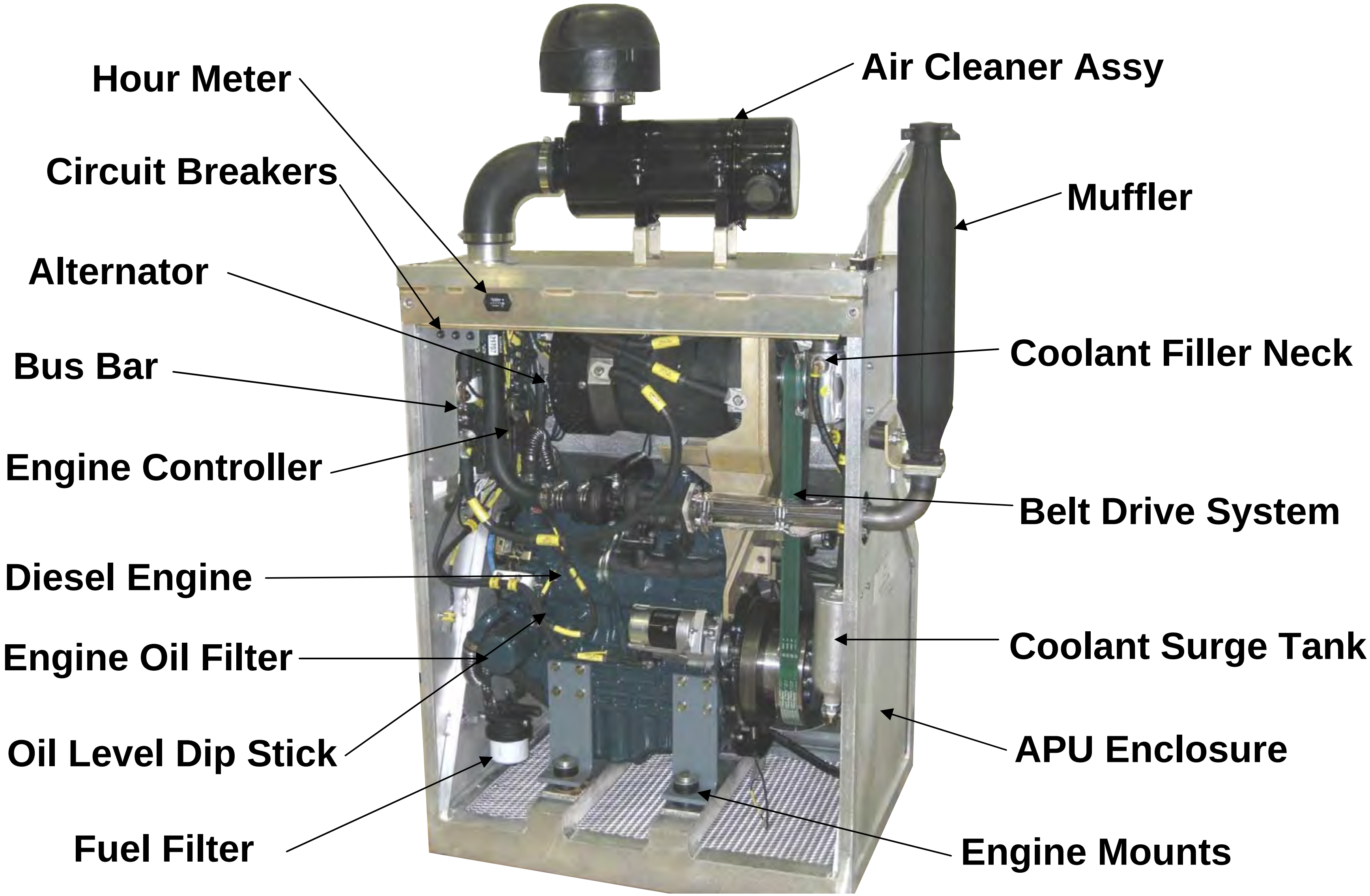
APU Product Specification

- **Rated power: 14.2kW at 0-12,000 ft, 508A, 28VDC**
- **Ambient Operating Temperatures: -25° to 131°F**
- **Weight: 650 lbs.**
- **Size: 38”(L) x 63” (H) x 25” (W)**
- **Fuel: DF-2, JP-8, Ultra Low Sulfur Diesel (ULSD)**
- **Coolant: Water-Ethylene Glycol (WEG) or Water-Propylene Glycol (WPG)**
- **Sand and Dust: Complies with MIL-STD-810F**
- **Emissions: Complies with EPA Interim Tier 4**
- **Fuel Consumption: 1.2 gal/hr at 10kW, 1.7 gal/hr at 14kW**

System Description

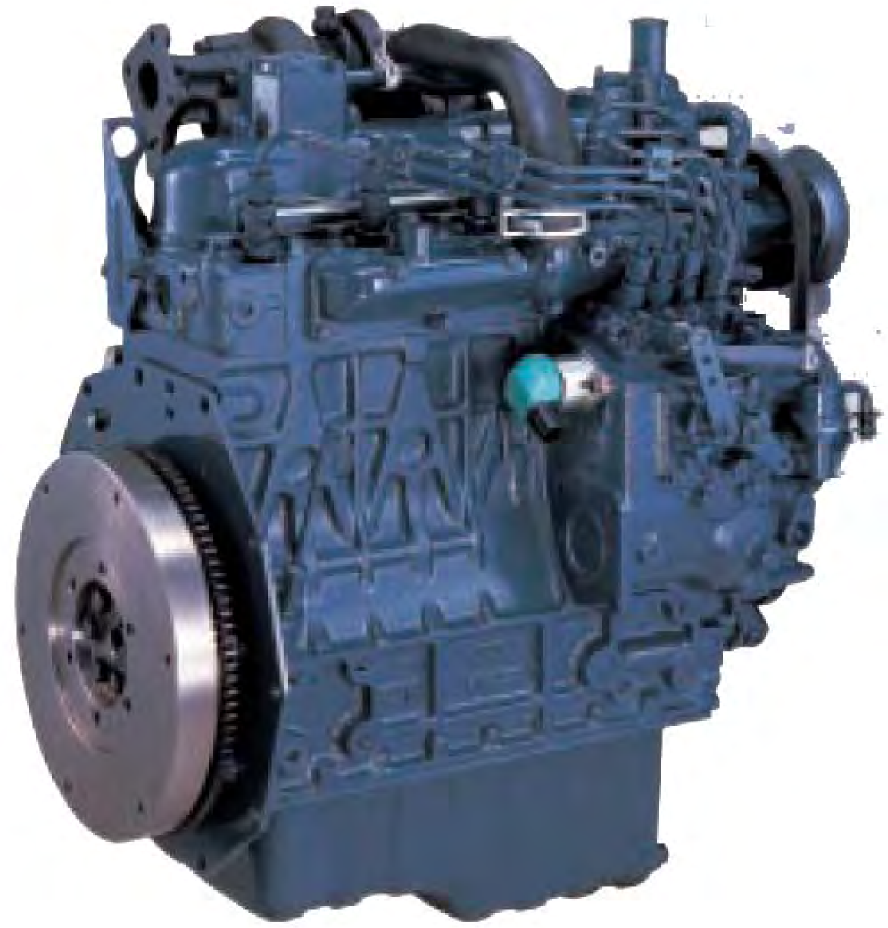
- **Diesel powered generator system with Commercial Off The Shelf (COTS) components**
- **Stand alone system independent of the vehicle except for fuel supply and batteries for starting**
- **Provides 508A, 28VDC directly to vehicles power distribution system to augment vehicle power**
- **Operates as load following for best fuel consumption rate and reduce wet stacking**
- **Manufactured by General Dynamics Robotics Systems**
- **Export power capability through vehicles NATO slave**

APU


Hour Meter
Circuit Breakers
Alternator
Bus Bar
Engine Controller
Diesel Engine
Engine Oil Filter
Oil Level Dip Stick
Fuel Filter
Air Cleaner Assy
Muffler
Coolant Filler Neck
Belt Drive System
Coolant Surge Tank
APU Enclosure
Engine Mounts

APU Engine

- **Kubota V1505-T, turbocharged, 44.2 HP diesel engine**
- **COTS hardware, in production since 1991**
- **Weight: 251 lbs**
- **Size: 24”9(L) x 24.5”(H) x 17”(W)**

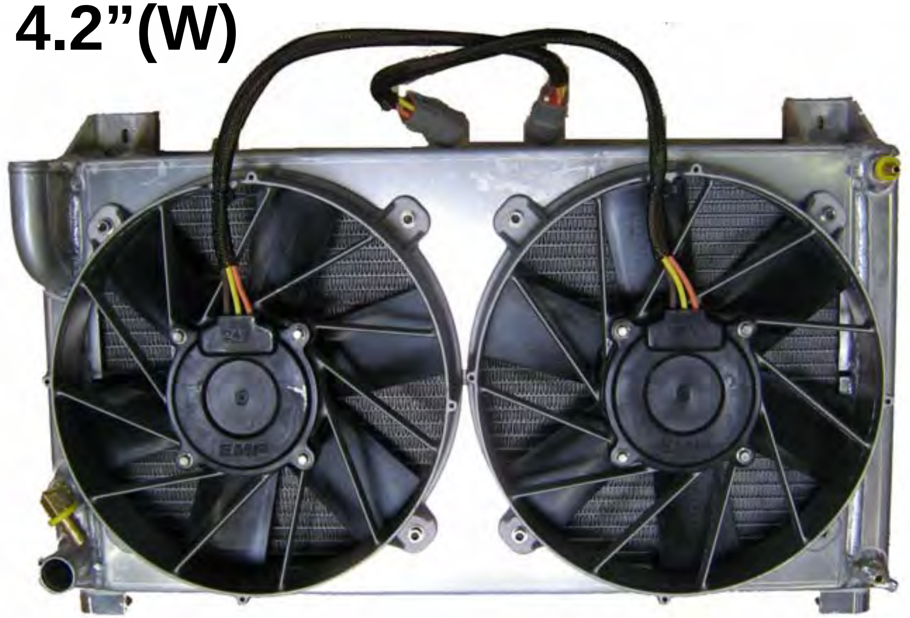


APU Generator

- C.E. Niehoff 570A, 28VDC Alternator
- COTS hardware
- Weight: 115 lbs.
- Air cooled with self contained cooling fan
- Rated for ambient air temp -65° to 200°F
- 1500 – 8000 RPM
- Belt driven

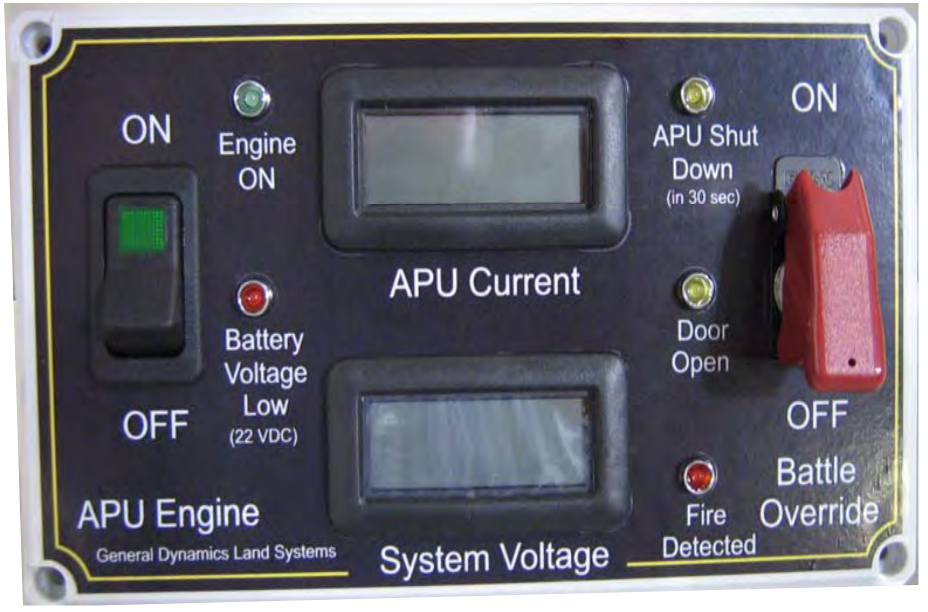
APU Cooling System

- Closed loop cooling system
- Variable speed COTS fans, reverse direction at periodic intervals to clean radiator core
- Custom sized
- Weight: 30 lbs.
- Size: 26”(L) x 15.5”(H) x 4.2”(W)



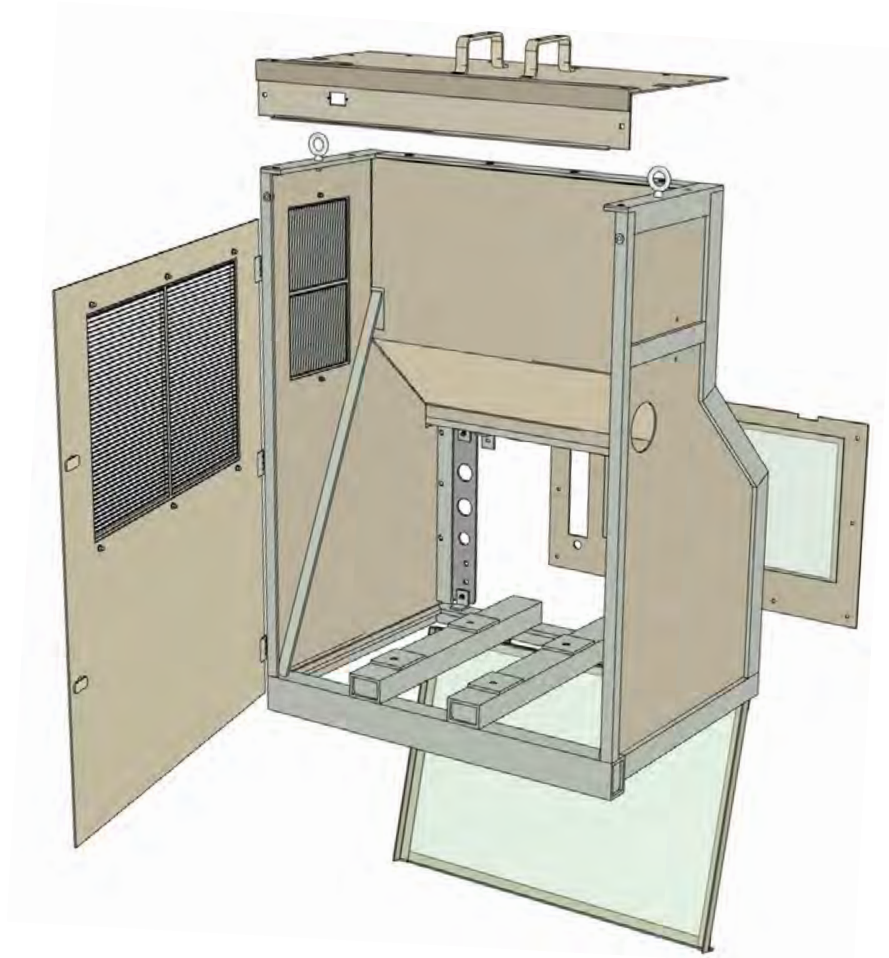
APU Controls

- **Remotely located inside vehicle**
- **On/Off switch, normal operating and warning lights, voltage and amperage indicators**
- **Battle Override to disable automatic shut down due to high coolant temp or low oil pressure**



APU Enclosure

- **Lightweight aluminum structure or optional armored enclosure**
- **Large door on front, removable top, bottom and back panels for easy access for maintenance**
- **Door locks for security**



APU Operation

- Operated from inside vehicle with remote MMI panel
- Once started, operation is automatic
- Load following and slaved to vehicle voltage regulator. Automatically controls APU engine RPM to match alternators output to that of the demand from the vehicle. Load following helps reduce wet stacking and improves fuel economy
- Automatic precautionary engine shutdown 30 seconds after a high coolant temp or low oil pressure is detected
- Battle override to disable automatic precautionary shutdown

APU Maintenance

- **Maintenance checks, fluid level checks and fill points are accessible at front of APU**
- **Clear access to system for maintenance and systems inspection/checks from large front door and access panels**
- **All major components can be removed and replaced while the APU is on the vehicle without needing to remove other major components first**
- **Reliability prediction of 1213 hours Mean Time Between Failures (MTBF) generated from Nonelectric Parts Reliability Data (NPRD)**

Summary

- Production ready APU with COTS major components
- Independent of vehicle engine, APU failure or destruction will not affect vehicle mobility or performance
- Can be Reconfigured for other military vehicles without changing COTS hardware

2009 Joint Services Power Expo

High Temperature PEM Fuel Cell/Lithium Ion Hybrid Power Source for Ground, Air and Sea Platforms

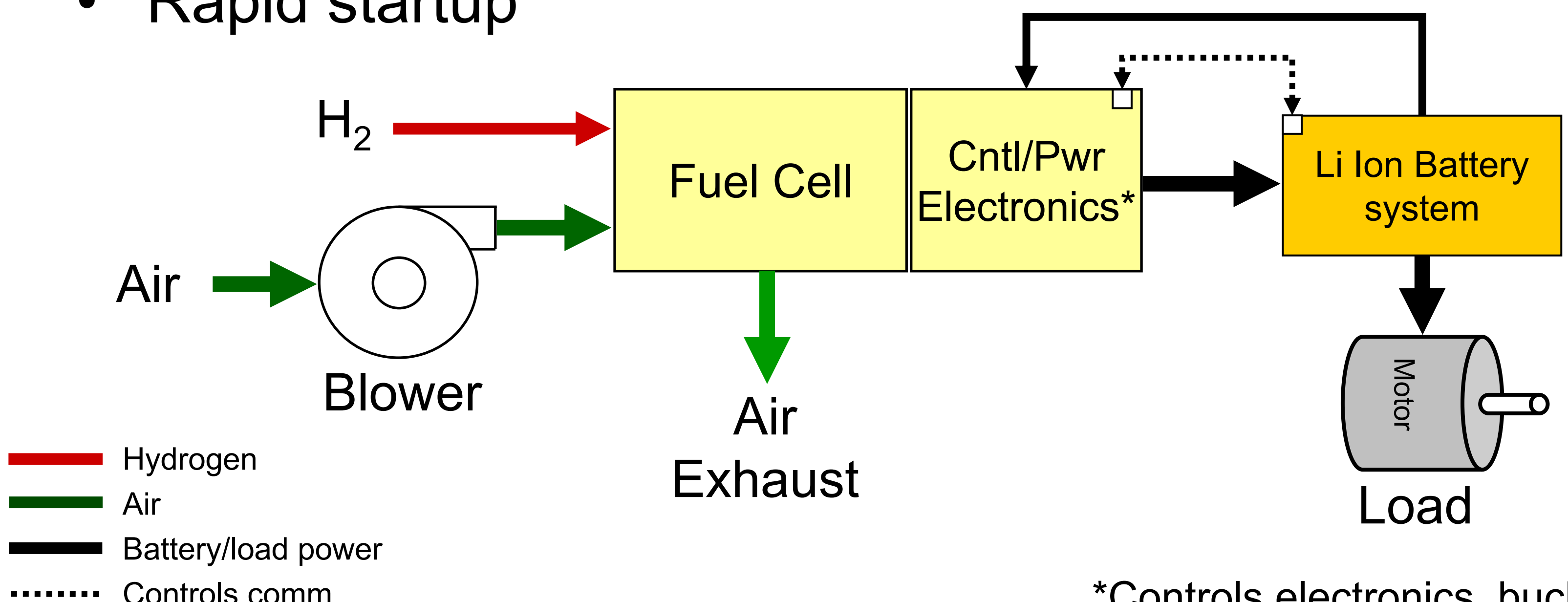
Michel Fuchs – EnerFuel
Adam Hunt – EnerDel

May 7, 2009
New Orleans, Louisiana

 Sales@enerfuel.com

EnerFuel Fuel Cell/Li-Ion Hybridization

- Fuel cell sized for average power, battery for peaks
- Smaller fuel cell and battery
- Reduced fuel cell and battery cost
- Maximizes fuel cell and battery longevity
- Rapid startup



*Controls electronics, buck converter, and power conditioning

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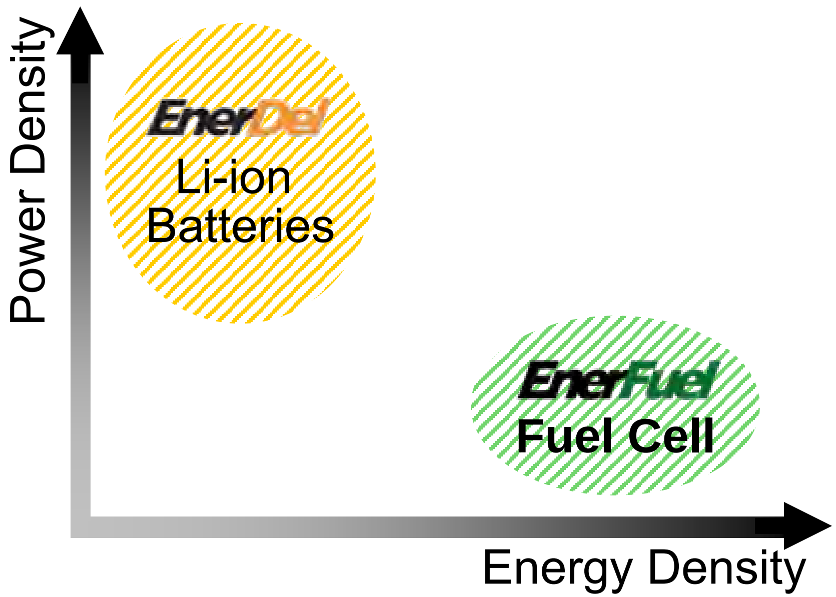
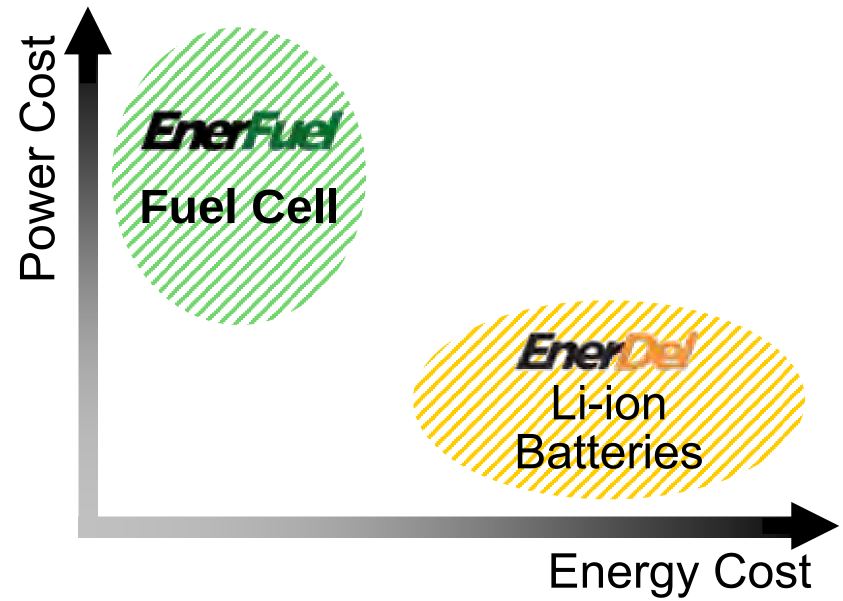
Fuel Cells & Batteries Enhance Each Other

Power / Energy Comparison



Cost Comparison



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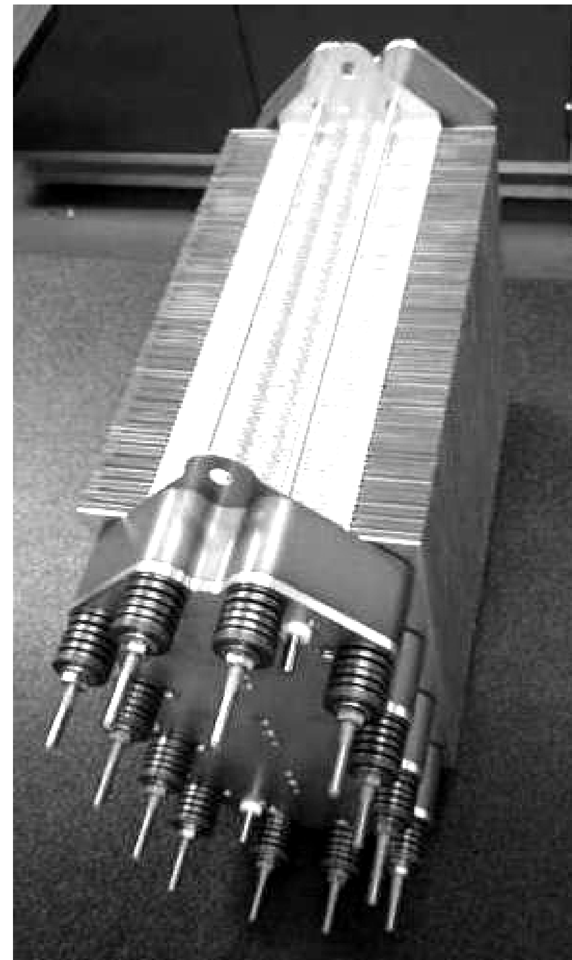
EnerFuel High Temperature PEM Fuel Cell Technology

- SIMPLE
- EFFICIENT
- LIGHT WEIGHT
- FUEL FLEXIBLE
- APPLICATION FLEXIBLE



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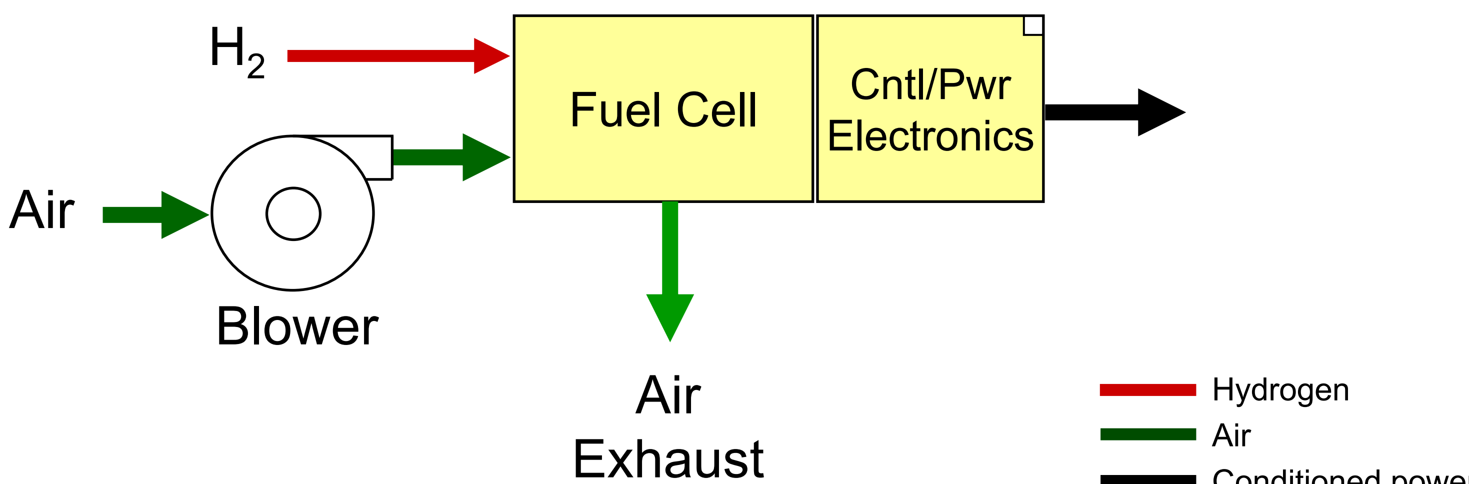
Simple

- Air cooled fuel cell stack, no radiator and liquid cooling system
- No liquid management problems
- No humidification of inlet air necessary
- Inherently suited to low cost mass production



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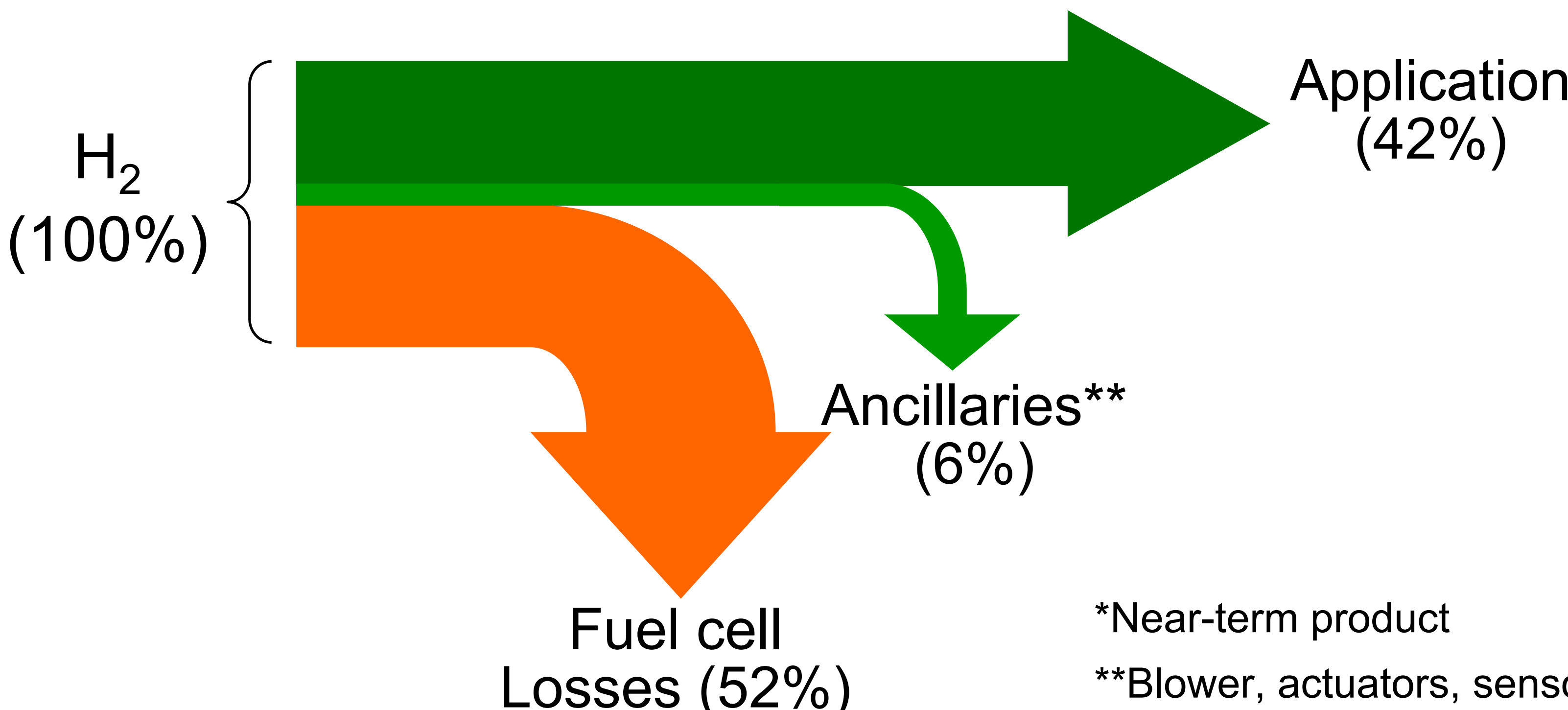
Efficient

- Efficiency greater than 42% (including power conditioning)
- Startup*: 50% power in less than 1 minute
- Startup*: <280 Wh (1.0 MJ) from +20°C



*Near-term product

**Blower, actuators, sensors, control electronics and power conditioning

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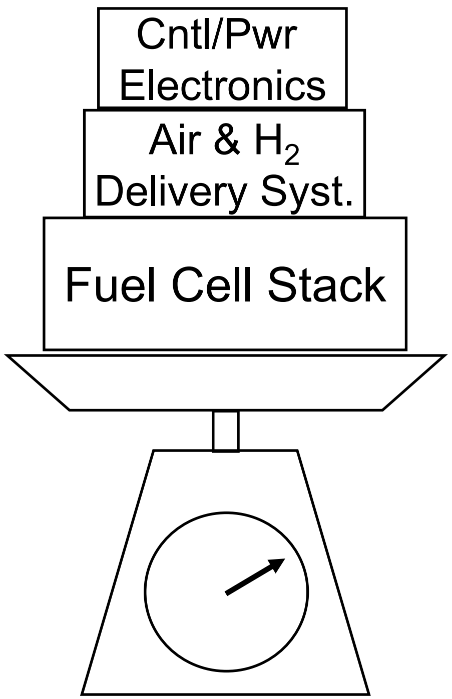
Light Weight

- Near-term commercial product: 133 W/kg
- With aggressive weight reduction: >150 W/kg



= 30 kg → 4kW @30 kg = 133 W/kg

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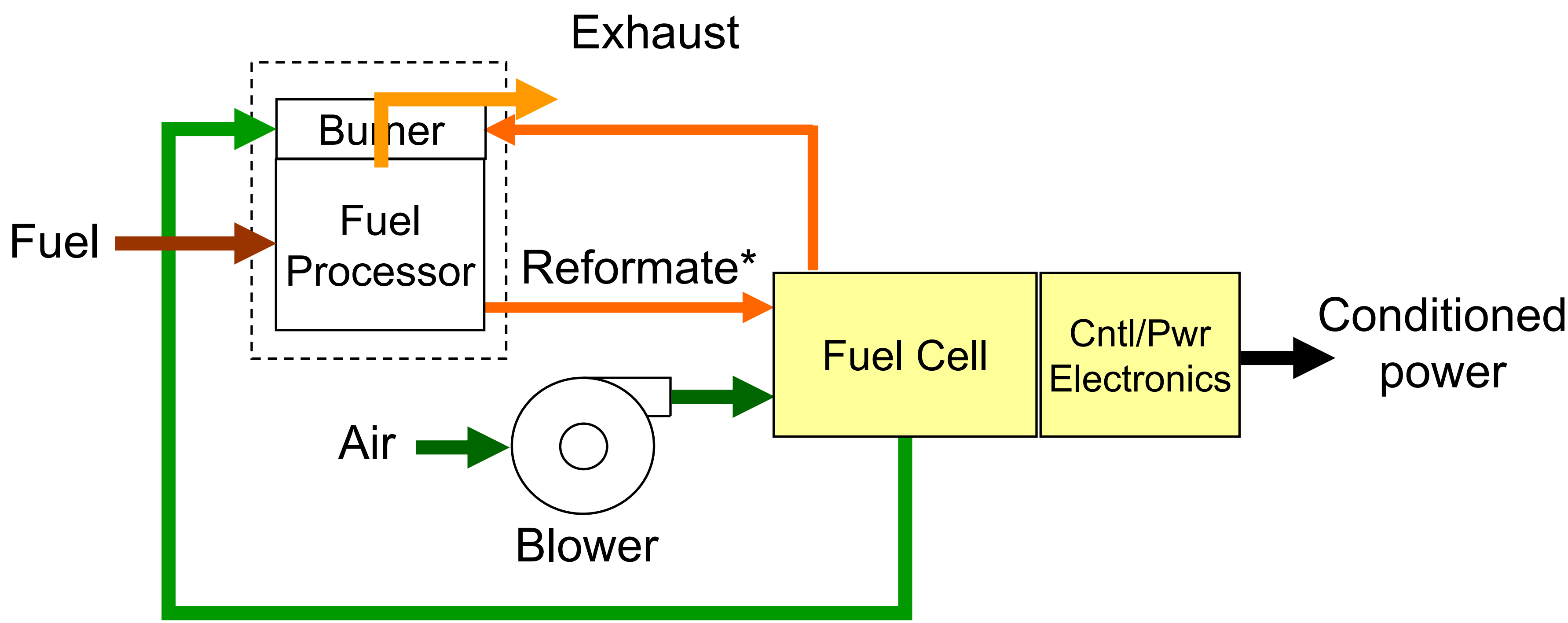
Fuel Flexible

- Can accommodate low quality reformate (CO ≤ 3%)
- Can use low cost reformer w/ minimal cleanup stage
- Possible fuel choices: methanol, NG, diesel, JP8



*H_2 rich gas

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Application Flexible

- APU, backup power, primary power
- Tolerate wide range of environmental temperatures
- Less susceptibility to freezing
- Low thermal & acoustic signature

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Transition to Commercialization

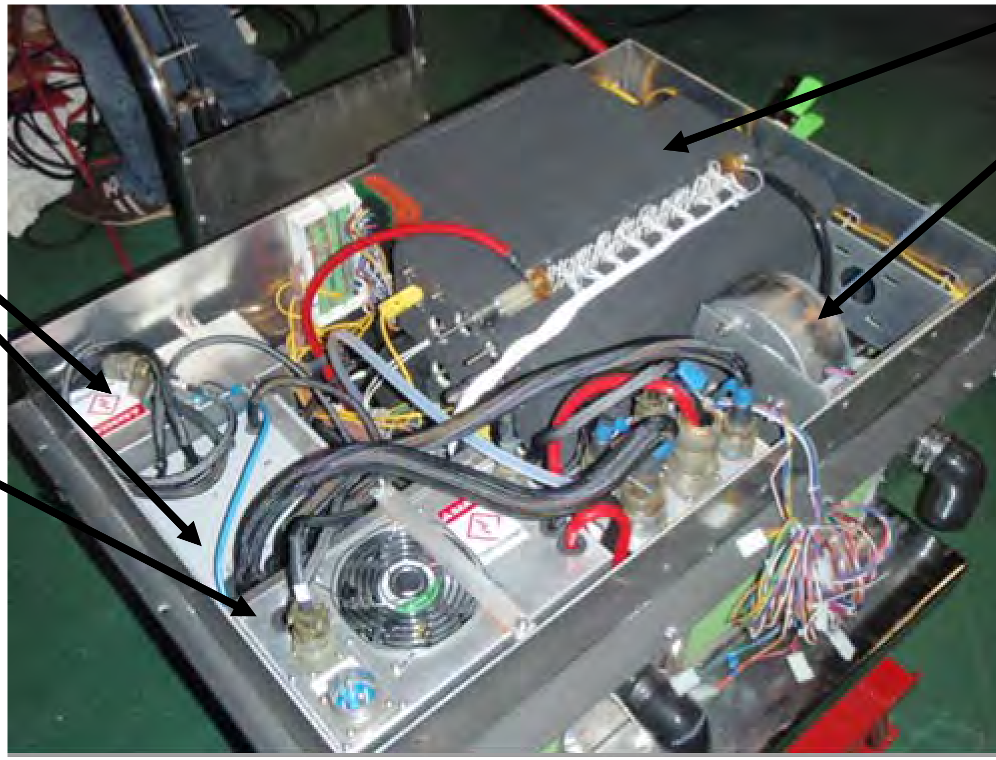
HT-PEM Fuel Cell System Status

Fuel cell stack
with manifolding

Blower

Control
electronics

Power
electronics



3kWnet TRL-6, HT-PEMFC system prototype

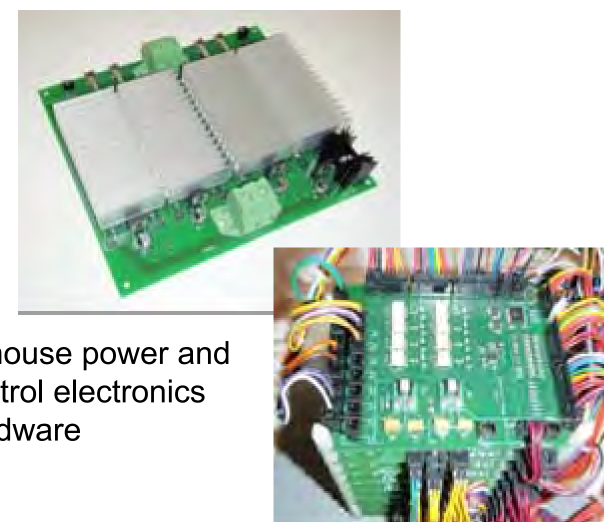
Specifications

- TRL-6 equivalent
- 57 kg
- >40% efficient
- $80k

Near-Term Product Goals

- Weight & Cost
  - Consolidate control/power electronics into single module
  - Stack material replacement and component reduction
  - Projected weight of: 30kg
  - Projected fuel cell cost: $9k*
- Timeline
  - Commercial ready product by end of 2011

Fuel cell stack
with manifolding



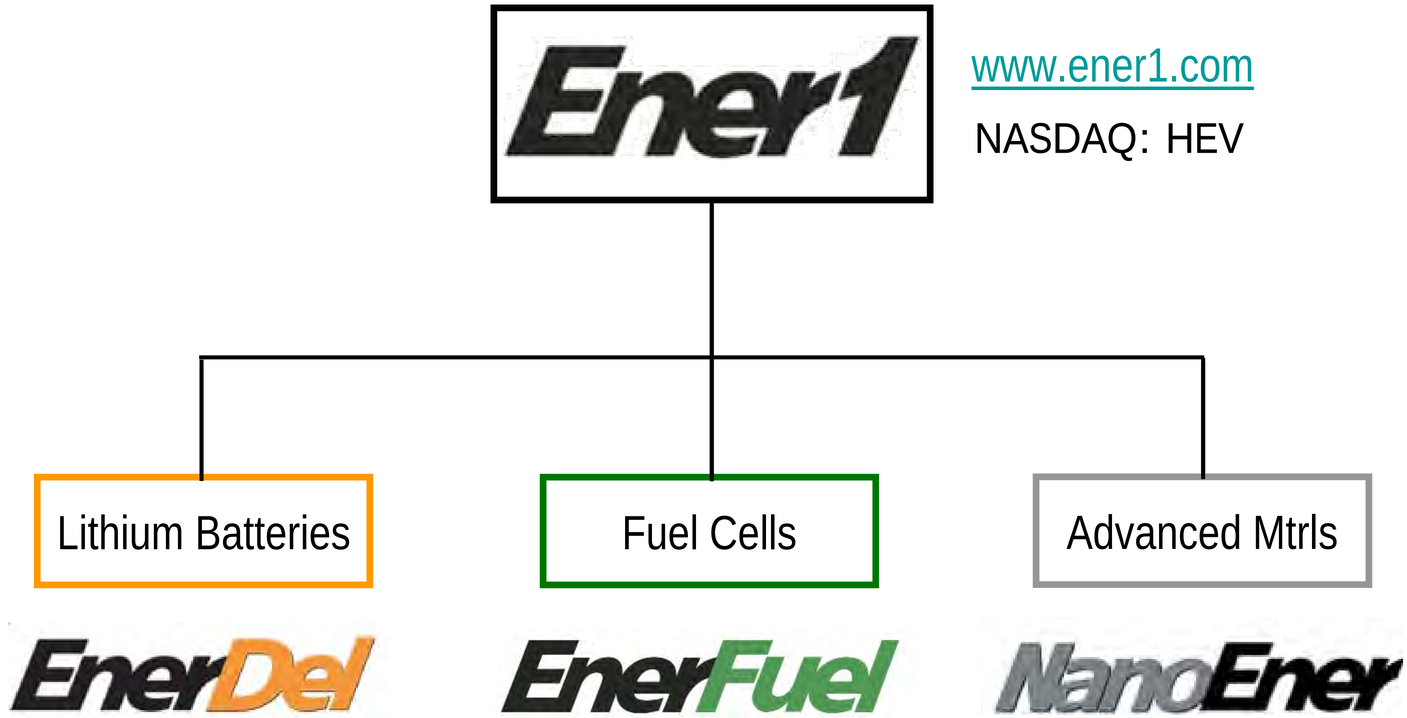
In-house power and
control electronics
hardware

* Minus margin, battery, or reformer

Company Overview

EnerFuel

Group Corporate Structure



The EnerFuel Team

- Senior staff of 10 with an average fuel cell experience of 12 yrs
- Majority of senior staff legacy of energy partners

  - Staff composition:
    - Mechanical Engineers
    - Systems Engineers
    - Electrical Engineers
    - Material Scientists
    - Computer Scientist
    - Chemical Engineer
    - Industrial Designer
    - Chemist
    - Technicians with close to 20 years individual fuel cell experience
    - Business professionals

EnerFuel

Product Roadmap

HT-Fuel Cell System 1kW to 15kW

Core EnerFuel Technology

NG or LPG Reformer

Initial Market Application

Backup Peak Shaving

Provides Point of Use Energy storage and Backup for the Electric Grid

- Increases grid efficiency
- Increase grid reliability
- Reduces carbon emissions

Commercialization Timeline:
First Article Test – 2010
Product Qualification – 2011
Market Introduction – 2012

Second Near-Term Market Application

APU & EV Range Extender

Key to Mass Market EV

- Increases driving range
- Reduces vehicle cost

Commercialization Timeline:
Proof of Concept - 2008
First Article Test – 2010
Product Qualification – 2012
Incorporation into OEM vehicle - 2013

Fuel Cell Vehicle

Fuel cell stack assembly

Prototype Vehicle
Range Extender Specifications

EnerFuel Fuel Cell PHEV

- 3 kW fuel cell system
- 20 kWh net capacity
- 60 to 80 mile range extension

Q&A

Please Visit Booth 111 for Additional Information

mfuchs@enerfuel.com
ahunt@enerdel.com

Protonex™

JOINT SERVICE POWER EXPO

Greg Cipriano, VP Marketing & Military Development

Phil Robinson, VP Electronics & Power Systems

May 7, 2009

THE NEXT GENERATION OF PORTABLE POWER.™

Agenda

- **Company Overview**
- Products and Technology
- Power Managers
- Alternative Energy Harvesting
- Questions

PROTONEX – The Next Generation of Portable Power…

PROTONEX Overview

- **Leading provider of 100 - 1000 watt PEM and SOFC power solutions**
  - Portable, remote and mobile power
  - Targeting applications underserved by batteries and small generators
- **Strong traction to date with US Government agencies**
  - Over $40M in program value with Air Force, Army, Navy, SOCOM, DARPA, DOE, NASA…
- **Well positioned to deliver product for military and non-military applications**
  - Offering PEM and SOFC products to meet diverse application needs
  - Capable of high performance and low cost
- **Key commercial partnerships in place, more in discussion phase**

Cummins Parker Raytheon TOTO CBC GROUP

- **Headquartered in Southborough, Massachusetts**
  - Development facility in Broomfield, Colorado focused on SOFC products
  - Excellent and experienced management and technical team
  - Over 90 employees today and growing
- **Publicly traded on the AIM market of the LSE - symbols: PTX and PTXU**

The Value of Portable Fuel Cells

VS. ADVANCED BATTERIES

- Reduced weight
- Extended run times
- Reduced size
- Lower life cycle cost
- Less hazardous contents
- Enables new missions

VS. ICE GENERATORS

- Low noise level
- Reduced emissions, indoor operation
- Greater efficiency
- Lower heat signatures
- Longer maintenance cycles
- Lower life cycle cost

Fuel cell based power systems provide many advantages over existing technologies

Protonex™

Portable Power Focus - 100 to 1000W

- **Wearable (1–2 kg, ~20-50 W)**
  - Individual soldiers
  - Direct power of soldier loads, single battery charging

- **Packable (4–8 kg, 100–200 W)**
  - Squad level
  - Battery charging for soldier batteries
  - Direct power of field gear

- **Portable (10–20 kg, 250–1,000 W)**
  - Platoon+ level
  - Forward base battery charging
  - Tent power, silent watch

- **Truckable (30–60 kg, 1,000–5,000 W)**
  - Current tactical generators
  - High power equipment
  - Fixed APU for vehicles

Agenda

- Company Overview
- **Products and Technology**
- Power Managers
- Alternative Energy Harvesting
- Questions

PROTONEX – The Next Generation of Portable Power…

Two Fuel Cell Technology Platforms

- **Proton Exchange Membrane (PEM)**
  - Fuels
    - Methanol
    - Chemical hydride
    - Hydrogen
  - Operating temperature: 50°C – 75°C
  - Configuration: planar
  - Readiness: now

- **Solid Oxide Fuel Cell (SOFC)**
  - Fuels
    - Propane
    - Gasoline, Diesel and JP-8
    - Biofuels
  - Operating temperature: 700°C
  - Configuration: tubular
  - Readiness: 1-2 years

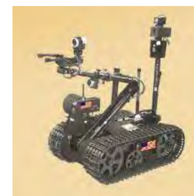
Fuel flexibility to address multiple applications
Strong overlap between PEM and SOFC

Current Military Platforms

M250-CX – Battery Charger/APU

- 35 pound, methanol-fueled PEM system
- Charges up to 5 batteries or functions as portable APU
- Proceeding to full product and 810f testing in 2009.
- Ongoing program funded by OSD, CERDEC, ARO

UAV and UGV Propulsion



- Demonstrated 9+ hours on Puma UAV vs. 2.5 hr on battery
- Moving to commercialize PUMA platform with Aerovironment
- Demonstrated over 3x range on FMI Talon

BPM and SPM Power Managers

- Provides soldiers with on-board power management of multiple devices
- High efficiency to reduce heat loads. Lightweight, compact and rugged
- Automatic and flexible for a wide range of applications
- Funded via RDECOM (AIDE), run by ARO/CERDEC

S125-CX – Battery Charger/APU

- 10 pound, propane or liquid fueled system
- Charges military batteries or functions as portable APU
- Early stage development, currently at TRL 5
- Ongoing initial program funded by ARO and CERDEC

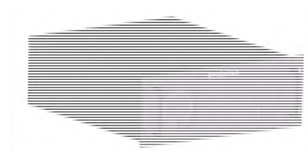
Future products to follow with higher power levels and different fuel types

Current Commercial Platforms

M250-B – Battery Tender

- Targeted mainly at recreation and renewable market
- Provides clean quiet power
- Methanol fuel
- Product introduction scheduled for December 2008

M250-U – Backup Power



- Targeted at Broadband and WiFi backup markets
- Provides extended run power for remote nodes
- Methanol fuel
- Provides compliance with Katrina Act

M250-G – Generator

- Targeted at recreation and emergency responder markets
- Operates indoors or outdoors
- Methanol fuel
- Product introduction scheduled for October 2009

P125 – Generator/Tender

- Targeted at recreation and commercial battery charging market
- Compact and easy to use
- Propane fuel
- Alpha prototypes scheduled for January 2009

Future products to follow with higher power levels and different fuel types

Non-Military Application Targets

DC Backup Power

- Telecom Wireless
- Telecom Wireline
- Traffic Systems
- Broadband / CATV
- Critical Systems
- Security Systems

Recreation

- Portable Power
- RV Power
- Marine Power
- Campsite Power
- Remote Cabins
- Expeditions

Emergency

- Homeowner Emergency
- Battery Chargers
- Communications Equipment
- Emergency Response
- Security Systems
- Traffic Control Systems

Professional

- Scientific Equipment
- Power Tools
- Battery Charging
- Communication Systems
- Security Systems
- Video Equipment

Mobile

- Electric Motorbikes
- Personal Mobility
- Vehicle APUs
- Golf / Utility Carts
- Mobile Signage
- Commercial Robots

Renewable

- Solar Power Systems
- Wind Power Systems
- Remote Monitoring
- Remote Signaling
- Off-Grid Homes

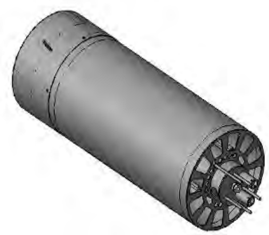
M250 Product Architecture

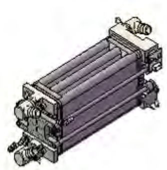
Fuel Reformer Core

- Unique patented design
- Commercial catalyst
- Designed for external fab

Fuel Processor Module

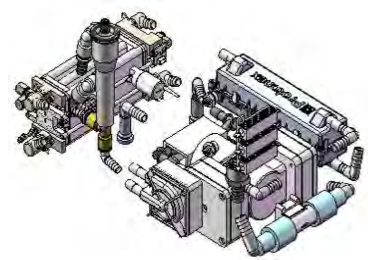
- Converts methanol to H_2
- Unique patented design and mfg process
- Designed for external fab





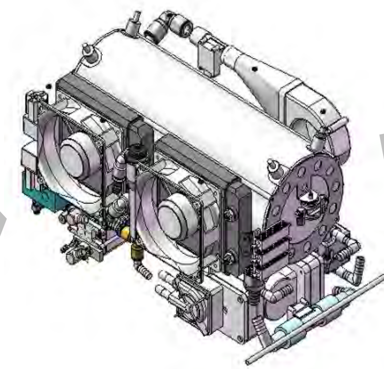
Fuel Cell Stack

- Unique patented design & mfg process
- In house manufacture
- Core of fuel cell system



Fuel Cell Module

- Feeds & controls for stack
- High performance, available balance of plant components
- Contains several proprietary PTX components

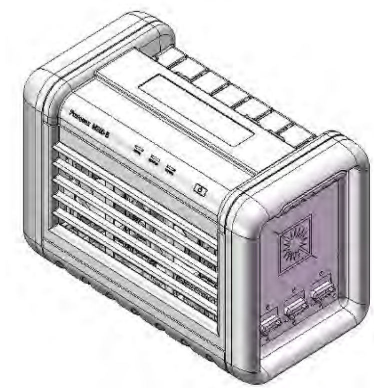


Integrated System

- Fuel reformer linked to fuel cell
- Control electronics, power management, safety systems
- Suitable for contract assembly at higher volumes

Packaged System

- Packaged specific to application
- Professional look and feel
- User interface
- All accessories and connections



M250-CX Battery Charger / APU

APPLICATIONS:

- Portable Battery Charger (Li145, LI80, BB2590)
- Primary Power Source (28 VDC, 110 AC with inverter)
- Portable Squad Power (Direct Power & Charging)
- Silent Power (Night Time, Quiet Environments)
- Vehicle Mountable (No need to run vehicle for power)
- Forward Operating Base Power (Long Endurance, Efficient)
- Long Endurance Missions
- Training Missions
- Battery Power Extension

M250-CX Battery Charger / APU

Battery Charging (250 watt continuous)

- BB 2590	3 Batteries @ Max Rate
- LI145	5 Batteries @ Max Rate
- LI80	5 Batteries @ Max Rate

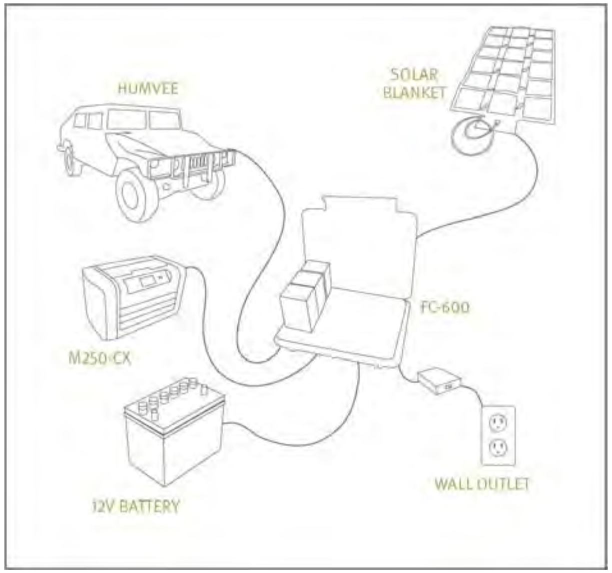
APU (250 watt continuous)

- 28 VDC output, hybridized with logistic batteries (BB 2590)
- Luggable weight – 30 lbs
- Replaces 3,600 BA 5590 batteries over lifetime
- Strong value prop – better than 80% savings in weight and cost
- Operates for > 10 hours / gallon of fuel
- Low emissions (indoor operable)
- Low noise (<55 dBa @ 1 meter)
- Hardened to pass mil-std-810f
  Previous generation passed
  810f drop, shock & vibration

FC-600 Lightweight Battery Charger

- BB-2590 - all variants
- 1-6 batteries
- 3 hour fast recharge
- Fuel cell & solar power sources
- Military & civilian vehicle power
- Worldwide AC power

- **Compact reduced weight and bulk**
- **Runs cool even while charging multiple batteries with 96—99% ultra high efficiency chargers**
- **Uses SMBus protocol, aka smart batteries**
- **Minimizes fuel use by negotiating optimal power rate with fuel cells**
- **Automatically recognizes solar input and applies Peak Power Point Tracking algorithm to maximize usable solar energy**



UAV Activities *$6.5M Funding to Date*

United States Special Operations Command

- AECV – 6 hour, Hand Launch

United States Naval Research Laboratory

- Ion Tiger – 24 Hour Demo

United States Air Force Research Laboratory

- Puma – 10 Hour, Hand Launch
- Raven B – range extension, 2-3x

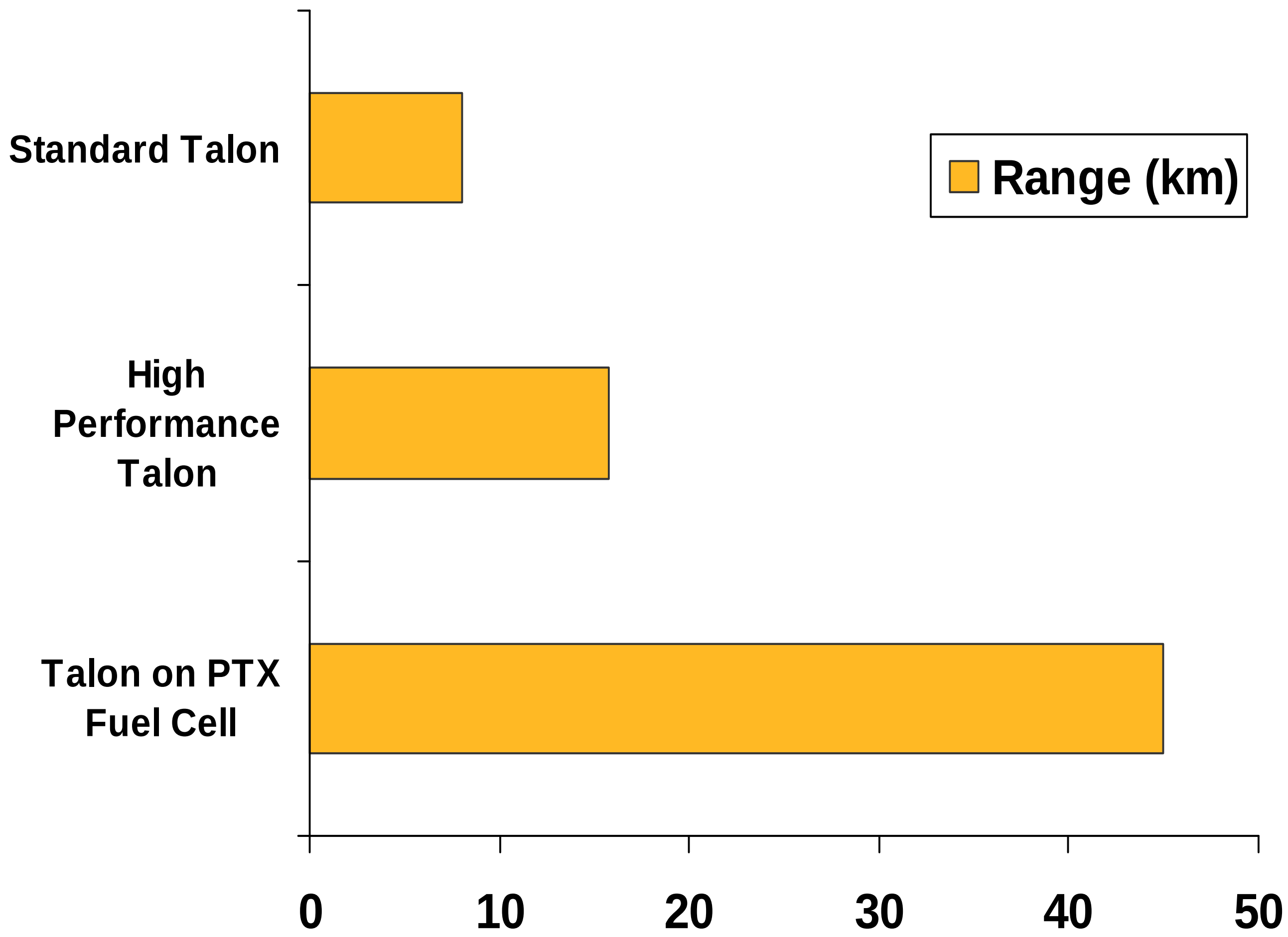
UxV Key Value Proposition

- Longer Electric Endurance
- Quiet Propulsion
- Low Thermal Signature
- High Efficiency
- Reliable Electric Start
- Silent Hybrid Mode

Unmanned Vehicles and Fuel Cells

UAV	UGV	UUV
		
▪ Tier I Planes ▪ Tier II Planes	▪ Talon ▪ Others in discussion	▪ Evaluating opportunity with the Naval Undersee Warfare Center (NUWC)

UGV Energy Storage Comparison



- Greater than 2X more energy storage compared to advanced batteries

UxV Power Spectrum

Vehicle	Power [watts] Nominal Power	Max Power Continuous	Peak Power	Hybrid	Fuel	FC Weight [kg]
Plane A	80	120	400	Y	NaBH4	0.6
Plane B	120	150	700	Y	NaBH4	0.78
Plane C	140	220	500	Y	NaBH4	1.2
Talon	250	300	1000	Y	NaBH4	2.5
Plane D	200	300	300	N	Hydrogen	1
Ion Tiger	300	500	500	N	Hydrogen	1
Next Gen	800	1500	2500	Y	H2 via JP8	1.5

UAV Product Development Status

- Hand, Tube, & Rail Launch
- Deep Stall Autoland
- MIL-810F Qualification
- Altitude: 15000 ft
- Temperature: -10 - 50 ºC
- Waterproof Designs
- Today: TRL 6-7
- One Year: TRL 7-8

Protonex™

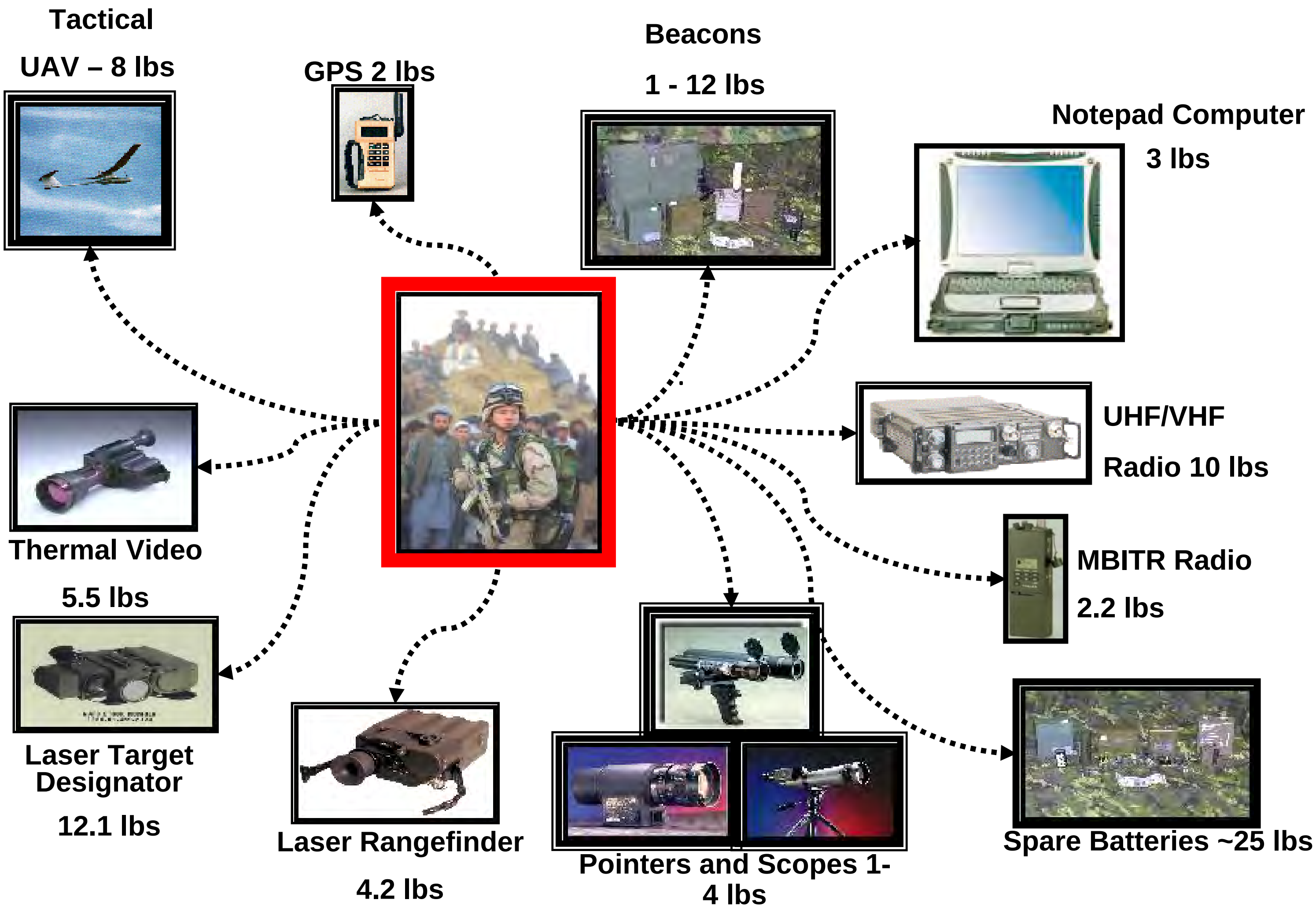
Agenda

- Company Overview
- Products and Technology
- **Power Managers**
- Alternative Energy Harvesting
- Questions

PROTONEX – The Next Generation of Portable Power…

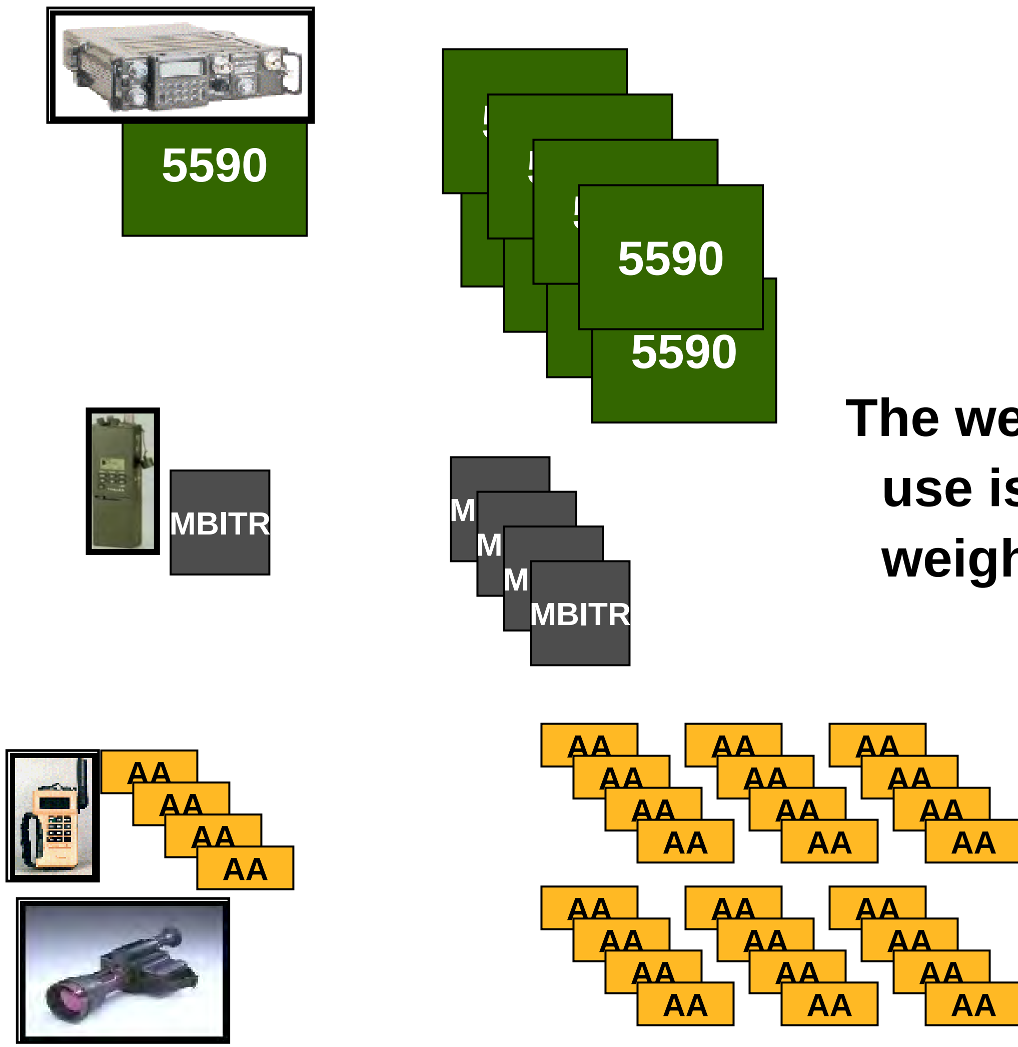
Why A Power Manager?

Today's Warfighter



All these devices use DIFFERENT batteries…

The Cost Of Battery Variety

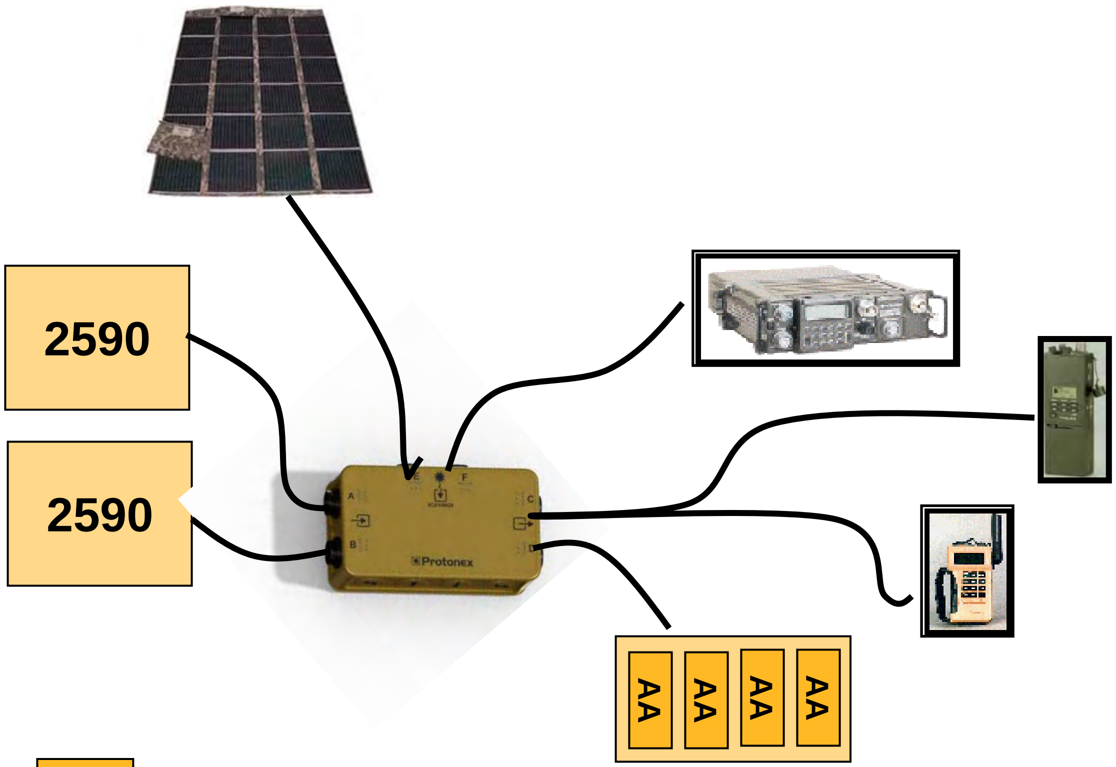


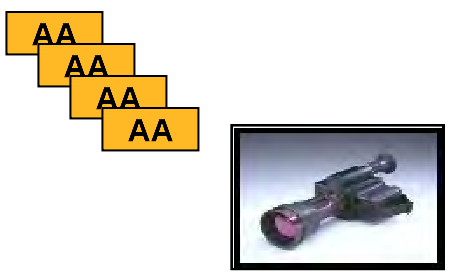
The weight of the batteries in use is dwarfed by the weight of the spares!!

So What Is A Power Manager?

- **A Power "Universalizer"**
  - Take energy from any military or commercial battery
  - Power virtually any combination of portable military equipment
- **A Universal Recharger**
  - Pull energy from solar, wind, fuel cell, garrison power
  - Harvest energy from primary batteries
  - Recharge virtually any military rechargeable battery
- **An Active Power Monitor**
  - Gives instant at-a-glance status to the whole power system
  - Warns of impending power failure
  - Can proactively power down non-critical gear

Same Gear…





Get rid of many spares…

Recharge locally….

A Little History

- **Air Force Research Labs – BRITES**
  – Fielded initial power manager concepts several years ago.
  – Very specific for Battlefield Air Operations (BAO) Kit.
  – Used with fuel cells and zinc-air batteries to reduce battery weight by 30-50%.

- **Army Research Office**
  – Recognized need for more general power managers.
  – Focus on warfighter simplicity – soldier not a power expert.

- **Natick Soldier Center**
  – Early parallel power manager development
  – Converging towards Soldier Power Manager

- **USMC Expeditionary Power**
  – Early evaluator of BRITES system applied to USMC Forward Air Controllers

Protonex Power Managers – BPM

- **BPM-602: Battlefield Airmen Power Manager**
  - Active power conversion and management for full BAO equipment suite, including laser designator (very high power)
  - Designed with AFRL / AFSOC / ARO
  - Positive field results at Ft. Dix, Hurlburt Field, and Ft. Polk
  - Deployed in Iraq and Afghanistan for non-BA missions.

- **Ongoing Activities:**
  - Invited by JRTC at Ft. Polk for testing at the Brigade level, followed by deployment.
  - Packaging of Portable Combat Outpost Power system (deployed in Iraq).
  - Weight / Cube reduction – Apply advances made in SPM development to the BPM platform.

Protonex Power Managers - SPM

- **SPM-611/612: Soldier Power Managers**
  - Smaller and lighter follow-on to the BPM
  - All battery conversion, recharge and management functions needed for a squad
  - Designed with PEO Soldier / ARO / CERDEC / USMC / AFRL / Natick

- **Summer 2009 Activities:**
  - Field trials at JRTC (Ft. Polk)
  - Field Trials at AEWE (Ft. Benning)
  - PM-SWAR Field Test

– **Enhancement Opportunities:**
  - Enhanced Squad Battery Chargers:
    - MBITR Battery
    - Multi-Bay BB-2557

SPM Details

- Six bidirectional power ports
- Three battery chargers / device converters
- Solar Peak Power Point Tracker
- System Intelligence – Zero Configuration
- Set n' Forget Charging
- Squad Charge
- Power Usage Management

Rechargeable Batteries: Need For A New Paradigm

- **Today's Concept**
  - Batteries are recharged in bulk at a "depot"
  - They are then used by soldier in the field
  - When mission is over, passed back to depot for recharge
- **Why It Doesn't Work**
  - Batteries are treated like bullets: small bulk commodity item
  - Model works well for disposable (primary) batteries
  - How many times would you want to reuse a bullet?
  - A matter of TRUST – just like with equipment
- **The New Paradigm**
  - Treat rechargable batteries like ***equipment***, not like ***supplies***
  - Soldier maintains his own equipment – builds TRUST
  - Moves battery charging from the depot to the squad and soldier

Agenda

- Company Overview
- Products and Technology
- Power Managers
- **Alternative Energy Harvesting**
- Questions

POWERED BY Protonex™

PROTONEX – The Next Generation of Portable Power…

Solar Power: Limits and Solutions

- **New Solar Panels: Lighter, More Robust, More Efficient**

- **Solar + Power Management: Flexible Power**

Solar + Fuel Cell: 24 x 7 Power

- **Active power management needed to minimize fuel usage and maximize availability.**
- **Efficient operation requires ballast battery system.**

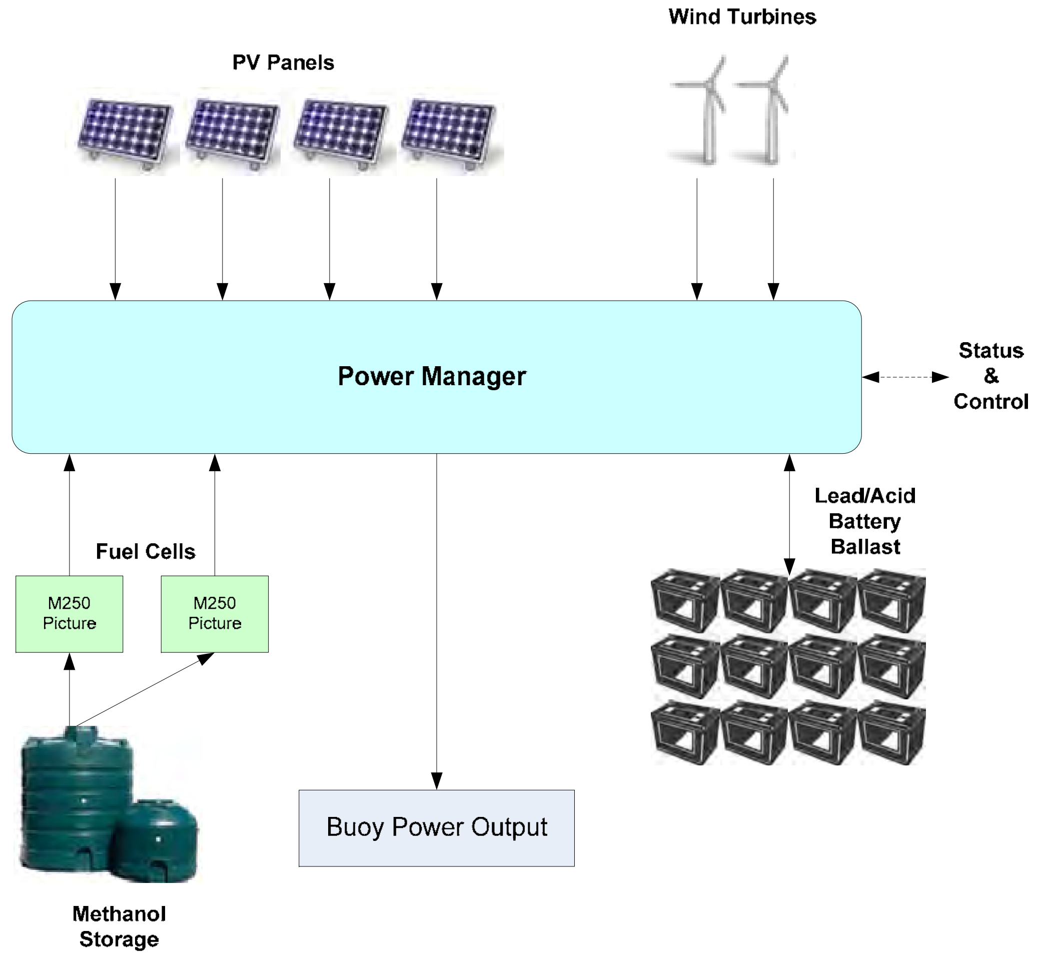
Afghanistan Deployment

- **UltraCell XX25, Global Solar and PowerFilm Panels, BPM-602**
  – Toughbook
  – PRD-13 SigInt Radio

  – Adding PRC-117F SatCom and PRC-4148 MBITR

- **Deployed late 2008 – Positive Feedback**

Alternative Energy Power Manager



Wrap-Up

- **Protonex is the Portable Power company**
  – Multiple fuel cell technologies and fuels
  – Full power management suite
  – Military and commercial battery charging

- **Power manager product line delivers:**
  – Less weight and bulk for the warfighter
  – More control and visibility
  – Significantly decreased logistics tail

- **Intelligent power management enables alternative energy use**
  – Enables combination of multiple energy sources – automatically
  – Applies this energy to many uses simultaneously

Protonex™

Questions?

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THE NEXT GENERATION OF PORTABLE POWER.™

Renewable Energy in Theater

On July 25, 2006, Al-Anbar commander and U.S. Marine Corps Maj. General Richard Zilmer submitted an MNF-W Priority 1 request for alternative energy solutions in theater.

The request focuses on the hazards inherent in American supply lines carrying fuel. Most of the fuel isn't even for vehicles…

…it's for diesel generators that provide power at U.S. bases.

Renewable Energy in Theater

Not as cost effective

Not a dependable resource

Difficult to deploy and set up

Too fragile for use in the field

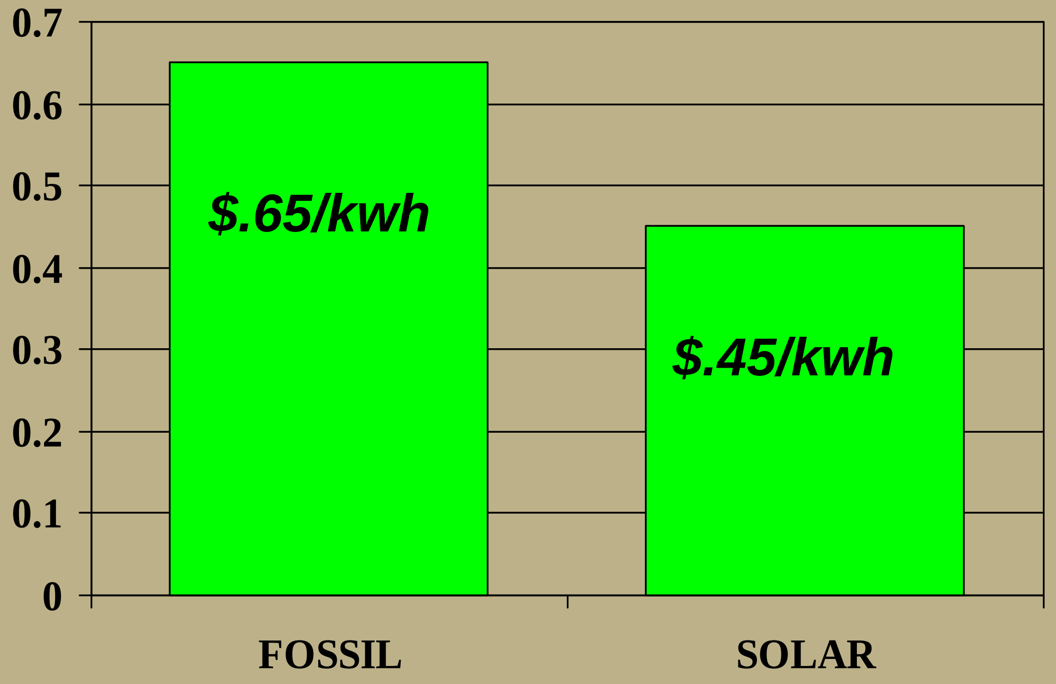
Not as transportable as gensets

?

Renewable Energy in Theater

Solar power isn't cost effective

Cost-per-kilowatt Comparison



Based on fuel cost of $5 per gallon-delivered
3-year payback period

Renewable Energy in Theater

Solar power generation is not dependable

Renewable Energy in Theater

Solar is complicated & difficult to set up

Renewable Energy in Theater

Solar is too fragile for use in theater

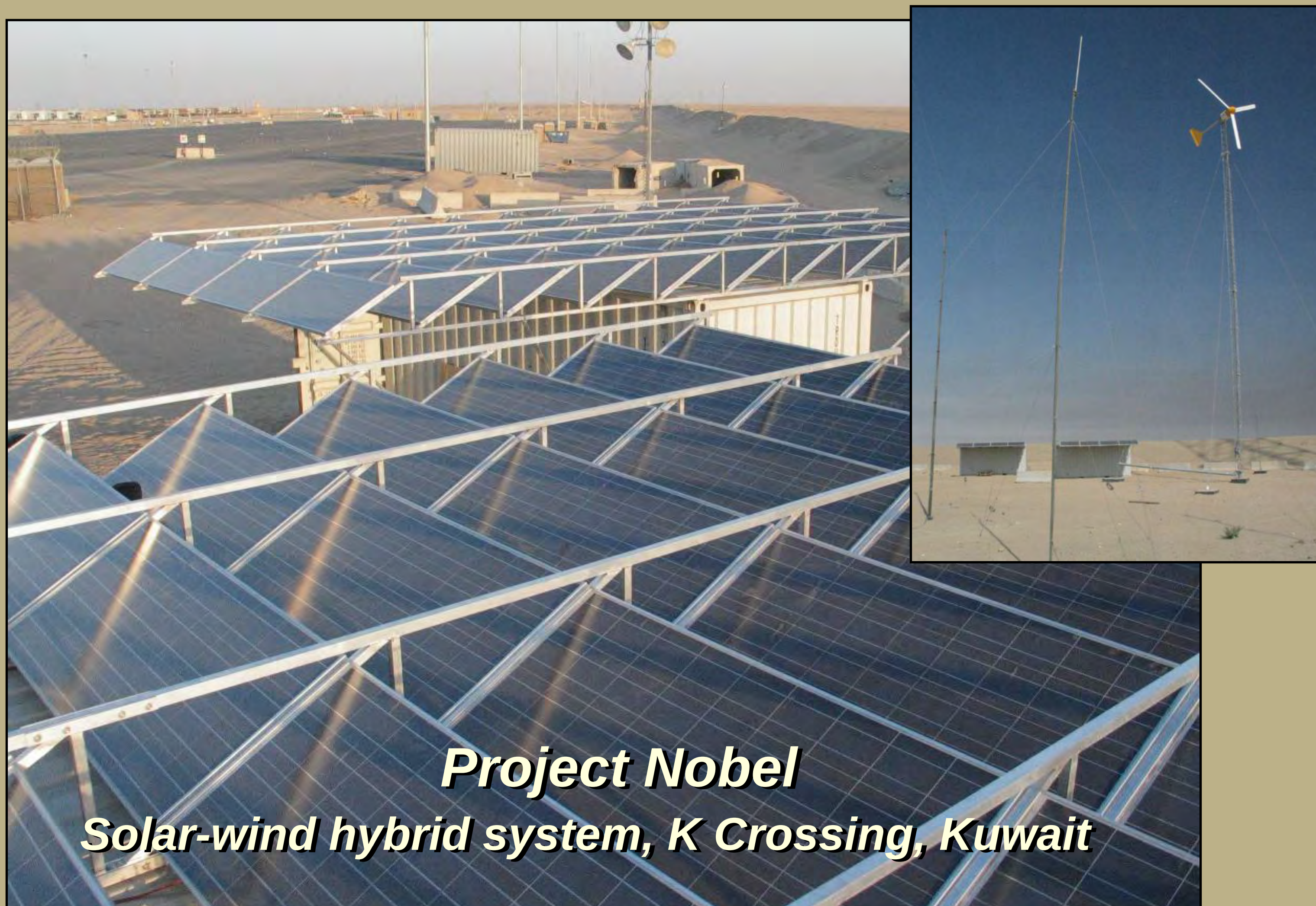
Fossil fueled generator	Solar
	

Renewable Energy in Theater

Renewable systems aren't very transportable

Handsome old dude

Renewable Energy in Theater



Project Nobel

Solar-wind hybrid system, K Crossing, Kuwait

Renewable Energy in Theater

Weather & environmental issues

Renewable Energy in Theater

Crowded installation site




Renewable Energy in Theater

Changing personnel on the ground

Renewable Energy in Theater

Spares not available at the corner hardware store

Renewable Energy in Theater

Was it Worth It?

Renewable Energy in Theater

How do we make solar solutions more portable?

Renewable Energy in Theater

Tactical, Solar-Powered Light Trailers

Renewable Energy in Theater

Cost Comparison

Diesel Light Trailer

Total Cost of Operation
3-Year Amortized Annual Average

Halide		Fluorescent
$5,924.10	Purchase price	$17,609.00
$4,927.50	Fuel cost, annual	$0.00
$648.00	Maintenance, annual	$648.00
$2,190.00	Genset replace / rebuild	$0.00
	Battery replacement	$746.67
$3,650.00	Annual operation	$0.00
$7.765.50	Total annual cost of operation	$1.394.67
$29,220.60	Total 3-Year Cost of Operation	$21,793.01

Solar Light Trailer

FUEL AT $2.50 A Gallon, Delivered

Renewable Energy in Theater

Cost Comparison

Diesel Light Trailer

Total Cost of Operation
3-Year Amortized Annual Average

Halide		Fluorescent
$5,924.10	Purchase price	$17,609.00
$19,710.00	Fuel cost, annual	$0.00
$648.00	Maintenance, annual	$648.00
$2,190.00	Genset replace / rebuild	$0.00
	Battery replacement	$746.67
$3,650.00	Annual operation	$0.00
$23.360.00	Total annual cost of operation	$1.394.67
$76,004.10	Total 3-Year Cost of Operation	$21,793.01

Solar Light Trailer

FUEL AT $10 A Gallon, Delivered

Renewable Energy in Theater

Cost Comparison

Diesel Light Trailer

Total Cost of Operation
3-Year Amortized Annual Average

Halide		Fluorescent
$5,924.10	Purchase price	$17,609.00
$39,420.00	Fuel cost, annual	$0.00
$648.00	Maintenance, annual	$648.00
$2,190.00	Genset replace / rebuild	$0.00
	Battery replacement	$746.67
$3,650.00	Annual operation	$0.00
$43,070.00	Total annual cost of operation	$1,394.67
$135,134.10	Total 3-Year Cost of Operation	$21,793.01

Solar Light Trailer

FUEL AT $20 A Gallon, Delivered

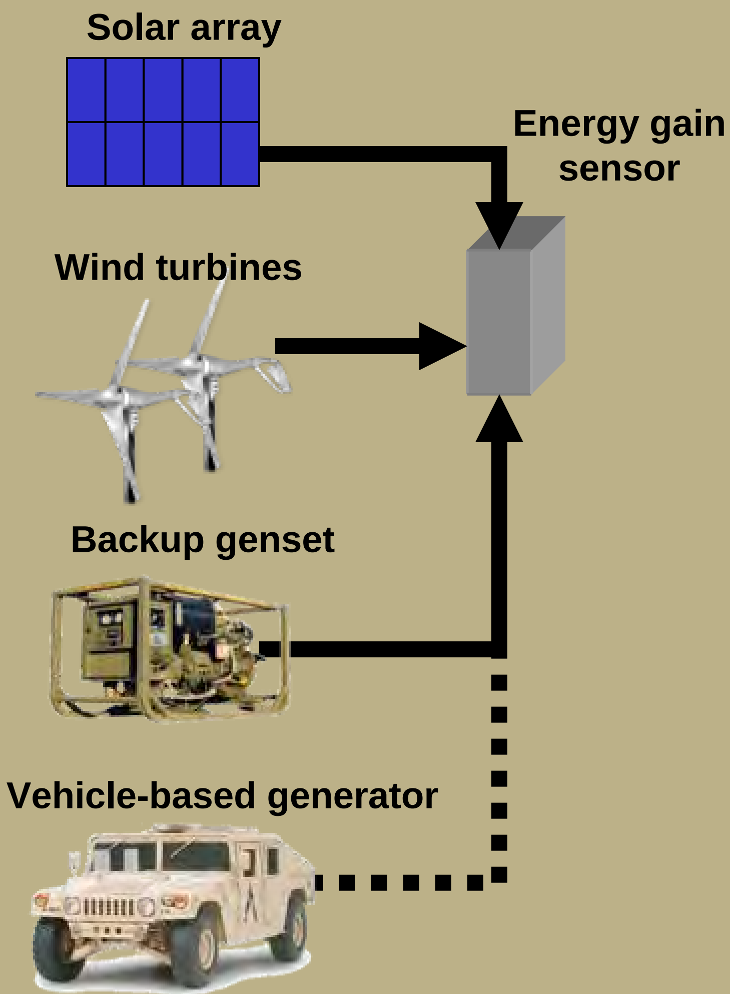
Renewable Energy in Theater

Tactical Hybrid Power Trailer

- Dual wind turbines
- Fold-out solar array
- On-board backup genset
- Battery pack and inverter
- Computerized energy monitor

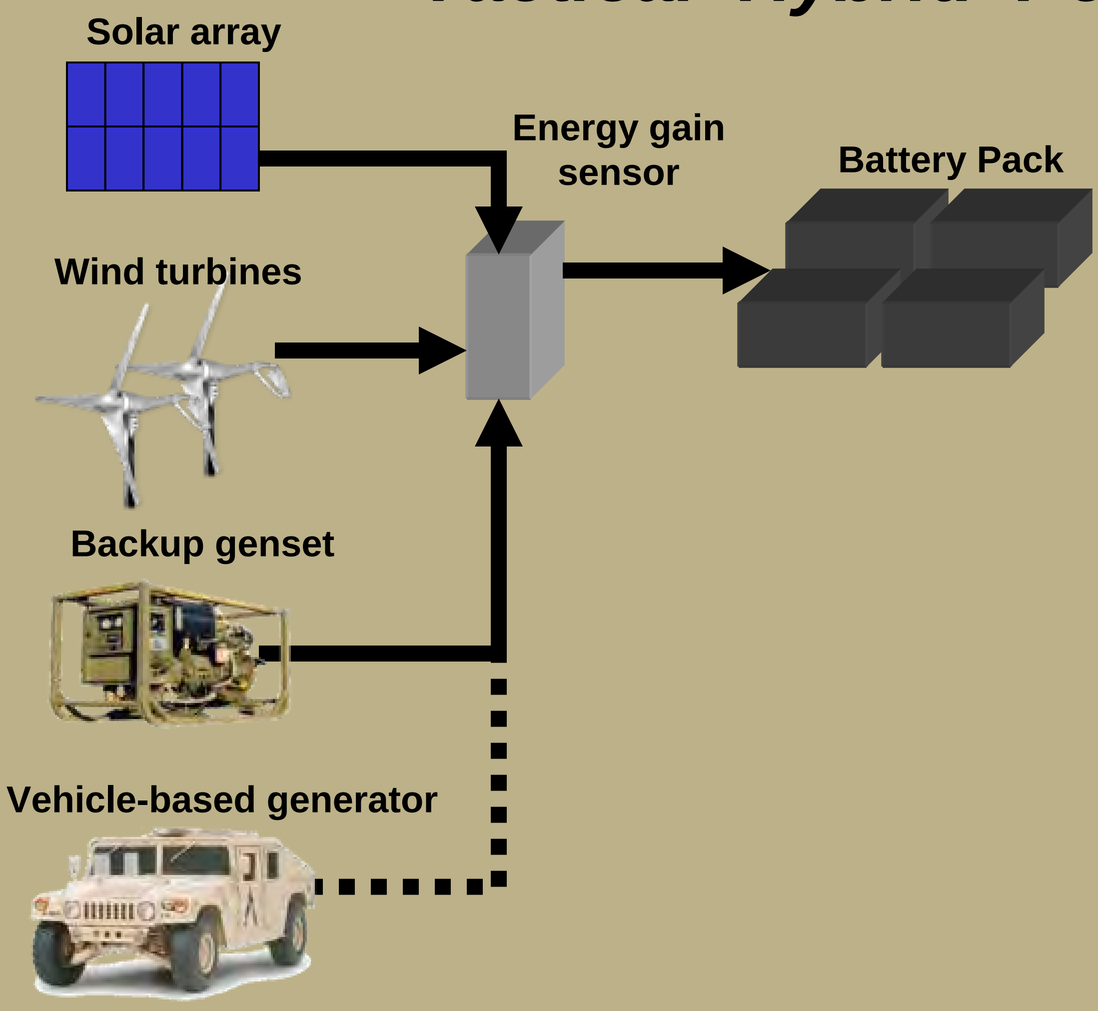
Renewable Energy in Theater

Tactical Hybrid Power Trailer



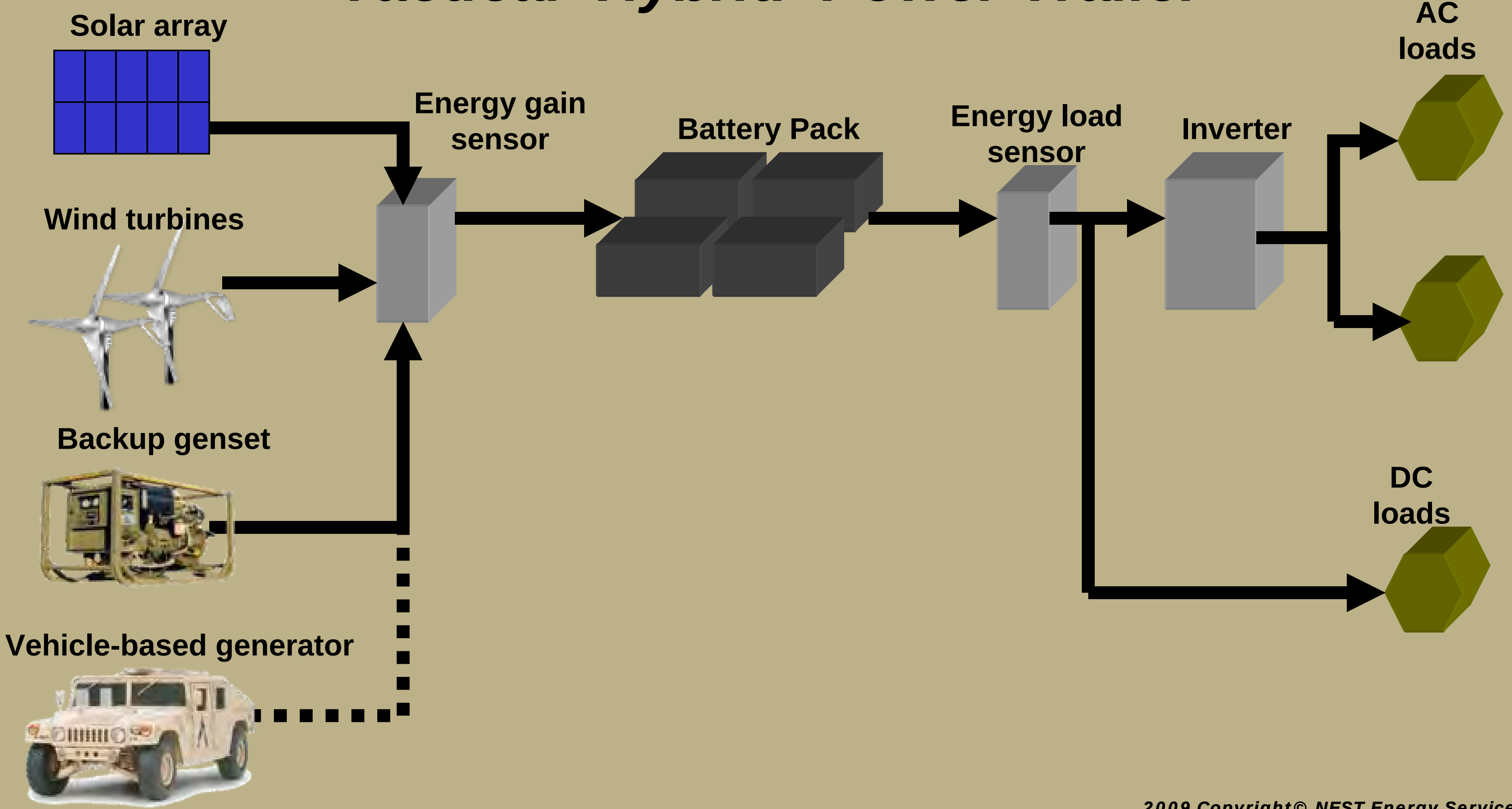
Renewable Energy in Theater

Tactical Hybrid Power Trailer



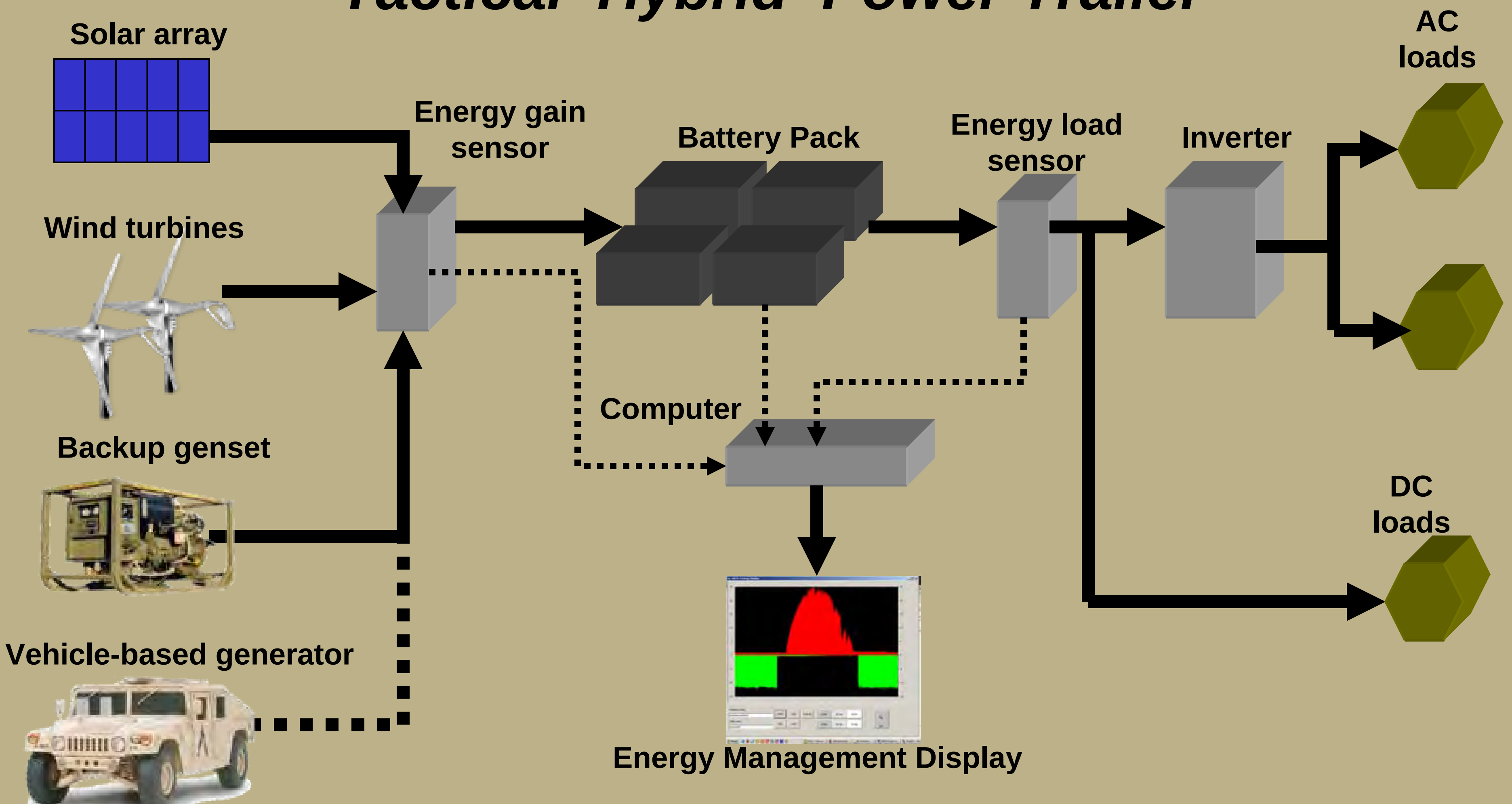
Renewable Energy in Theater

Tactical Hybrid Power Trailer



Renewable Energy in Theater

Tactical Hybrid Power Trailer



Renewable Energy in Theater

NEST Energy Services LLC

NEST ENERGY SERVICES


The Solinator®


Solar –powered Light Trailer


Condor Solar Station


Raptor Surveillance


Eagle Solar Station


Prescott Valley, AZ

GSA Advantage!
www.gsaAdvantage.gov
Contract GS-07F-9584S

DOD EMALL
www.emall.dla.mil

Toll-free: 877-640-4701

www.nestenergyservices.com

System Considerations when Integrating New Battery Technologies into the XM1124 Hybrid Electric HMMWV

Mike Marcel, Ph.D., Terry Stifflemire and Brent Brzezinski, Ph.D.

DRS Test and Energy Management

Joint Power Expo, May 2009

DRS TECHNOLOGIES

XM 1124 Overview

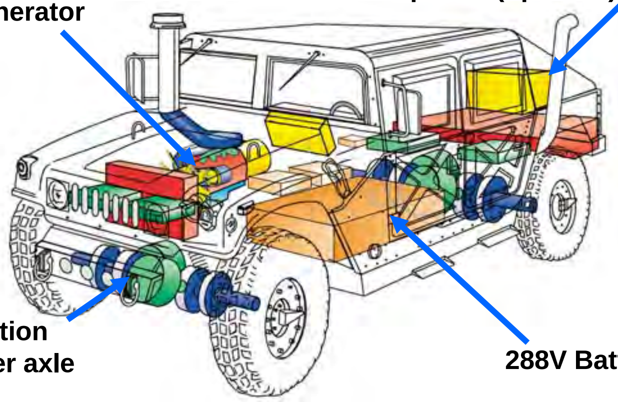
DRS TECHNOLOGIES

Description

- Replaces the conventional HMMWV drive train with a hybrid drive train while retaining the capabilities of the standard HMMWV
- Quiet, mobile platform for silent watch, reconnaissance missions
- Reduced thermal and acoustic signatures
- Power generation capability

Key Requirements

- ***Provide 33 kW of continuous power***
- ***C130 Transportability***
- Silent Mobility
- Silent Watch
- Multi-phase mobile power (AC/DC)
- Maintain HMMWV capabilities; mobility, transportability, and payload.
- Two level maintenance
- Open Architecture for upgrades



Integrated Battery Technologies

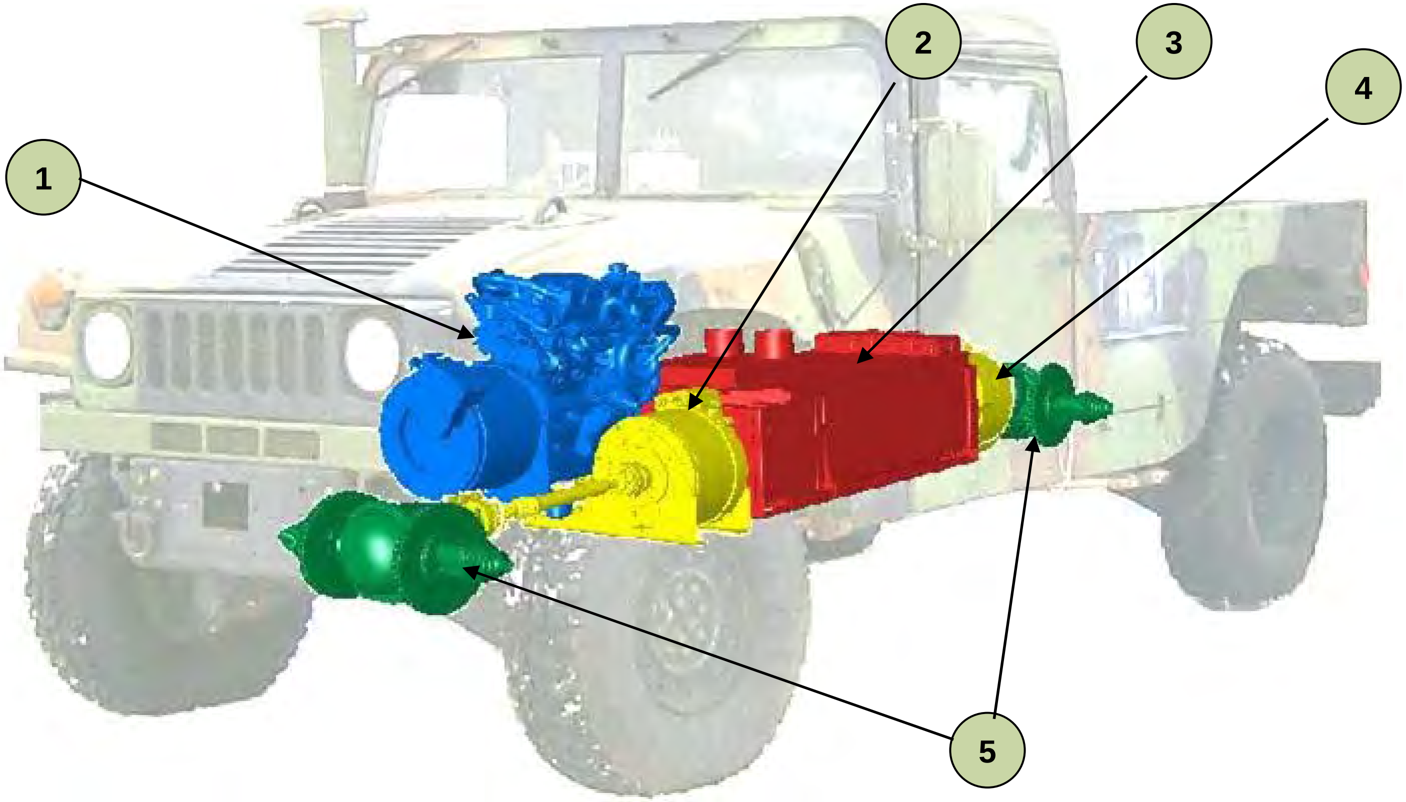
- Lead Acid (Optima Yellow Top)
- Lithium Ion
- Lithium Iron Phosphate

Considered Future Upgrades

- Integration of Hard Carbon and Lithium Titanium Oxide battery pack
- Upgraded traction motors
- Upgraded motor drives utilizing Silicon Carbide technology

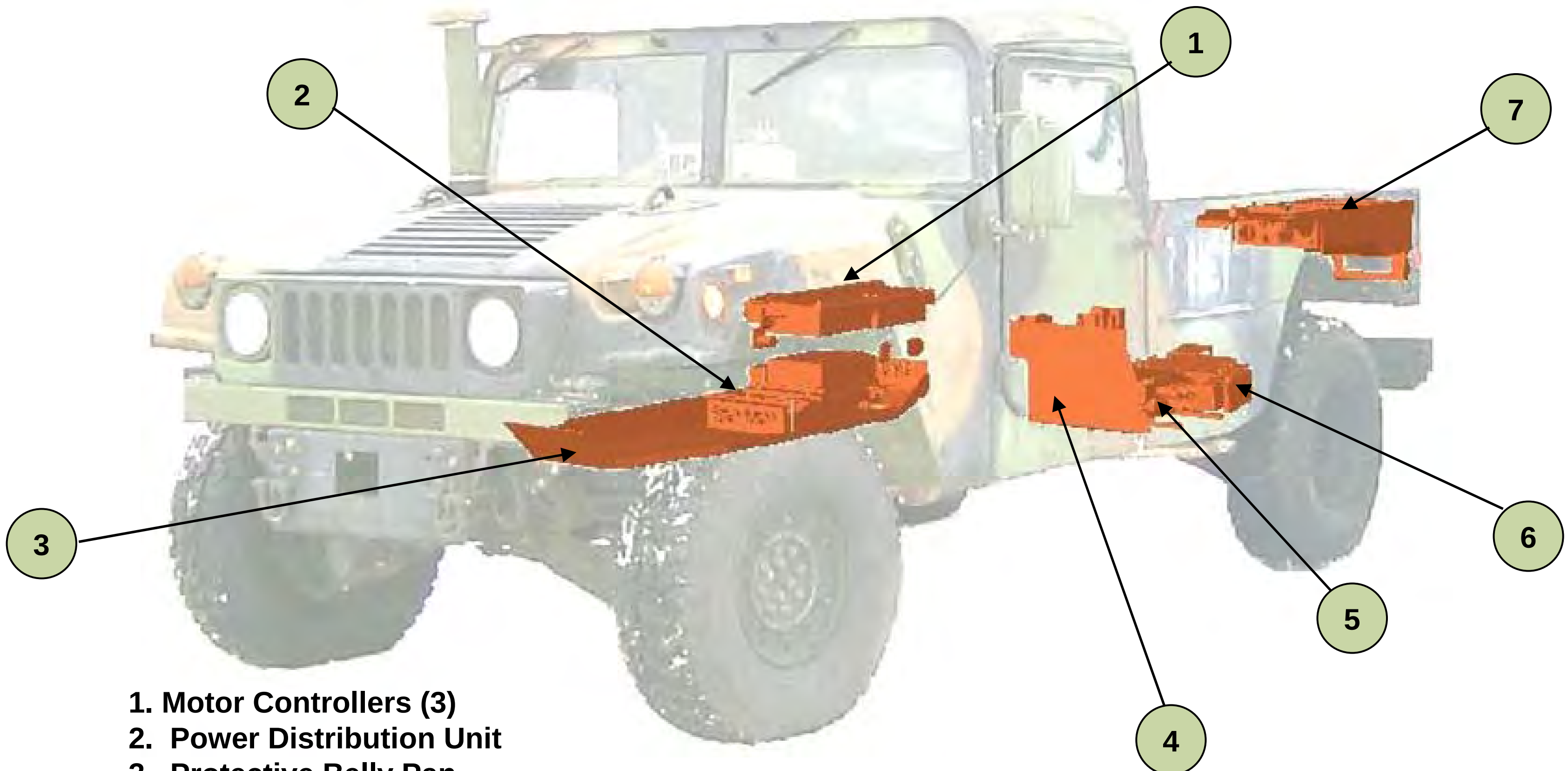
Hybrid Electric HMMWV XM1124

XM1124 and HE-DRIVE Components



1. Engine and Generator
2. Front Traction Motor
3. Battery Pack
4. Rear Traction Motor
5. Modified HMMWV Differentials

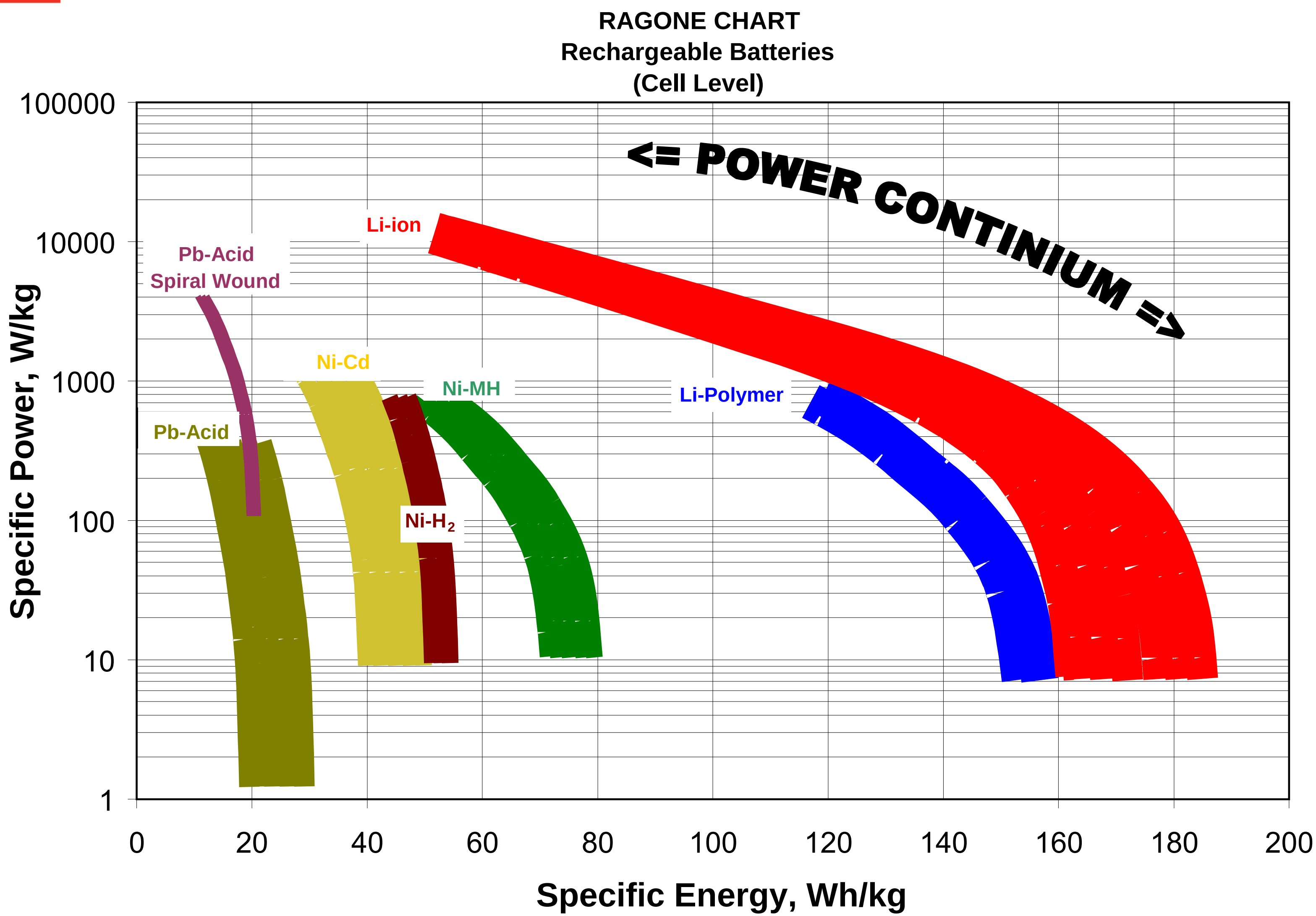
XM1124 and HE-DRIVE Electronics



1. Motor Controllers (3)
2. Power Distribution Unit
3. Protective Belly Pan
4. System Control Unit
5. Battery Control Unit
6. Auxiliary Power Converter
7. Auxiliary Power Distribution System (Option)

Battery Comparison

A trade-off between power and energy



HE HMMWV Configuration Flexibility
Pick-a-Power and Payload Capacity

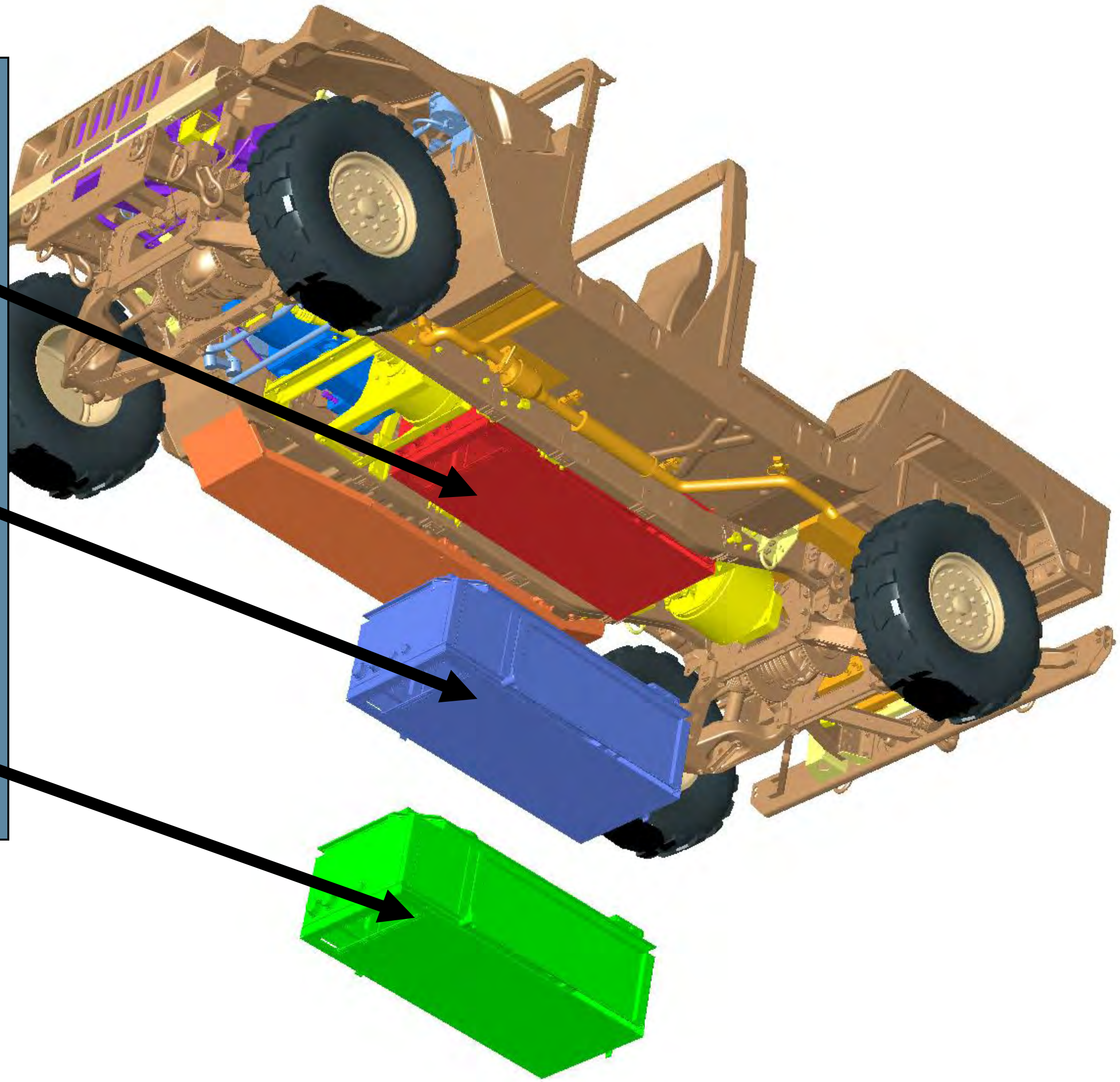
DRS TECHNOLOGIES

Plug 'n Play Battery Packs

Mobility Pack (Pb Acid)
Export Power: 125 kW Peak (6 min)
75 kW Continuous
Silent: 15 kW (18 Minutes)

Mid-Energy Pack (LiFePh04)
Export Power: 175 kW Peak (6 min)
75 kW Continuous
Total energy Storage: 4.8kW

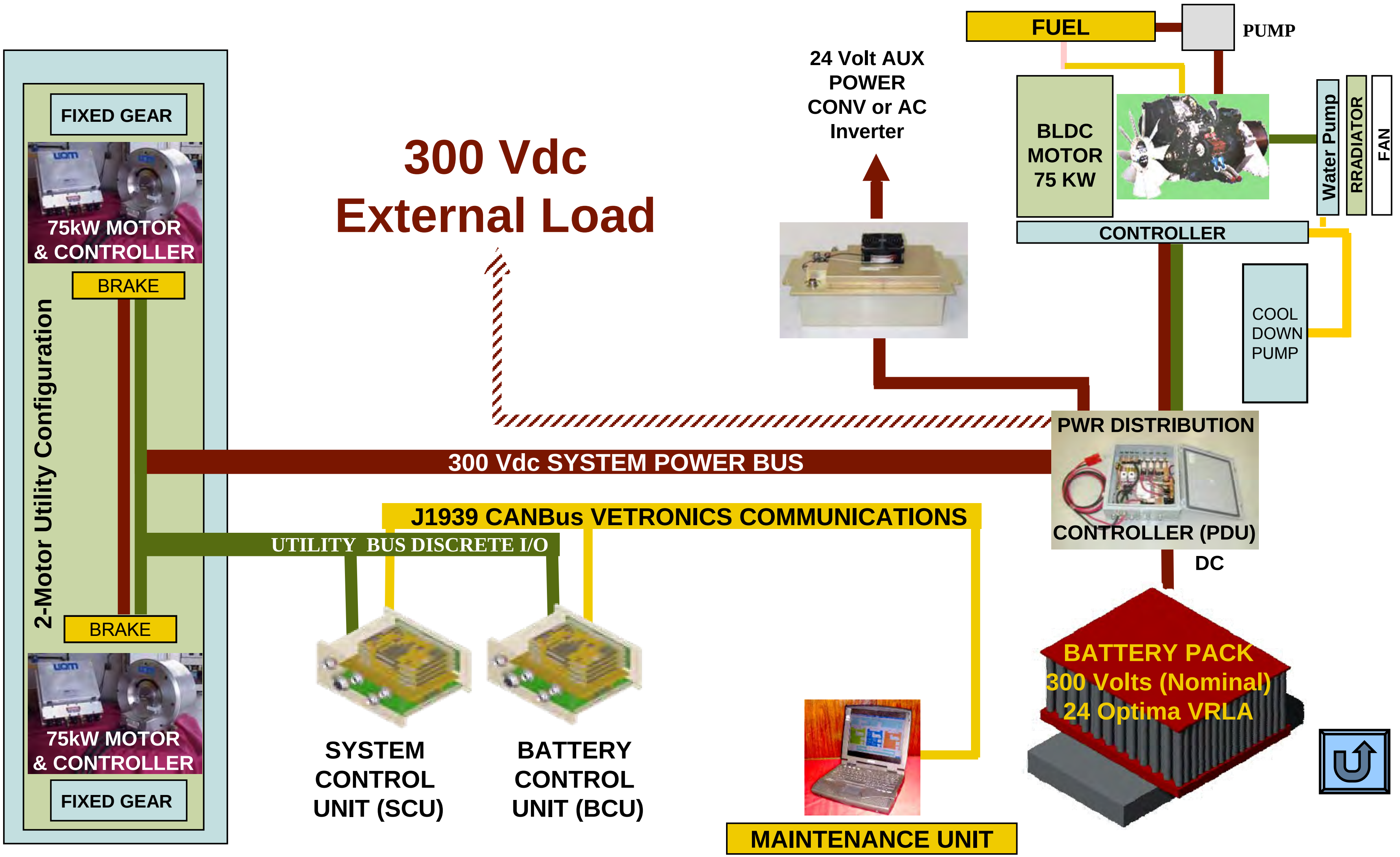
High-Energy Pack (Li Ion)
Export Power: 225 kW Peak (6 min)
75 kW Continuous
Silent: 15 kW (1.1 Hour)



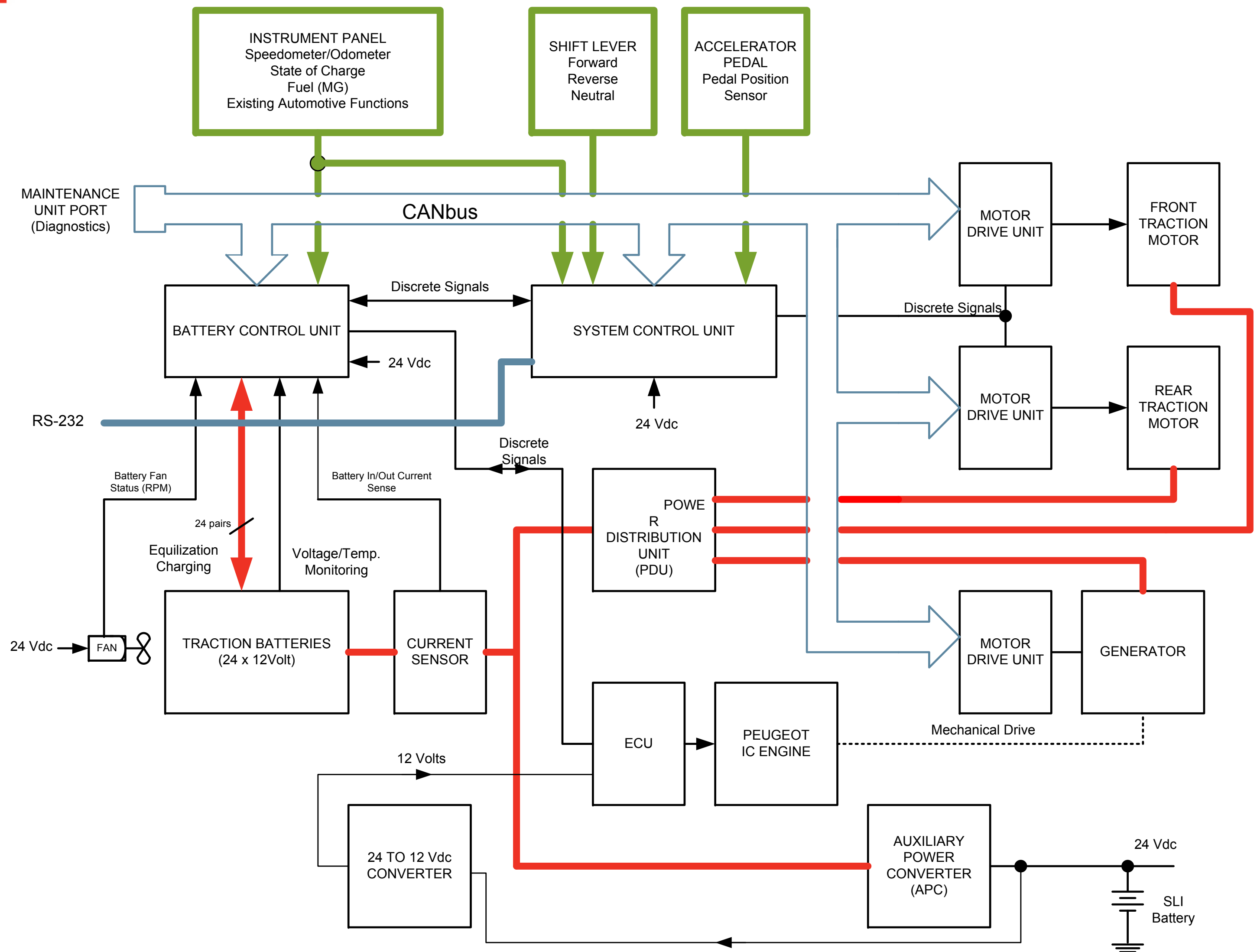
Note: Payload capacity already includes:

- **Soldier Load and BII (580lbs)**

XM1124 System Block Diagram



Control Topology



Hardware Modifications

- Thermocouples/RTDs
  - Sometimes part of BMS
  - Location is EXTRMELY important

- System Controller
  - If multiple batteries/modules
  - Monitors all of the module/battery information and reports highs/lows and faults to Battery Control Unit (BCU)
  - Is used to compute SOC and other critical battery status
- Interface Hardware
  - Connectors
  - Cabling
  - Need to be compatible (to include type and pinout) with existing vehicle hardware
- Grounding
  - Need to ensure any added harware is properly grounded for safety and noise
  - Pack needs to be connected to chassis ground with a resonable impedance to prevent touch voltages

Software Modifications

- Communication
  - Need to ensure added hardware can communicate to the system controller (typically vis CAN messages)
  - A complete ICD needs to be provided with pack hardware
  - Essential data from CAN message needs to be identified along with “don’t care’s” from existing battery pack
  - What happens when communication is lost?
- SOC calculation/Battery Management
  - Need to ensure the battery pack’s SOC is calculated correctly and reported to the Battery Control unit (BCU)
  - Methods need to ensure temperature compensation
  - SOC calculation for various chemistries can be tricky
    - Lead acid has a “predictable” V-I curve
    - Lithium Ion has a very “flat” V-I curve
- Maintenance Unit
  - Needs to monitor new hardware if added (such as Thermocouples)
  - Modify the user’s GUI to reflect any new hardware or features added

Algorithm Modifications

- Safety
  - The possibility of cooling with 120F ambient air creates a challenge for each energy storage unit
  - Protection during fault; how many times does the system retry
  - What to do if pack exceeds temperature, voltage, current, etc.
- Pack Specific Operating points
  - Maintain the pack in a SOC window (Ensure you account for regenerative systems)
  - Need to incorporate limits (current, voltage, temperature) based on the safe operating parameters of the battery pack
- Timing
  - How often is data being sent
  - Is there too much chatter on CAN line
  - Need to ensure delays are inserted where they need to be (startup, controlled shutdown, etc.)
- Faults
  - What do you do in case of a fault
  - Controller shutdown vs. Emergency shutdown
  - Who controls the Master Relay

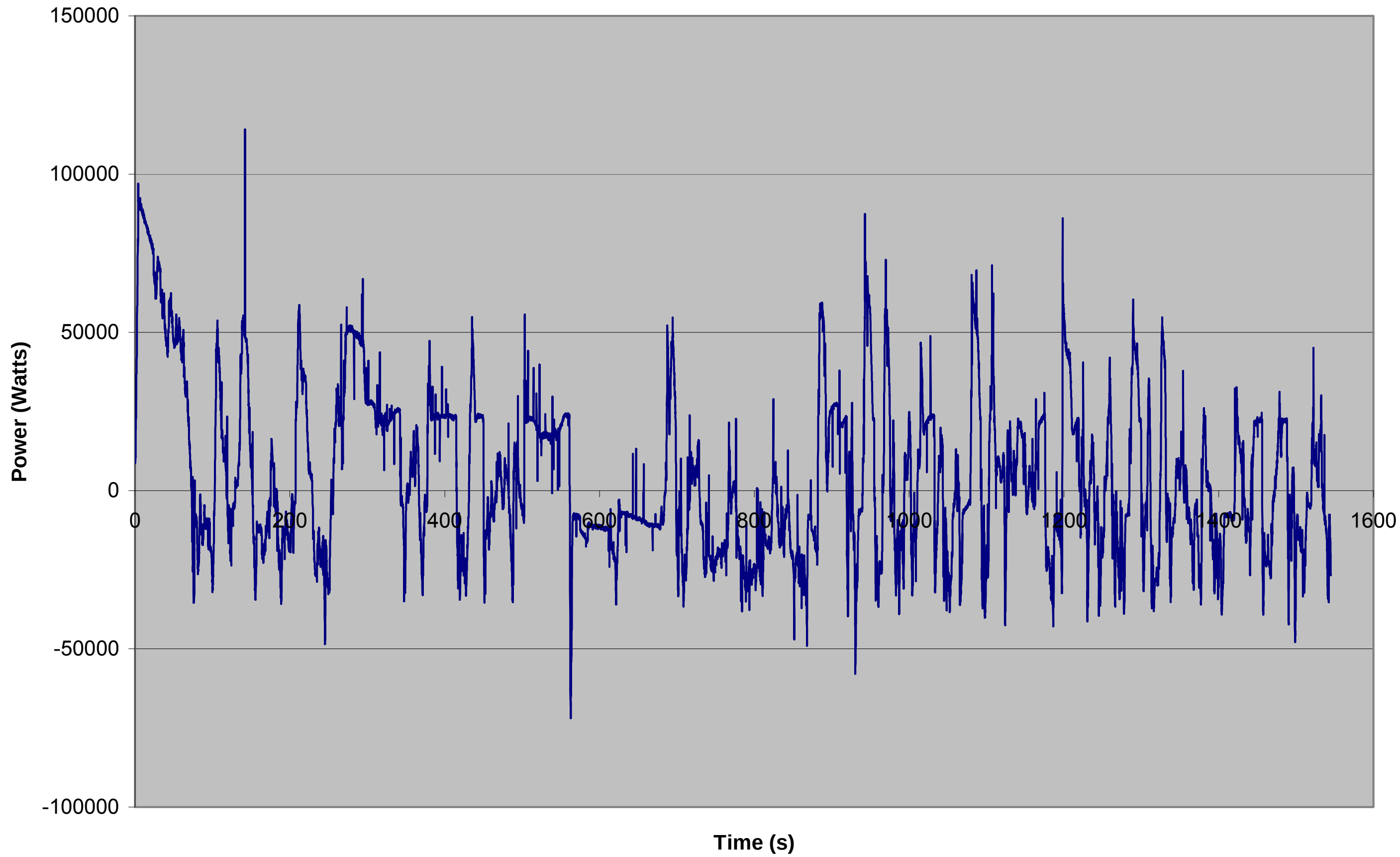
Verification – Bench Testing

- HAVE A TEST PLAN!!!!
  - A standard test plan needs to be used to do “apples to apples” comparison of battery technologies
- Objective of bench testing is to determine if pack is safe to integrate to vehicle
- Can also validate safe operating conditions from data sheet of pack
- Reference Performance Test
  - Performed between each major test
  - Shows any degradation of the pack
- Discharge/Charge Test
  - Essential to monitor temperature rise
  - Perform at various levels up to the levels the pack will see in the vehicle
- Cycle/Pulse Testing
  - Much like the pack will see when integrated to the vehicle

ABC-150 Power Processing System

Verification – Bench Testing

- Subject the pack to typical operating conditions
  - Known charge/discharge profiles



Power profile of XM1124 Navigating Hartford Loop at APG

Verification – Vehicle Testing

- Pack will be integrated once successful bench test is complete
- Lessons learned during bench test can be applied to pack prior to integration
  - Verification of SOC values
  - Verification of Temperature sensing
  - CAN communication and adequate control and protection

- Functional Test
  - Usually a “drive slowly around the parking lot” test
  - Ensure all systems are functioning properly and safely
- Acceleration Test
  - Determine how well the pack allows the vehicle to accelerate over a known distance
  - Perform at various battery SOC levels and compare
- Road Test
  - Include various terrain (hardball vs. dirt) and slopes (flat vs. hilly)
  - Finalize with an “extended” test that will simulate driving conditions in the field (at least two hours)
    - Monitor Temperature <u>CAREFULLY!</u>

Conclusion

- Safety is extremely important when integrating new battery technologies
- Hardware/Software/Algorithms need to be considered to accommodate the new technology
- Bench testing needs to be performed prior to integration to the vehicle to ensure safety during vehicle operation
- Upon integration on vehicle, sufficient testing using realistic scenarios/conditions needs to be performed
- Having a detailed, consistent test plan will allow for comparison between technologies
- The best measure of performance comes from the person sitting in the driver's seat!

Acknowledgements/Contact

DRS-TEM would like to thank TARDEC for their continued support in the XM1124 program!

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DRS TECHNOLOGIES
A Finmeccanica Company

TARDEC

8393 ~ by Edward J. O'Rourke

StarPower Technology – Solar Charging, Power Management and Distribution

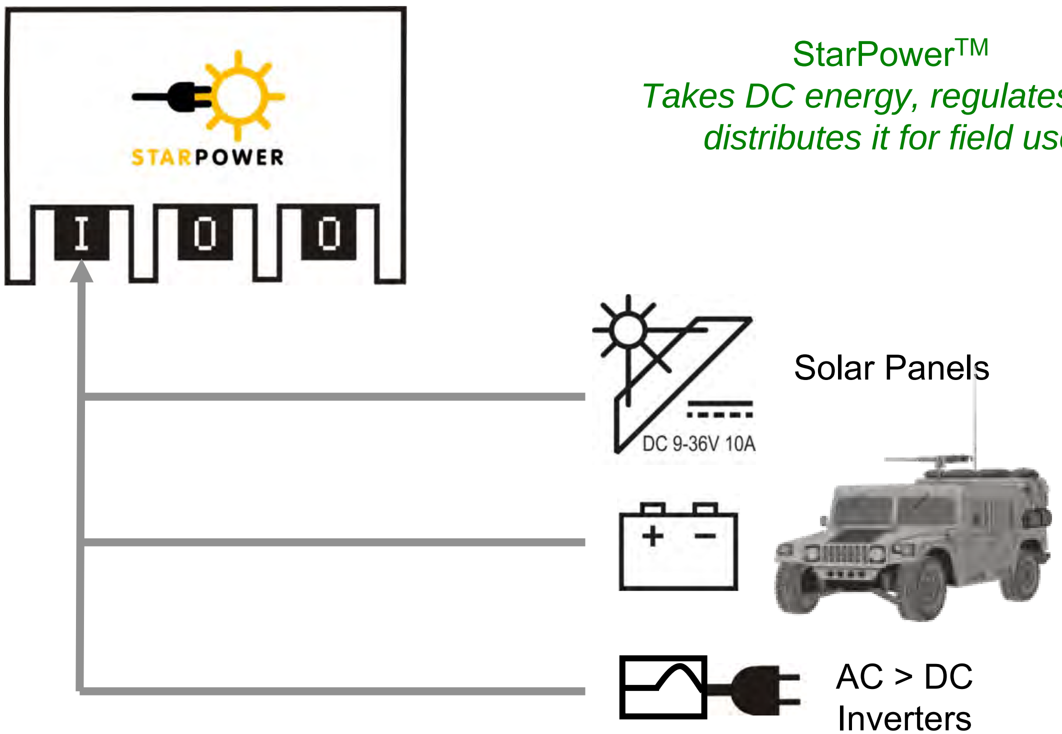
Abstract

- The Iris Technology StarPower system, in development for more than three years, was recently selected by the Marine Corps to fulfill the comprehensive objectives of their Solar Portable Alternative Communications Energy System (SPACES) / Multifunction Solar Device (MSD) program. Iris is now in production of this equipment suite with product available now.
- We discuss the basic architecture and capabilities of this equipment and the growth options it will afford users for years to come. Based completely on our proprietary software platform, the StarPower is currently able to address any rechargeable battery chemistry, now and in the anticipated future. Natively, it powers all 12/24V tactical radios. StarPower can receive any DC input source (9-36 VDC), charge multichemistry batteries, and/or power any loads (12-32 VDC).
- Iris will detail StarPower benefits including Growth Potential, Flexibility, Interoperability, Javelin Compatibility, BA-5590/U Scavenging, Lightweight, Ease of Use, Safety, and Product Quality.

Equipment Suite

Basic Inputs

StarPower™
Takes DC energy, regulates and distributes it for field use

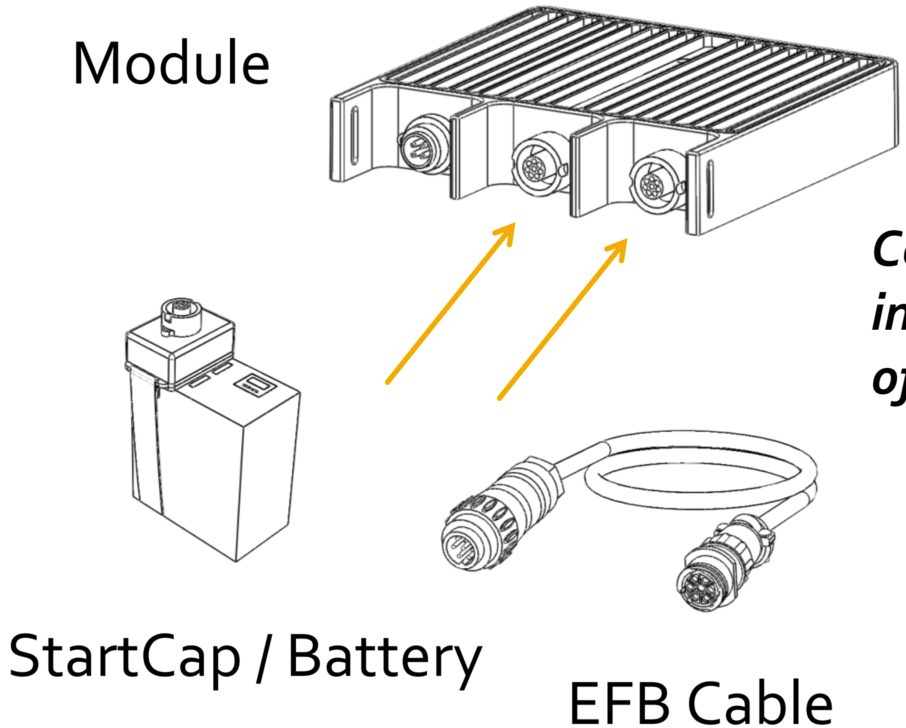


Solar Panels

Vehicle Batteries

AC > DC Inverters

Basic Outputs



Compatibility with EFB provides interoperability with wide variety of adapters in the DLA system.

EFBA Compatibility

EFBA Device Compatibility List

This is list of the devices compatible with the StarPower^{TM} Unit. This list is not comprehensive; the unit is compatible with any EFBA connector device that accepts 12V / 24VDC power.

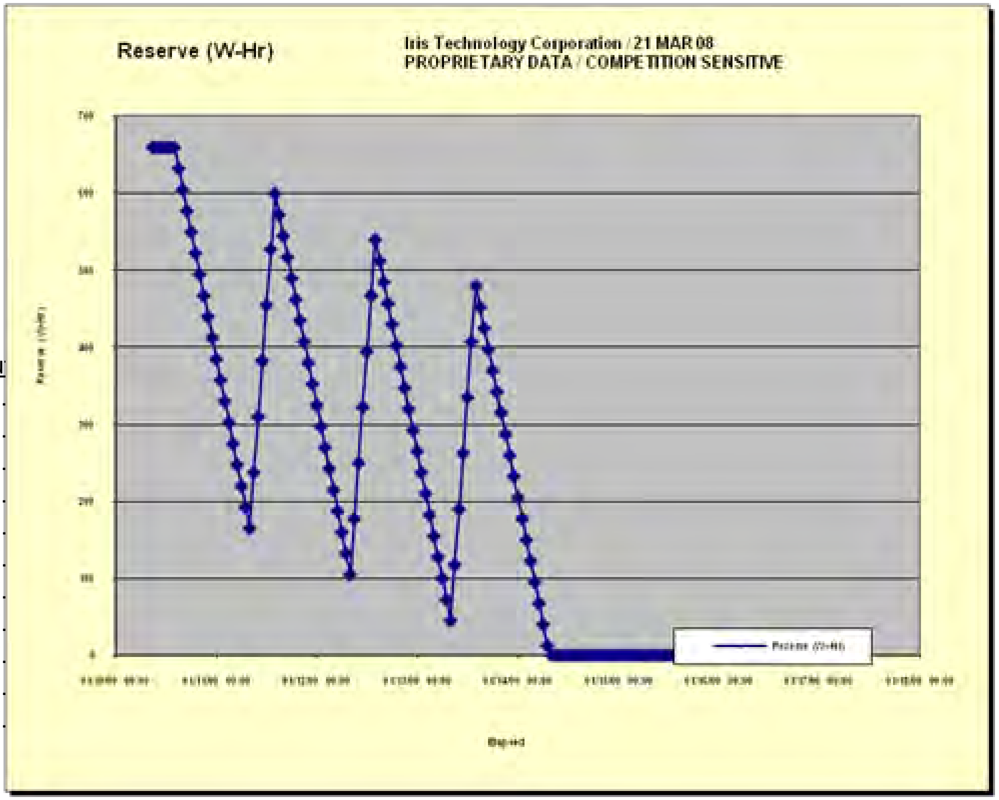
AN/PSC-5	**5940-01-516-9787**
AN/PRC-113	**5940-01-516-9787**
AN/PRC-117	**5940-01-516-9787**
AN/PRC-119F	**5940-01-504-3218**
AN/PRC-119 A/B/C/D	**5940-01-504-5597**
AN/PRC-148	**5940-01-517-3390**
AN/PRC-150	**5940-01-516-9787**

Mission Planning Tool

Iris Technology Corporation / 21 MAR 08
PROPRIETARY DATA / COMPETITION SENSITIVE

Input Power	100	W
Output Power	27.5	W
Energy Reserve	660	W-Hr
System Class	*Nonsustaining*	
Test Start Time	01/10/00 09:00	
Test End Time	01/14/00 07:00	
Test Run Time	94	Hr

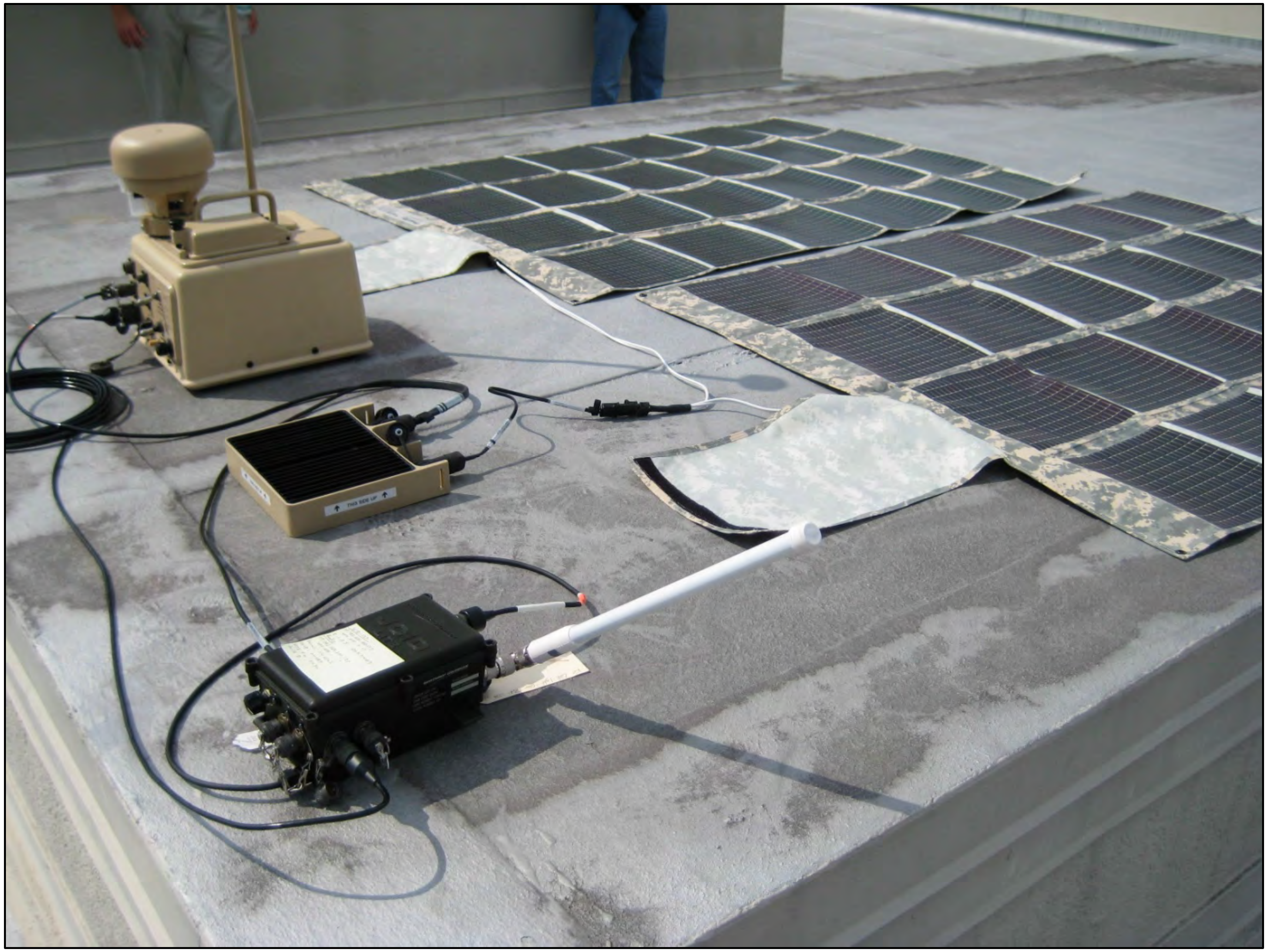
Time Starting	Input (W)	Outpu
01/10/00 09:00	100.0	27.
01/10/00 10:00	100.0	27.
01/10/00 11:00	100.0	27.
01/10/00 12:00	100.0	27.
01/10/00 13:00	100.0	27.
01/10/00 14:00	100.0	27.
01/10/00 15:00	0.0	27.
01/10/00 16:00	0.0	27.
01/10/00 17:00	0.0	27.
01/10/00 18:00	0.0	27.
01/10/00 19:00	0.0	27.



Kestrel ~ AN/PRC-117G

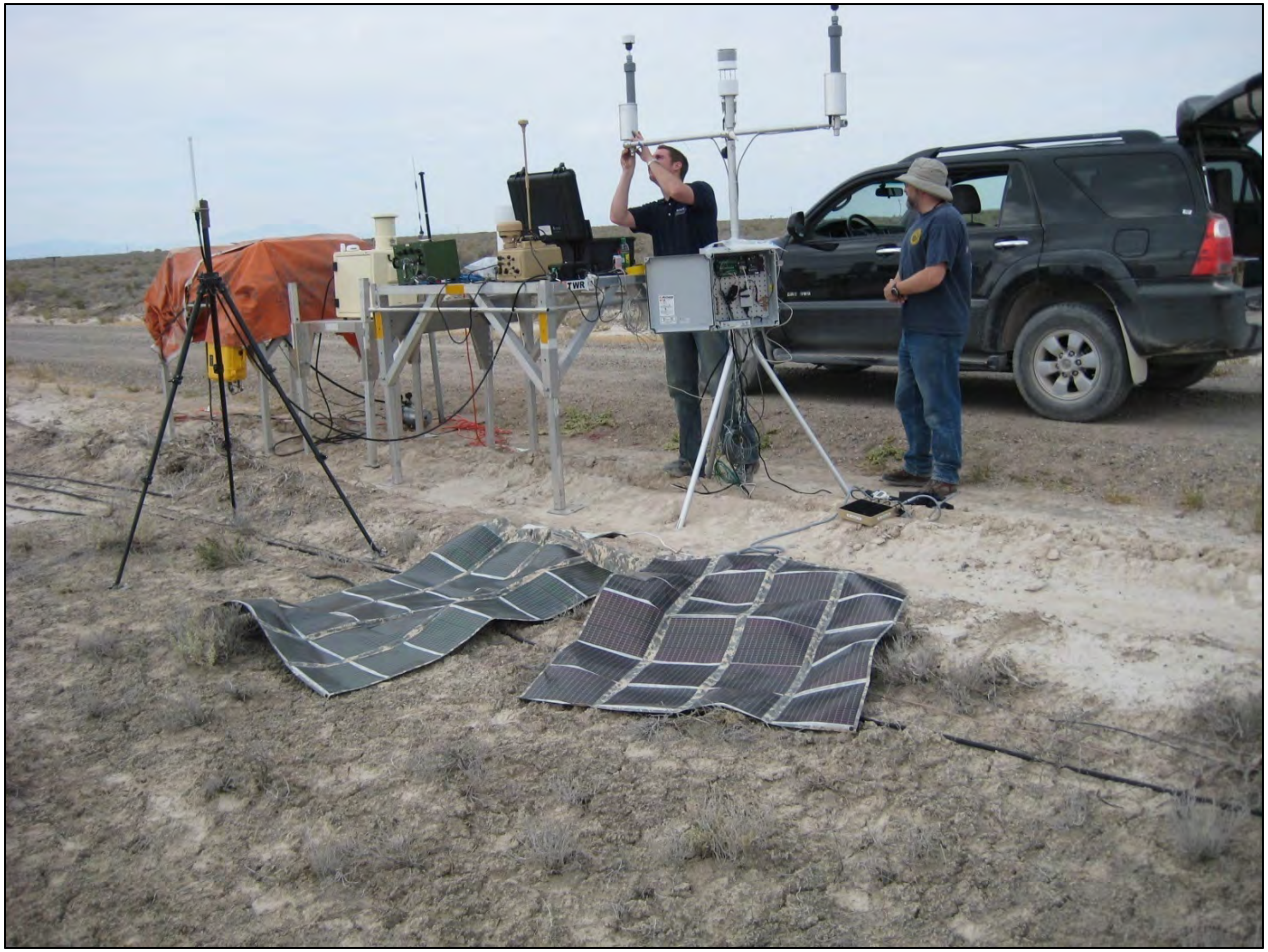
Interoperable with Iris Technology Kestrel Adapter for the AN/PRC-117G

JBTDS ~ JCID / IBAC



Remote Site Testing

STARPOWER



Why StarPower (1)

Growth	We're ready when you are. Able to be easily reprogrammed (and without disassembly) through the external connectors, the StarPower module can adapt to future energy storage devices and a multitude of powered accessories unknown today.
Flexible	The StarPower platform powers a variety of DC appliances using our SmartCable technology. Each cable is preprogrammed to request the voltage and current required for any load in the range of 8 – 32 VDC (up to 100W per channel).
Interoperable	The StarPower has been demonstrated with the JBTDS hardware suite and supports multiple DoD and agency missions.
12V COTS	A multitude of 12 VDC appliances can be used safely in native mode including automotive DC/AC inverters to support comfort and convenience items such as cell phone chargers and iPods™.

Why StarPower (2)

Scalability	StarPower systems can be connected into very large arrays to deliver multiple kW of usable power.
Javelin	Because input and output circuits are separate, StarPower can output regulated voltages above or below the battery voltage. This means that Javelin operators can power their weapon system from BB-2590/U using StarPower (BB-390/U will no longer be required).
Converter	Beyond charging batteries, the StarPower system delivers four (4) independently programmable DC outputs from any suitable input supply. This can mean either powering multiple radios from a HMMWV or executing a low power daylight operation directly from a solar blanket. In either case, batteries are not required.
BA-5590/U	Safe for use with all non-rechargeables, StarPower can efficiently and safely scavenge power from BA-5590/U, BA-5390/U, BA-8140/U, and BA-8180/U as well as a multitude of lead acid batteries.

Why StarPower (3)

Lightweight	The lightweight StarPower 400 module can deliver a remarkable 400W at a footprint of only 2.4 lb for a power density of 166 W/lb.
Ease of Use	StarPower was developed with the End User in mind. This technology is inherently plug-and-play with respect to all input and output cables and accessories.
Safety	StarPower automatically identifies battery chemistry and adapts its charging algorithm based upon battery voltages, thermistor (temperature) data, and charge enable pins. No User training or intervention is required. In addition to these important software safety algorithms, StarPower includes at least eight (8) internal hardware protection mechanisms
Quality	Iris manufactures all products on ISO 9000 manufacturing lines to deliver the highest performance to our service men and women.

Questions

- Equipment on display in Booth 314

A Mobile Hybrid Power Source with Intelligent Control

Rick Silva
CME

Joint Service Power Expo
7May09

Overview

DREAM

DREAM Revisited

A HI-Power DREAM

Summary

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Deployable & Renewable Energy Alternative Module

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- 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.

Requirements

Mechanical

- DREAM had to be HMMWV towable
- The Light Tactical Trailer, Heavy Chassis (LTT-HC) had to be used
  - Can't support the full HMMWV towable load
  - An additional structure such as the Marine Corp Chassis (MCC) is required to support the full load
- Must meet all environmental specifications

Energy Options

Usable Technologies

- Solar (mentioned)
- PM-MEP Genset (mentioned)

Not So Usable Technologies

- Wind – A niche solution for certain locations
- Biomass – Not in an austere environment
- Hydro

Phase I

CME was awarded a Phase I contract

- Phase I started on May 10, 2007

Two other awards

- AeroVironment
- Skybuilt

Phase I completed Aug 7, 2007

- By simulation, no one met the load for all cities

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
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DREAM Modeling

Best HOMER Results

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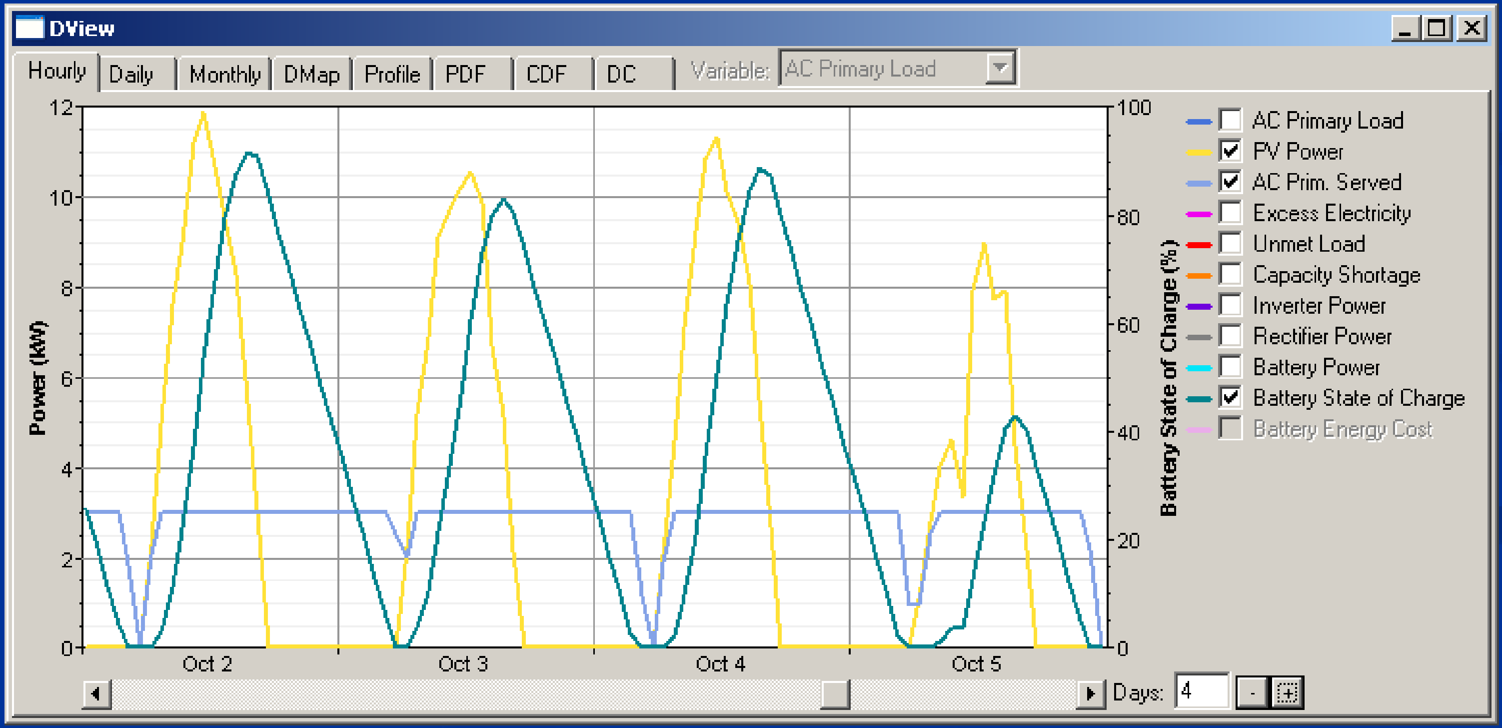
- Downtime was 3 hours



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- With two trailers connected together, Baghdad load could be met 91.7% of the time.

Phase II

CME was awarded a Phase II contract

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One other awards

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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

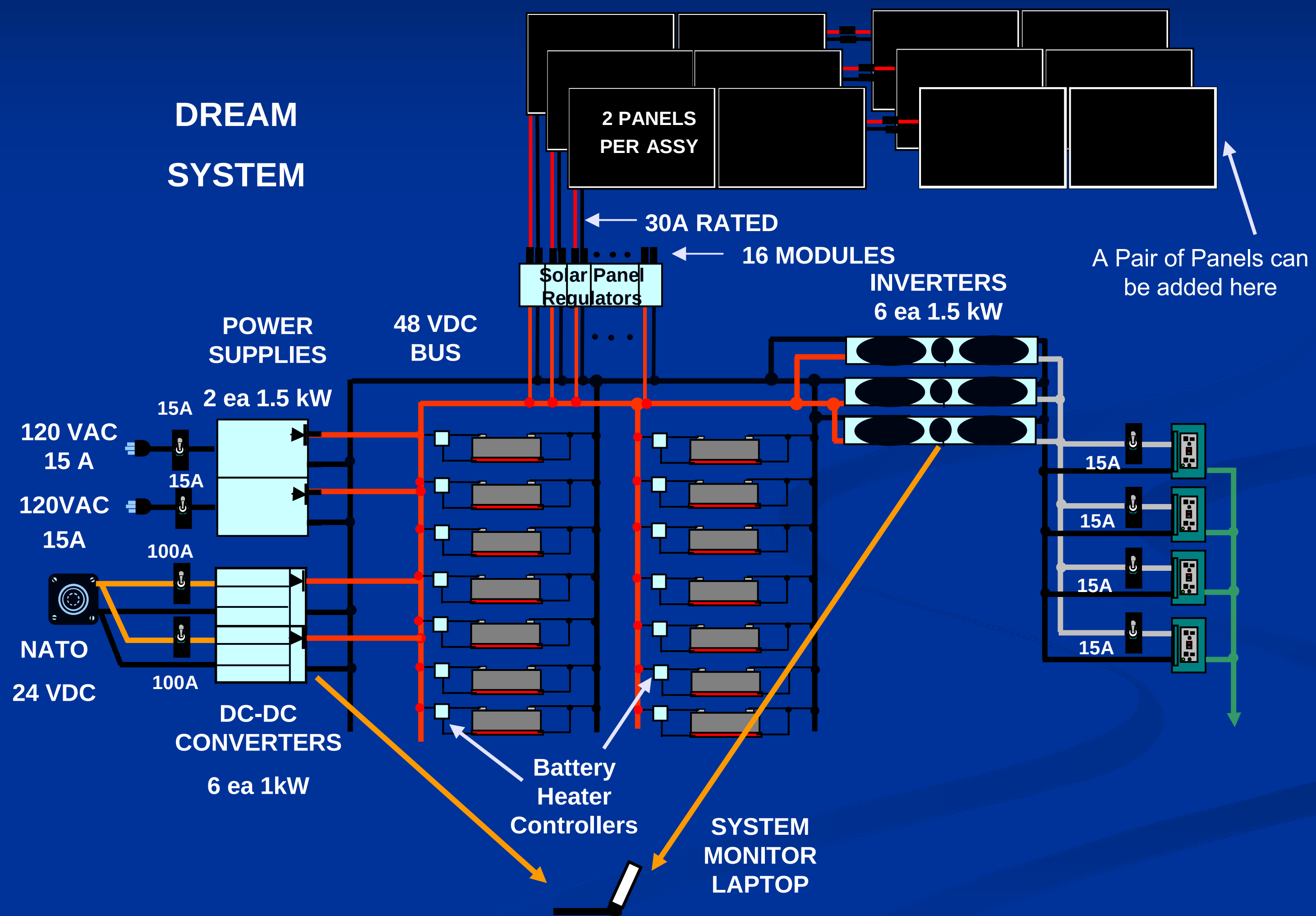
Weight was king (4200 lb – 1440 lb = 2760 lb)

- 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

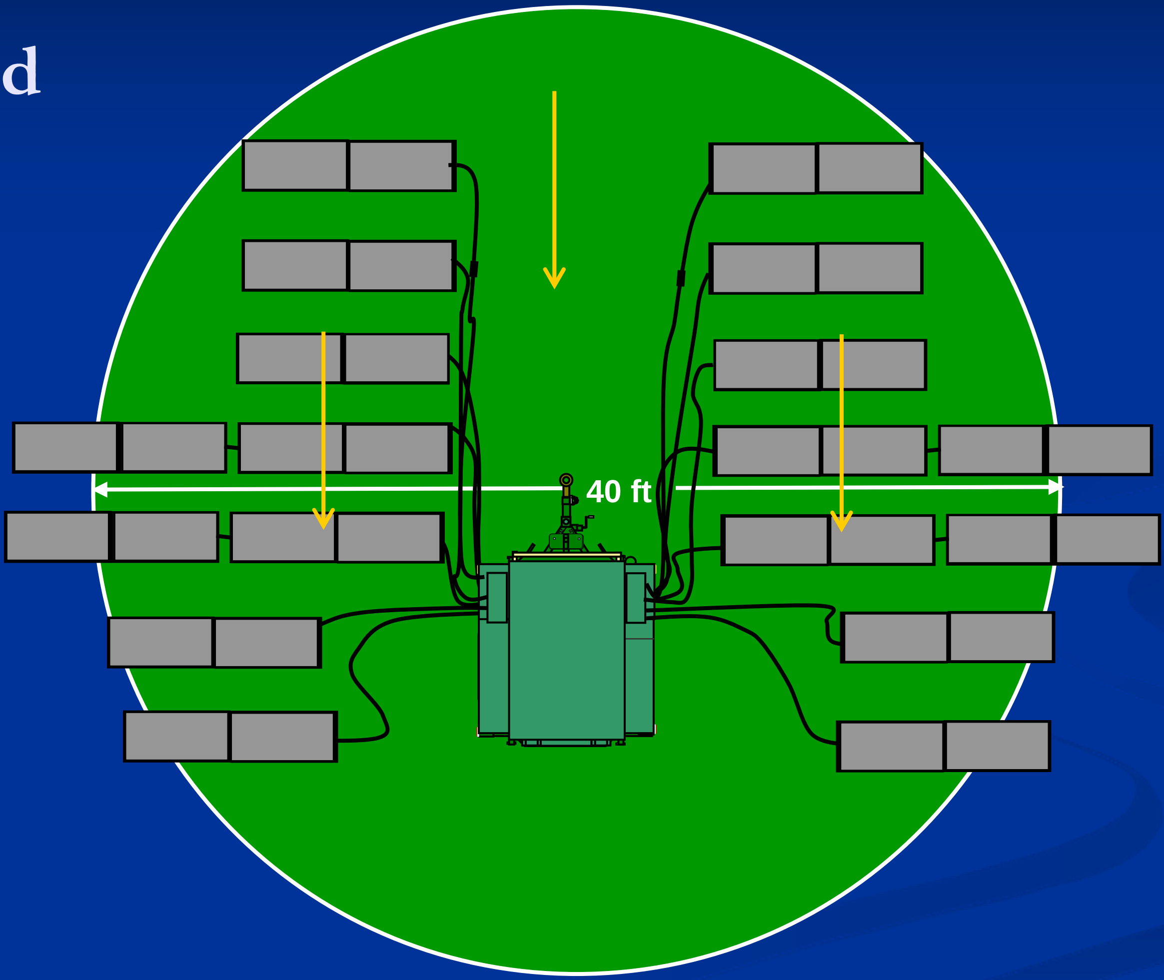
LTT-MCC	1440
Panel Assemblies (18)	1440
Battery Bank	676
Electronics/Wiring	97
Misc & Structures	493
Total	4146

Expansion

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

DREAM Design

Deployed



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Solar Panel

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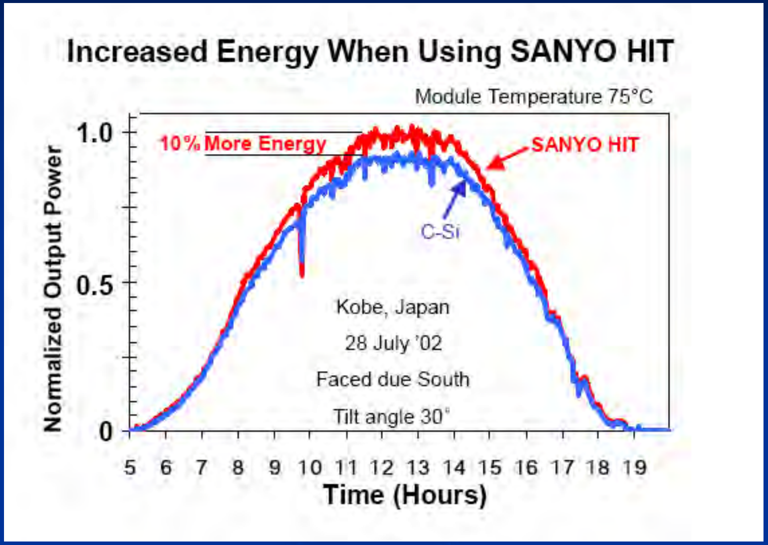

Panel Assembly

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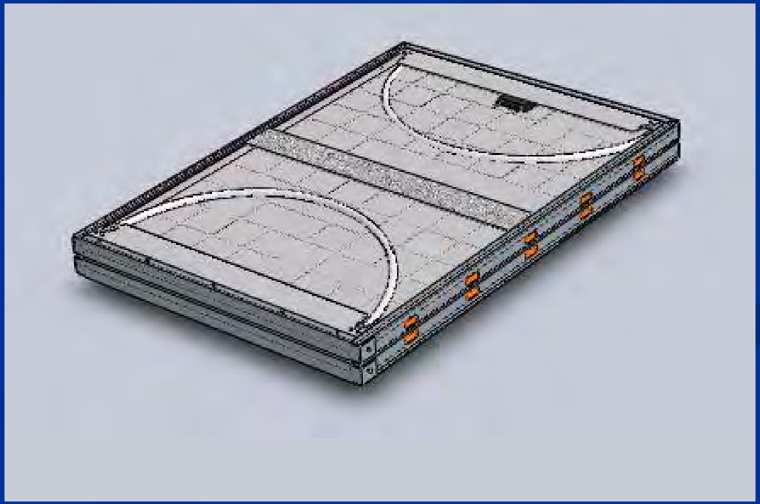
- Single pin IP67 connectors



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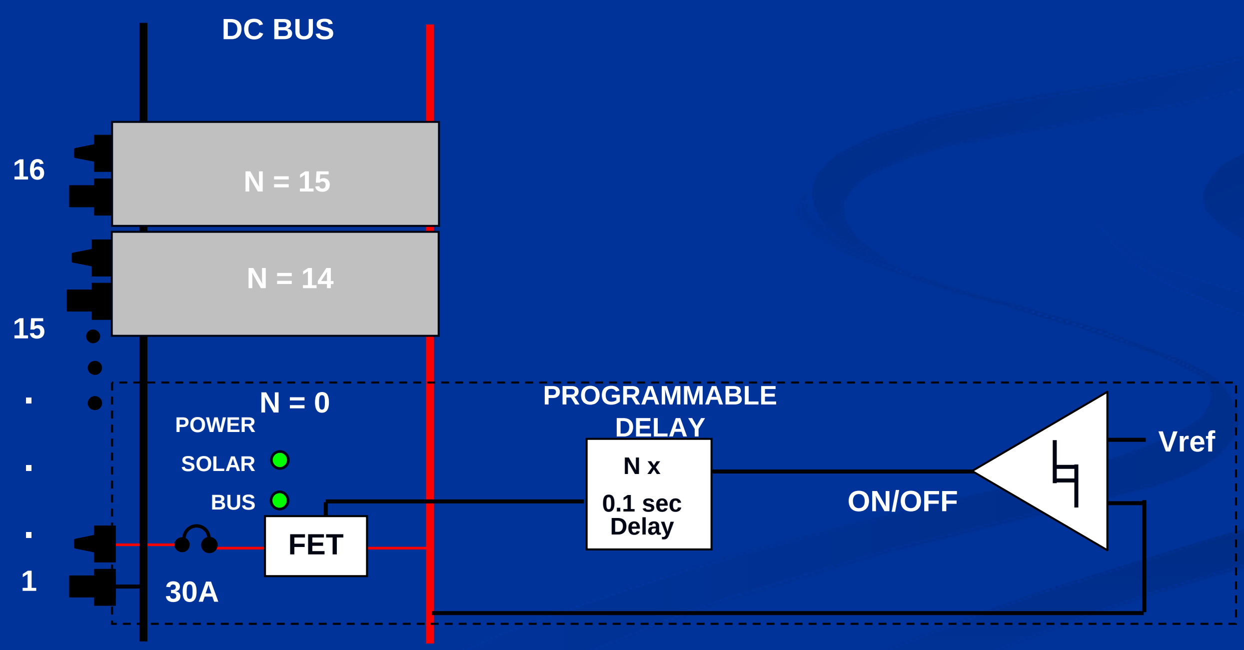

DREAM Design

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
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  - Includes renewable and traditional sources, AC and DC, controls them and delivers clean, reliable AC

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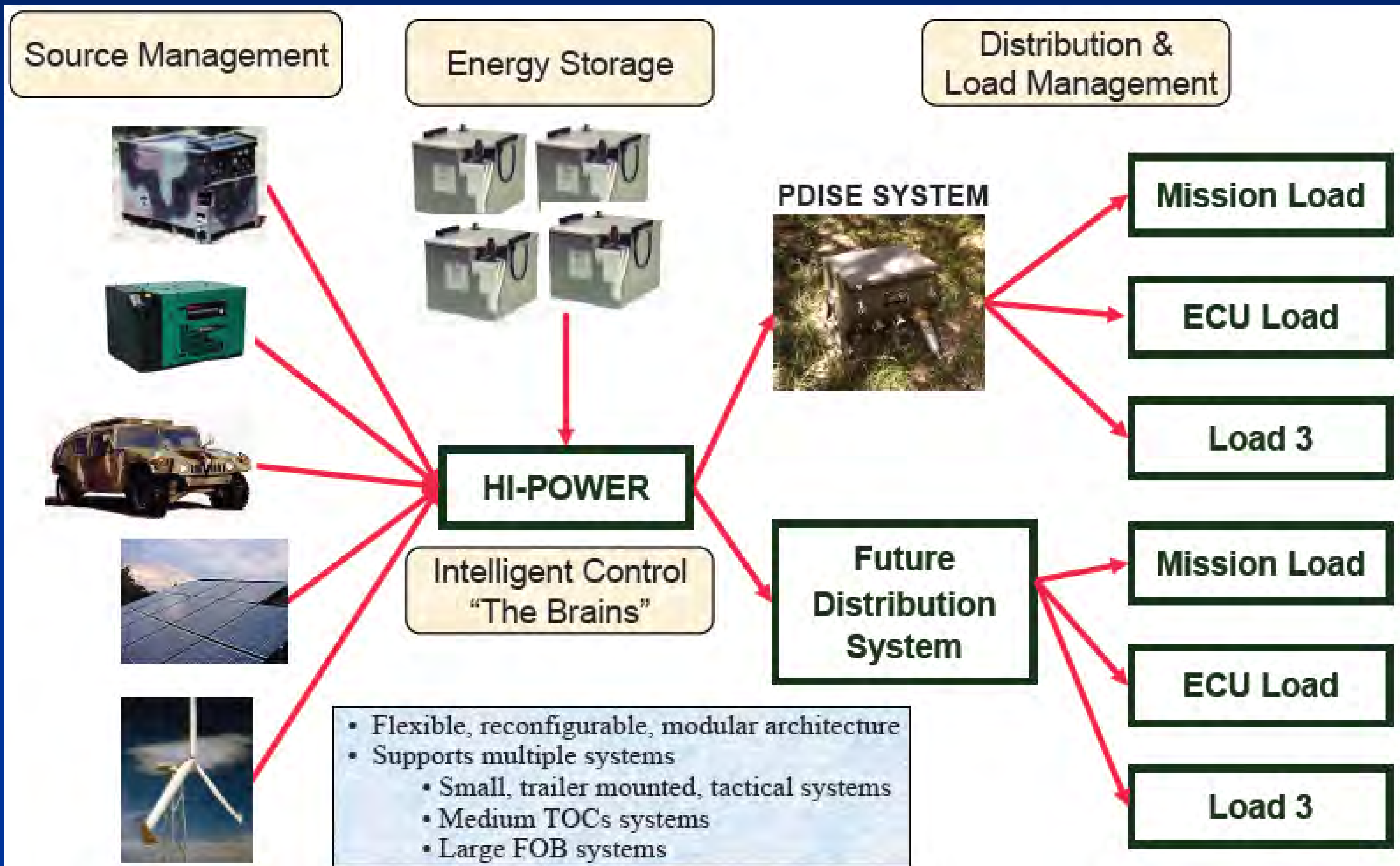
Source Management
Energy Storage
Distribution &
Load Management
PDISE SYSTEM
Mission Load
ECU Load
Load 3
HI-POWER
Intelligent Control
"The Brains"
Future
Distribution
System
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ECU Load
Load 3
• Flexible, reconfigurable, modular architecture
• Supports multiple systems
• Small, trailer mounted, tactical systems
• Medium TOCs systems
• Large FOB systems

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

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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

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- Rolls-Royce 15 kW VSG
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- Start-Stop controlled by
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- 15% less fuel usage at low loads

Smart Technology

Fixed Speed Smart Generators

- PSI 20 to 60 kW Gensets
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- 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 of 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
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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

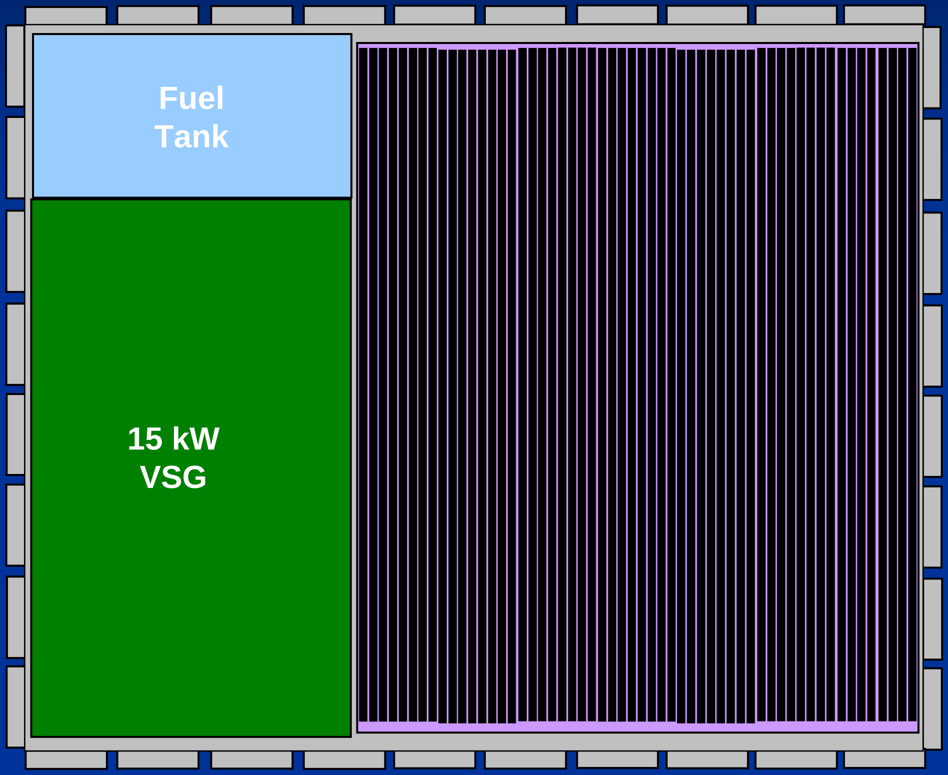
- Source usage
- Load management
- Adaptive charging current

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

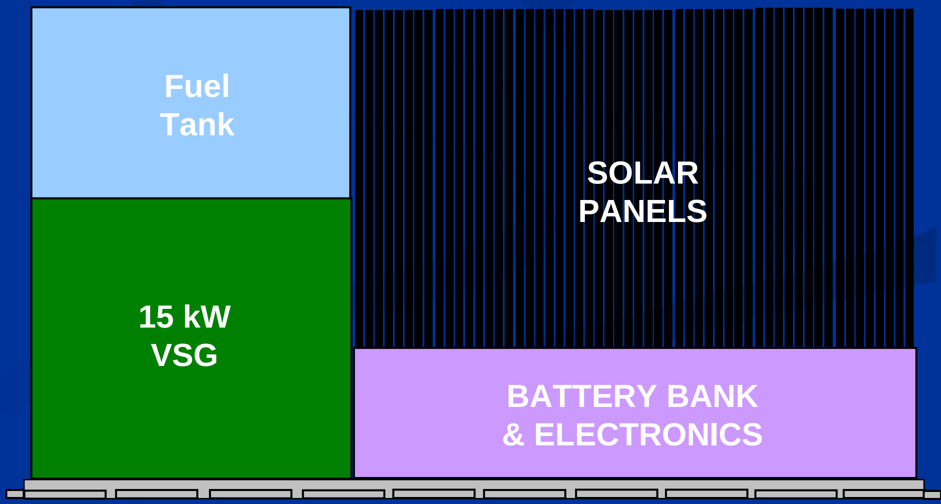
Concept Design



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

Contact Information

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Sr. Systems engineer

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Cell: 727-422-8082

FAX: 727-541-8822

rsilva@custom-mfg-eng.com

BOOTH 124

Custom Manufacturing & Engineering, Inc.

2904 44th Avenue North

St. Petersburg, FL 33714

A Mobile Hybrid Power Source with Intelligent Control

Rick Silva
CME
Joint Service Power Expo
7May09

Overview

- DREAM
- DREAM Revisited
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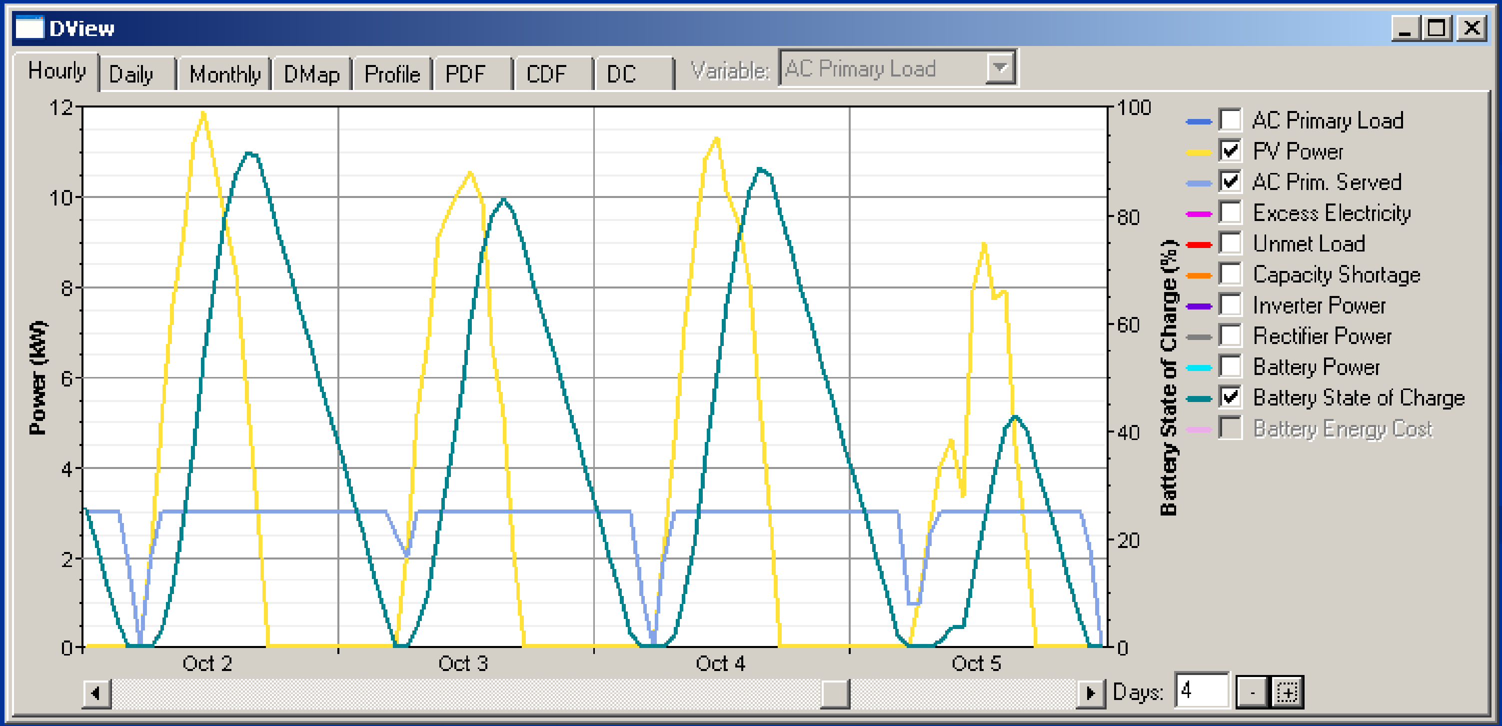

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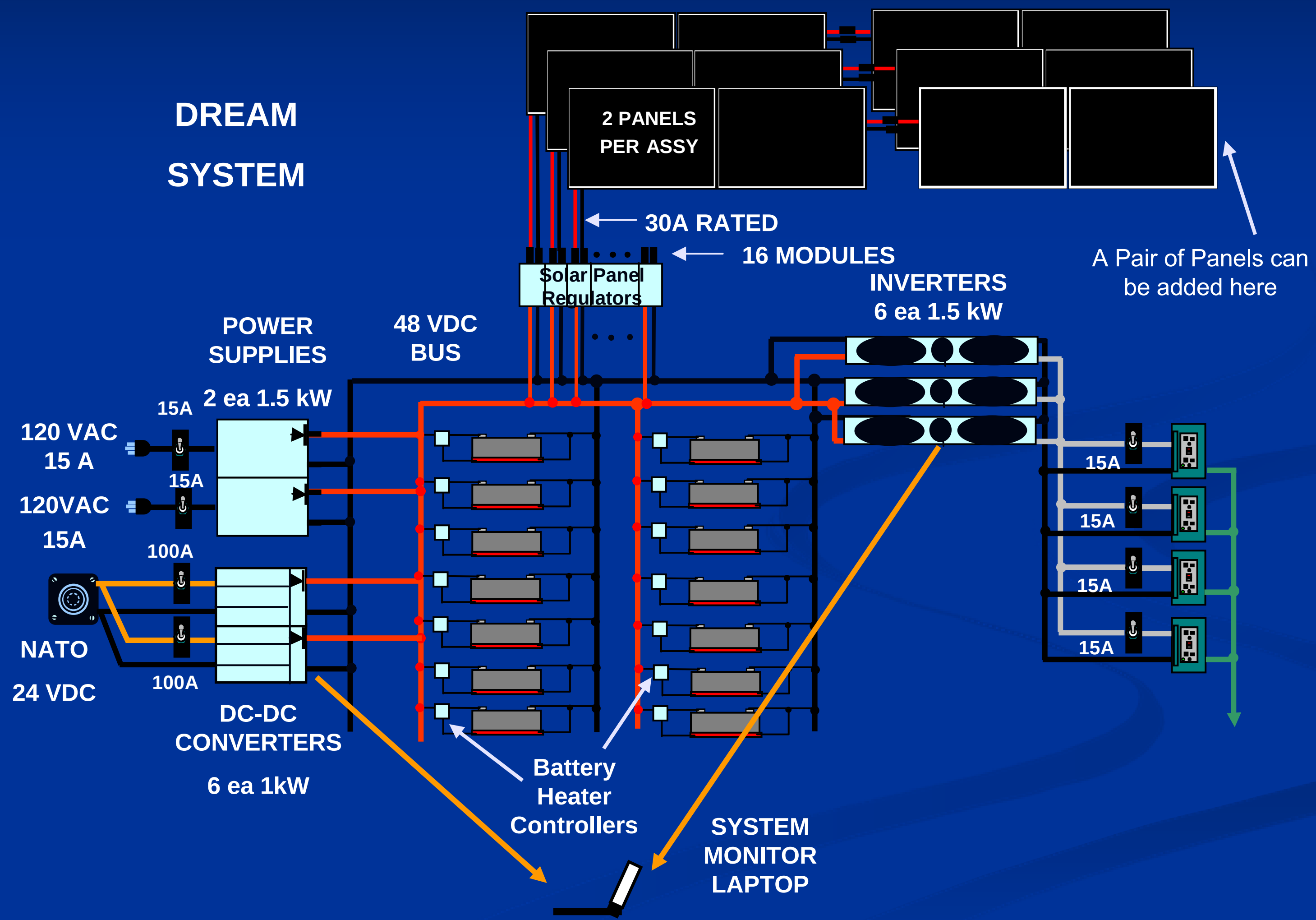

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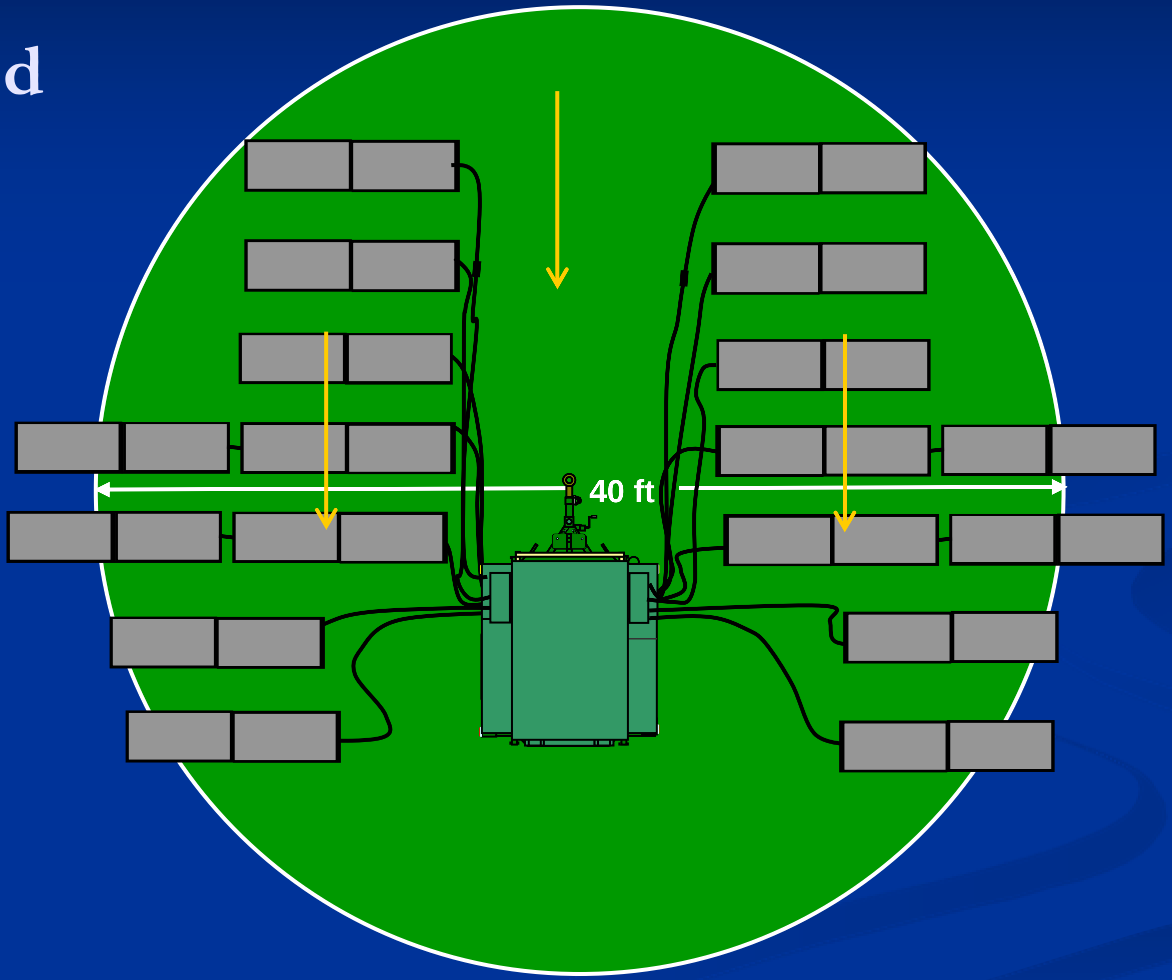

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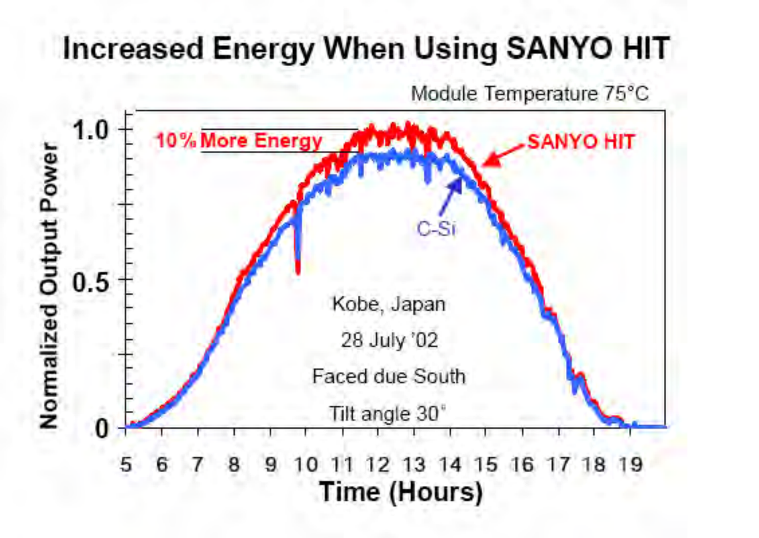

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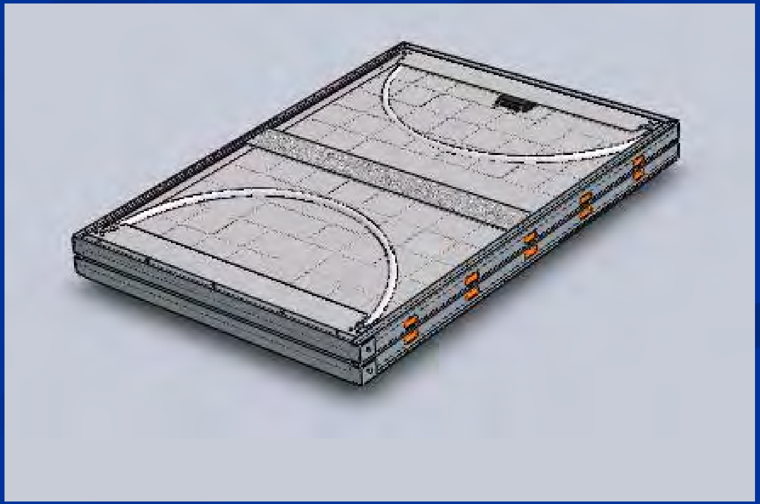

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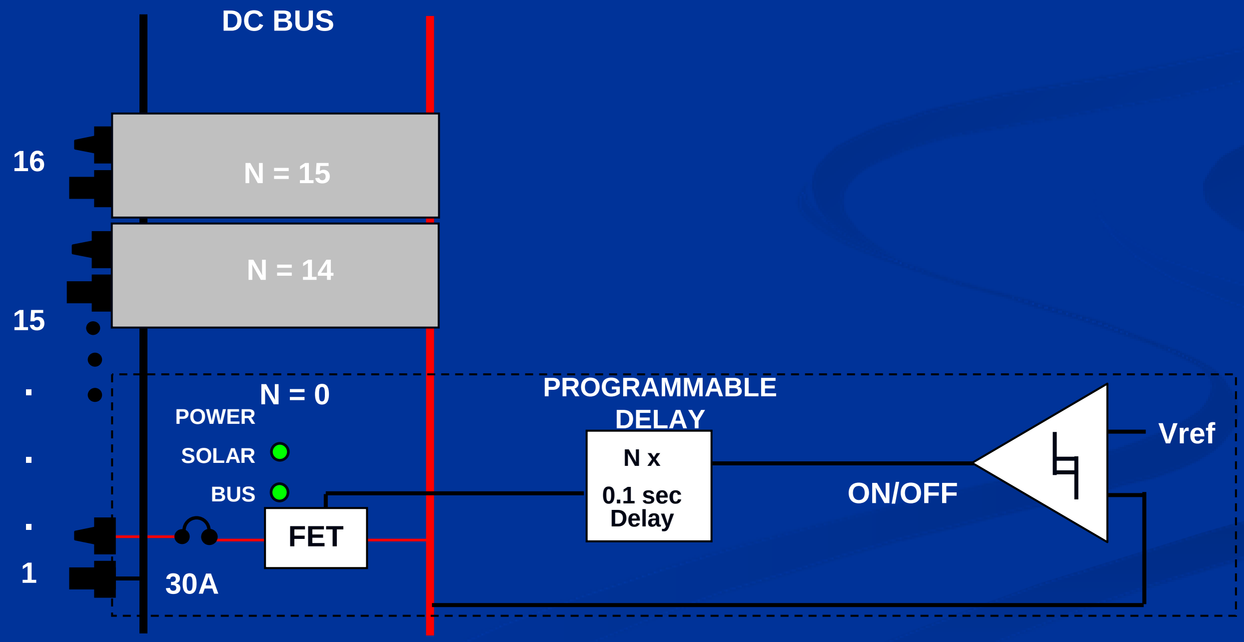

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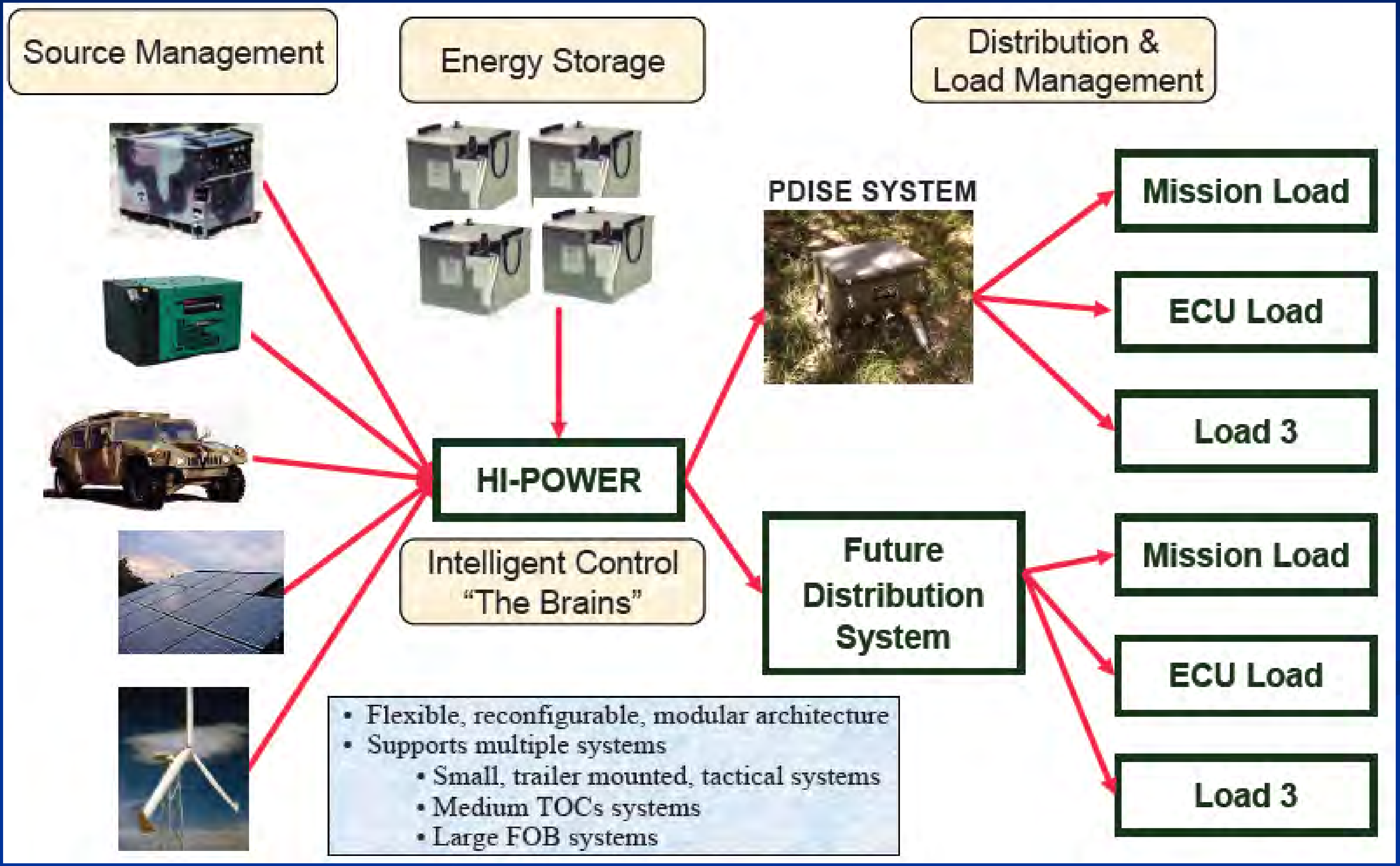
Source Management
Energy Storage
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Load Management
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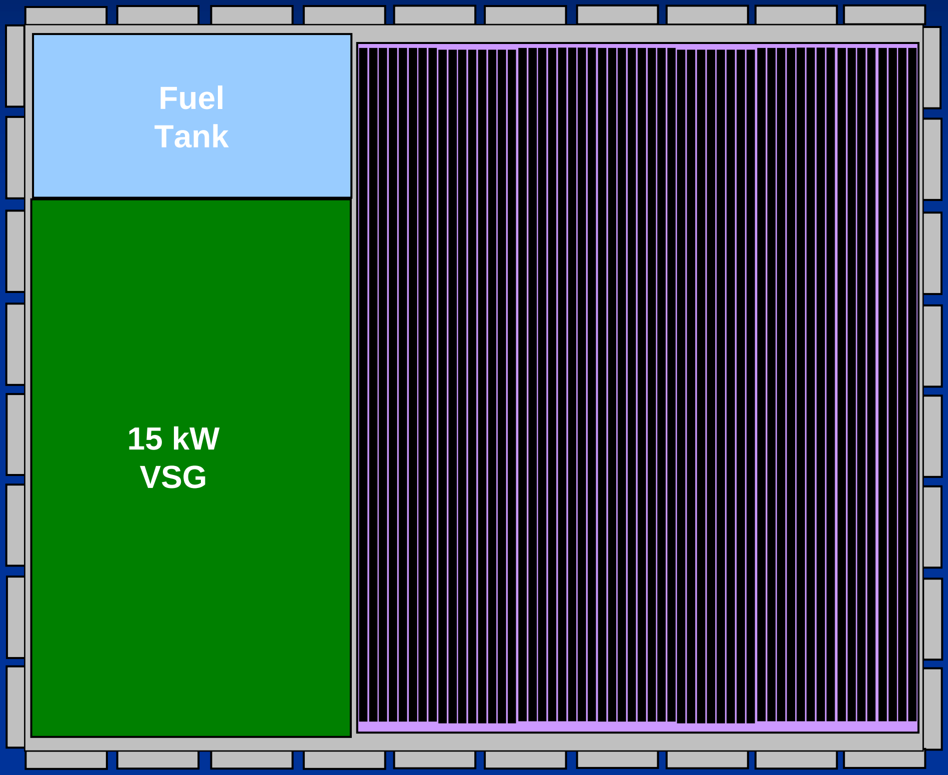
- Built-in battery management

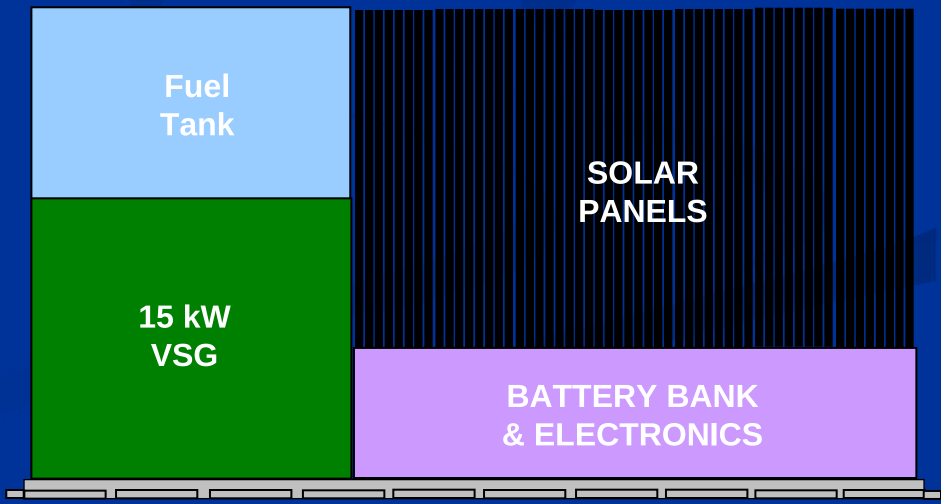
Concept Design



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

Contact Information

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BOOTH 124

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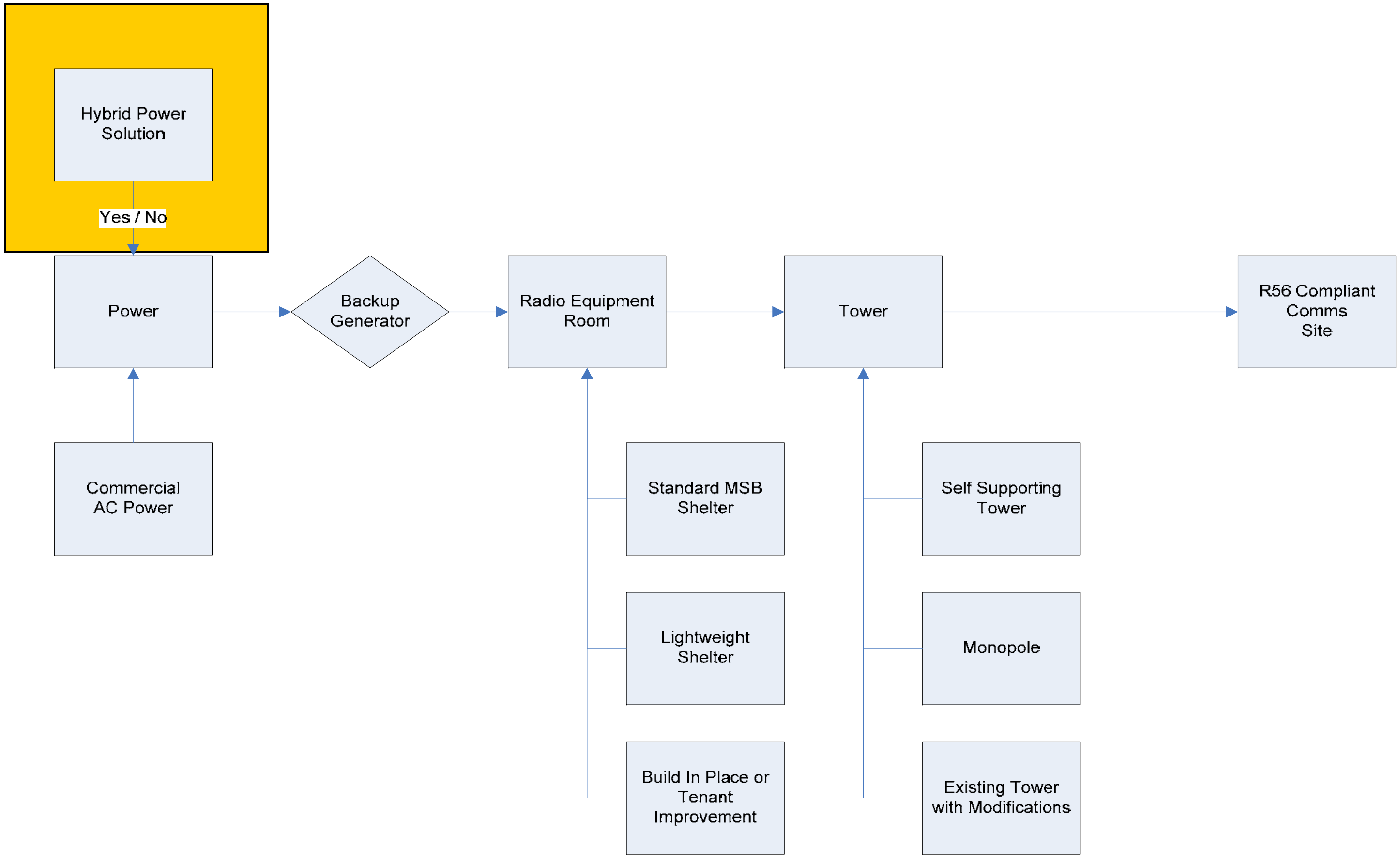
St. Petersburg, FL 33714

HYBRID POWER SYSTEMS FOR MISSION CRITICAL ENTERPRISE LAND MOBILE RADIO SITES

By:

Mark H. Viness, Motorola
National Site Design and Integration Team

Radio System Overview



Remote Site Hybrid Power Supply Needs Assessment

- Cost effective as an alternative to high cost for commercial power
- Highly reliable and redundant power supply system
- System designed for worst case scenario – typically low solar months of Dec – Jan with expected radio traffic
- Battery backup is sufficient to allow normal preventative maintenance schedules
- System monitoring provides status of system at component level.

Hybrid Energy Power Solutions

Search of Marketplace for Manufacturers / Providers

- **Solar**
- **Wind Turbines**
- **Fuel Cells**
- **Generators**
- **Non-Traditional**
  - **Geothermal**
  - **Hydro**
  - **Micro-CoGen**
  - **BioFuels**
- **Motorola Ventures efforts in this space (partnerships, investments, etc.)**

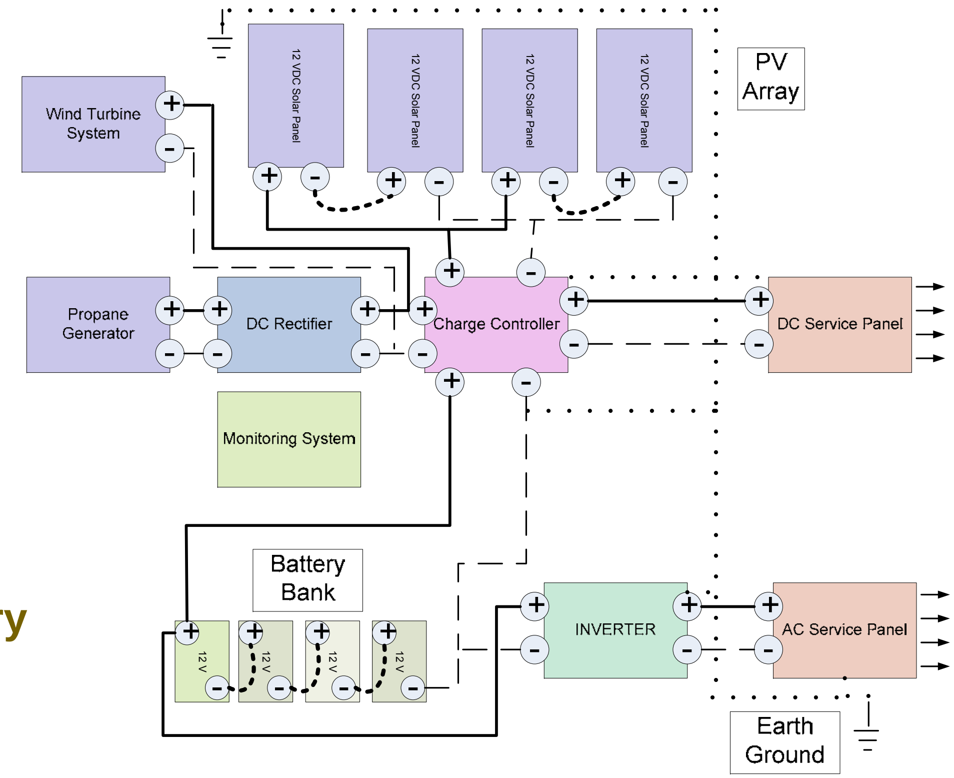
Design and Cost Drivers for Remote Sites

- **Radio System Design**
  - **–Number of Radio channels**
  - **–Duty Cycle (standby versus active)**
  - **–Backhaul solution**
- **Site Access**
  - **– Paved or Dirt road**
  - **– Helicopter**
- **Days of Autonomy**
  - **–Battery bank**
- **Climate**
  - **–Temperature range**
  - **–Humidity**
  - **–Wind**
- **Shelter Design and Size**
- **DC Load**
  - **–DC by Design**
  - **–Load shedding**
  - **–Lights**
  - **–Wiring**

Actual System Design

2000 Ah/Day Load– 7800 Ah Battery Bank – 35.8 KW solar plant (270 panels) – 4 wind turbines – 1.2 Design to Load Factor

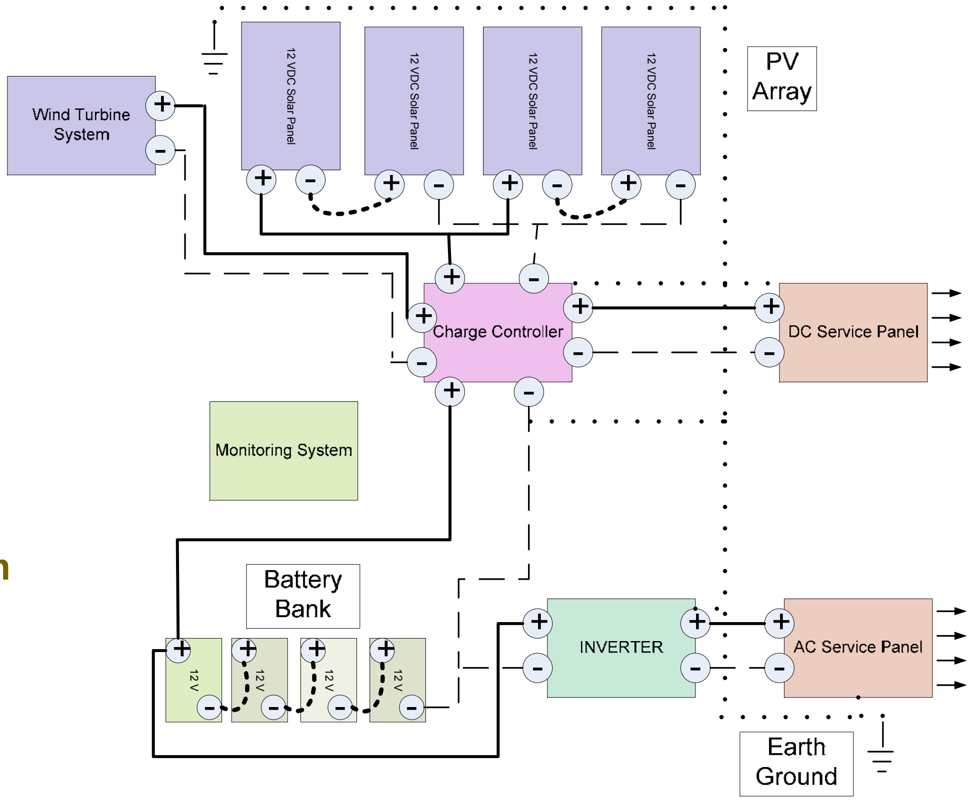
- Radio System Design
  - –3 Radio channels
  - –8 hr Active Duty Cycle (standby versus active)
  - –Backhaul solution – MW to HQ
- Site Access
  - – Dirt road – 2 hr from paved
- Days of Autonomy
  - – 3 Days – 7800 Ah Battery bank
  - – Backup 35 KW propane generator
- Climate
  - – Hot Summers – Cold Winters
  - – Design includes HVAC system
  - – 4 Wind Turbines – cliff edge – good wind
- 2 Shelter Design – one radio / one battery and solar system controller
- DC Load
  - –Load shedding
  - –All LED Lights



Actual System Design

600 Ah/Day Load– 650 Ah Battery Bank – 2.6 KW solar plant (40 panels) – 2 wind turbines – 1.0 Design to Load Factor

- **Radio System Design**
  - –2 Radio channels
  - –8 hr Active Duty Cycle (standby versus active)
  - –Backhaul solution – MW Loop
- **Site Access**
  - – Helicopter
- **Days of Autonomy**
  - – 3 Days – 650 Ah Battery bank
  - – Backup 35 KW propane generator
- **Climate**
  - – Hot Summers – Cold Winters
  - – Heavy insulation – DC fan/louver system
  - – 2 Wind Turbines – 400W
- **smartShelter Design – Full DC shelter design with integrated controls**
- **DC Load**
  - –Load shedding
  - –All LED Lights



Continuing need seen in our customer base

- Integrated systems with high reliability
- Remote site deployment solutions in a variety of climates and field conditions
- Low operations and maintenance costs
- Standard system designs with COTS components
- smartShelter design with full DC integrated, R56 compliant, components and standards

PRESENTER

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Joint Service Power Expo

RENEWABLE POWER IN OIF

Daryl Wilson

Former Expeditionary Power Systems FSR in Iraq

July 2004 to November 2008

L-3 Communications

May 5-7 2009

Briefing Topics

- Logistics Support for Generators
- Solar Power Equipment Uses
- Adaptive Field Expedient Solutions

Logistics Support for Generators

Logistics Support for Generators

	Fuel Capacity	Fuel Consumption	Oil Capacity	Coolant Capacity
2KW Mep 531A	1.6 gal	**.33 GPH**	.85 qt	Air
3 KW Mep 831A	4 gal	**.5 GPH**	1.2 qt	Air
10 KW Mep 803A	9 gal	**.97 GPH**	5.9 qt	8.2 qt
20 KW MMG-25	46 gal	**2.1 GPH**	8.5 qt	10.4 qt
30 KW Mep 805B	23 gal	**2.60 GPH**	15 qt	15.5 qt
60 KW Mep 806B	43 gal	**4.7 GPH**	18 qt	20.5 qt
100 KW Mep 007B	91 gal	**12 GPH**	30 qt	42.3 qt
Commercial Mega Watt	External Tank	**41.5 GPH @75% load**	58 gal	27.1 gal

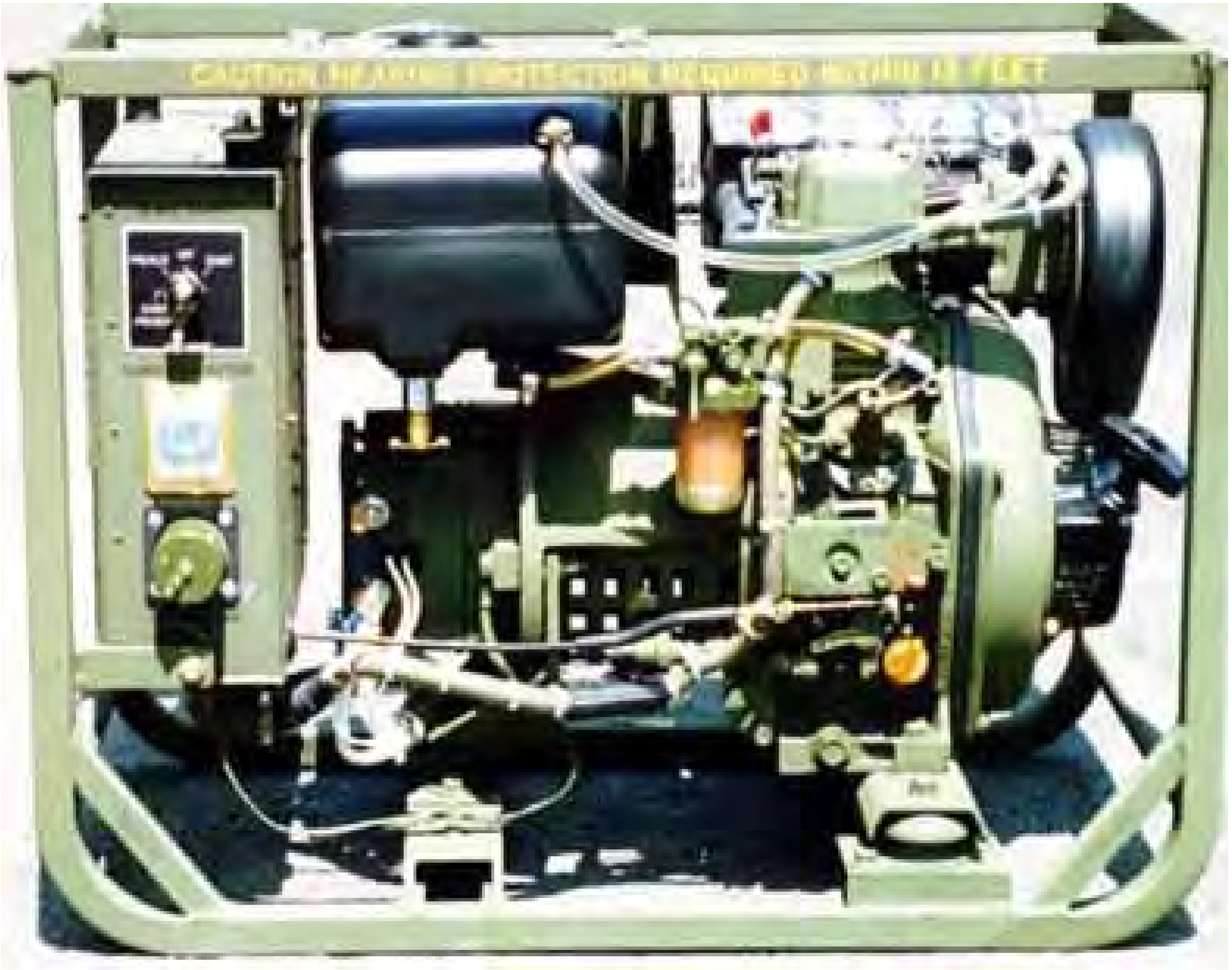
Logistics Support for Generators

2 kW

Week (168 Hrs)
Fuel 55 Gal
Oil .85 Qt
JP8 $157.75

Month (672 Hrs)
Fuel 221.7 Gal
Oil 1.2 Gal
JP8 $631.00

6 Months (4032Hrs)
Fuel 1,330.5 Gal
Oil 8.5 Gal
JP8 $3,786.04



Logistics Support for Generators

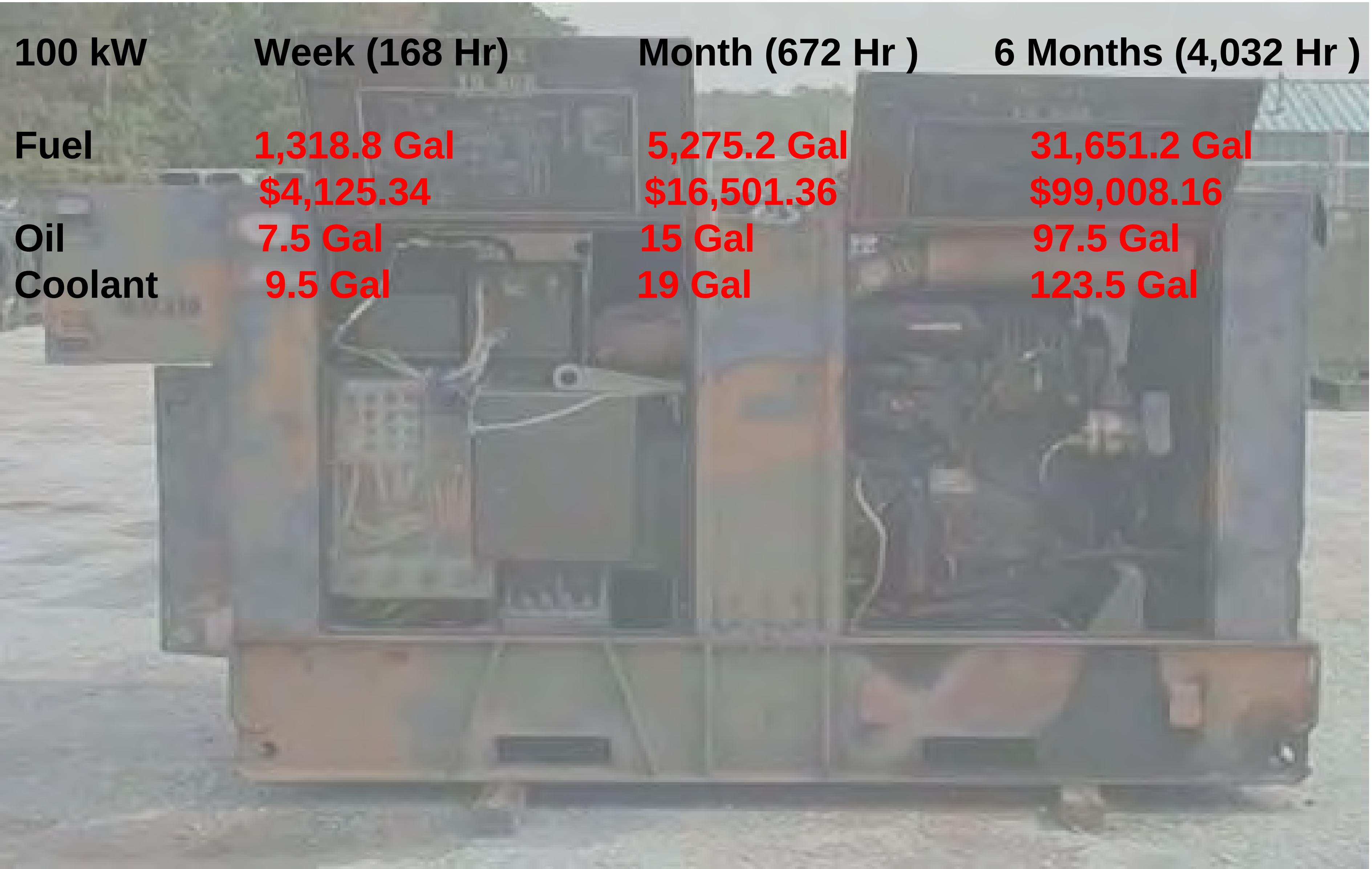
30 kW

Week (168 Hrs)
Fuel 436.8 Gal
$1,364.68
Oil 3.7 Gal
Coolant 3.8 Gal

Month (672 Hrs)
Fuel 1,747.2 Gal
$5,458.72
Oil 7.5 Gal
Coolant 7.7 Gal

6 Months (4,032 Hrs)
Fuel 10,483.2 Gal
$32,752.32
Oil 48 Gal
Coolant 59 Gal

Logistics Support for Generators



100 kW	Week (168 Hr)	Month (672 Hr)	6 Months (4,032 Hr)
Fuel	1,318.8 Gal	5,275.2 Gal	31,651.2 Gal
	$4,125.34	$16,501.36	$99,008.16
Oil	7.5 Gal	15 Gal	97.5 Gal
Coolant	9.5 Gal	19 Gal	123.5 Gal

Logistics Support for Generators

Mega watt	Week (168 Hr)	Month (672 Hr)	6 Months (4,032 Hr)
Fuel	6,972 Gal $21,822.36	27,888 Gal $87,289.44	167,328 Gal $523,736.64

Solar Power Equipment Uses

Whelen Solar Powered Siren System

Solar Power Equipment Uses

Solar Street Light Fallujah

Solar Power Equipment Uses

Solar Power Equipment Uses

World Water & Solar Technologies
Solar Powered Water Purification System

Solar Power Equipment Uses

Flair T-3000 Camera

Solar Power Equipment Uses

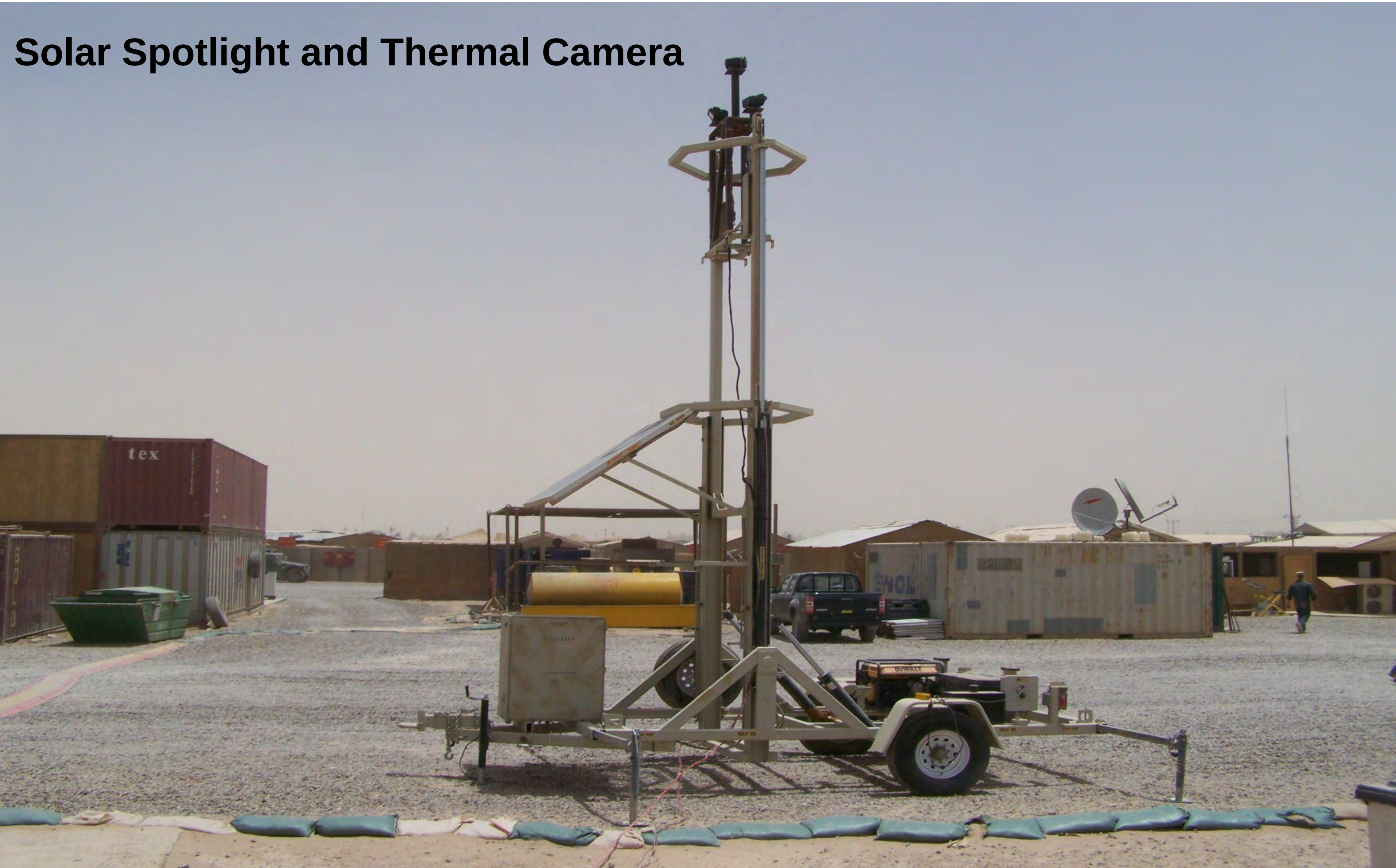
Commercial 12VDC Solar Power Supply

Adaptive Field Expedient Solutions

Adaptive Field Expedient Solutions

Adaptive Field Expedient Solutions

Solar Spotlight and Thermal Camera



Adaptive Field Expedient Solutions

Adaptive Field Expedient Solutions

Adaptive Field Expedient Solutions

Sun Wize 60 Amp Solar Power Supply

Adaptive Field Expedient Solutions

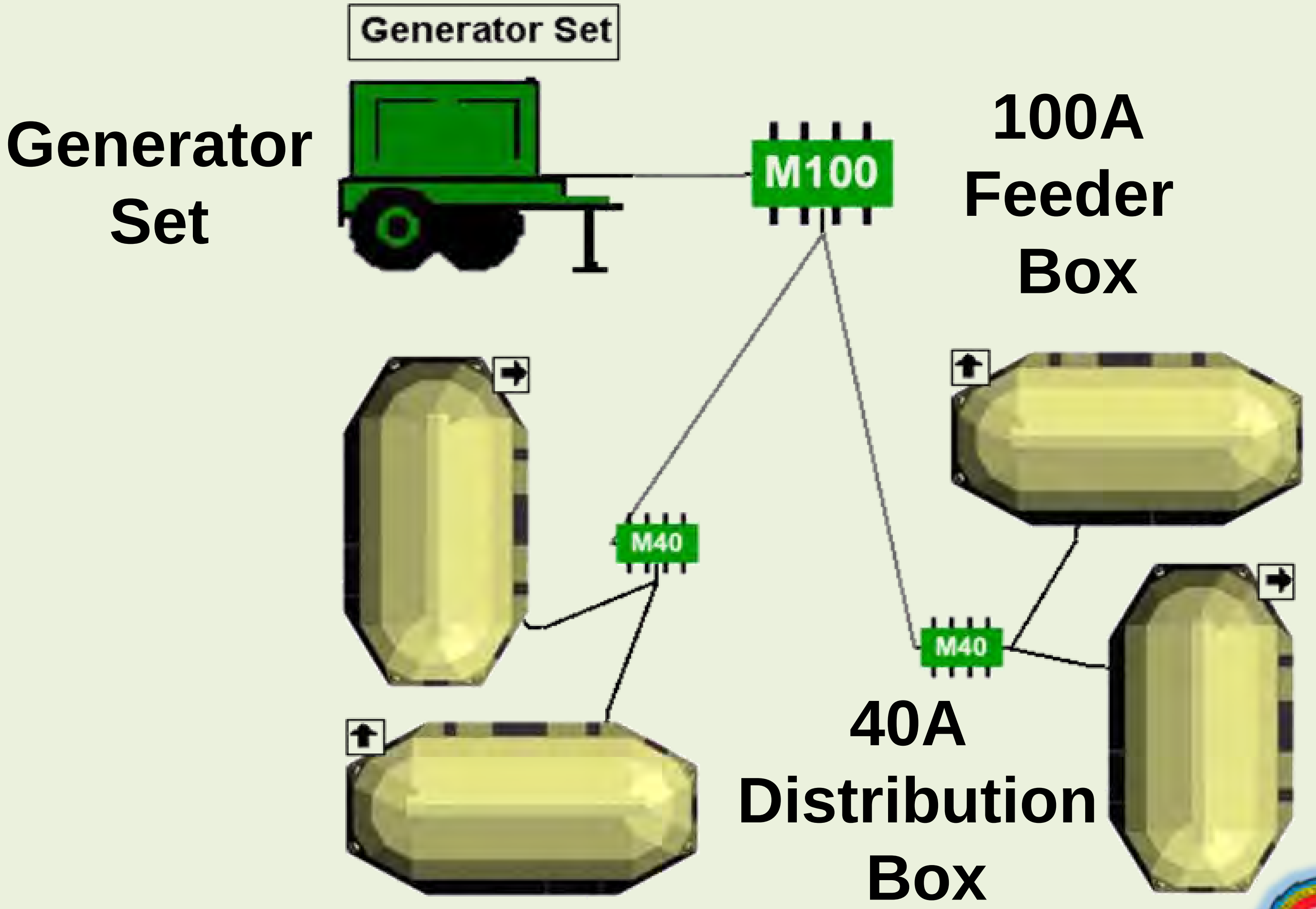
Adaptive Field Expedient Solutions

?? Questions ??

Introduction

- US Army utilizes TQG's for power generation & PDISE for power distribution.
- Power grid is setup based on recommendations of PM MEP.
- Typical setup:
  - a generator set or power plant
  - connected to a M200 or M100 feeder system
  - connected to a M40 and/or M60 power distribution system.

Introduction



IPM IPT Results

- Many who set up power grids in the field do not have the knowledge base to set up the grid, parallel generator sets or manually balance loads.
  - Potential safety issues due to poor grounding practices
  - Instances of poor power grid setup

IPM IPT Results

- Those who have the knowledge still have issues with improper electrical phase balance due to changing requirements.
  - Dedicated soldiers to manually balance loads
  - Frequent shut down of power grid
  - Potential lengthy time to restart if trained personnel are not available

Current System

- Has single phase outputs that must be manually wired in a balanced configuration
- No indication if a proper ground is present
- Reconfiguration requires power down

Recommendations

- Automatic Load Balancing
- Electrical Safety Features

Threshold

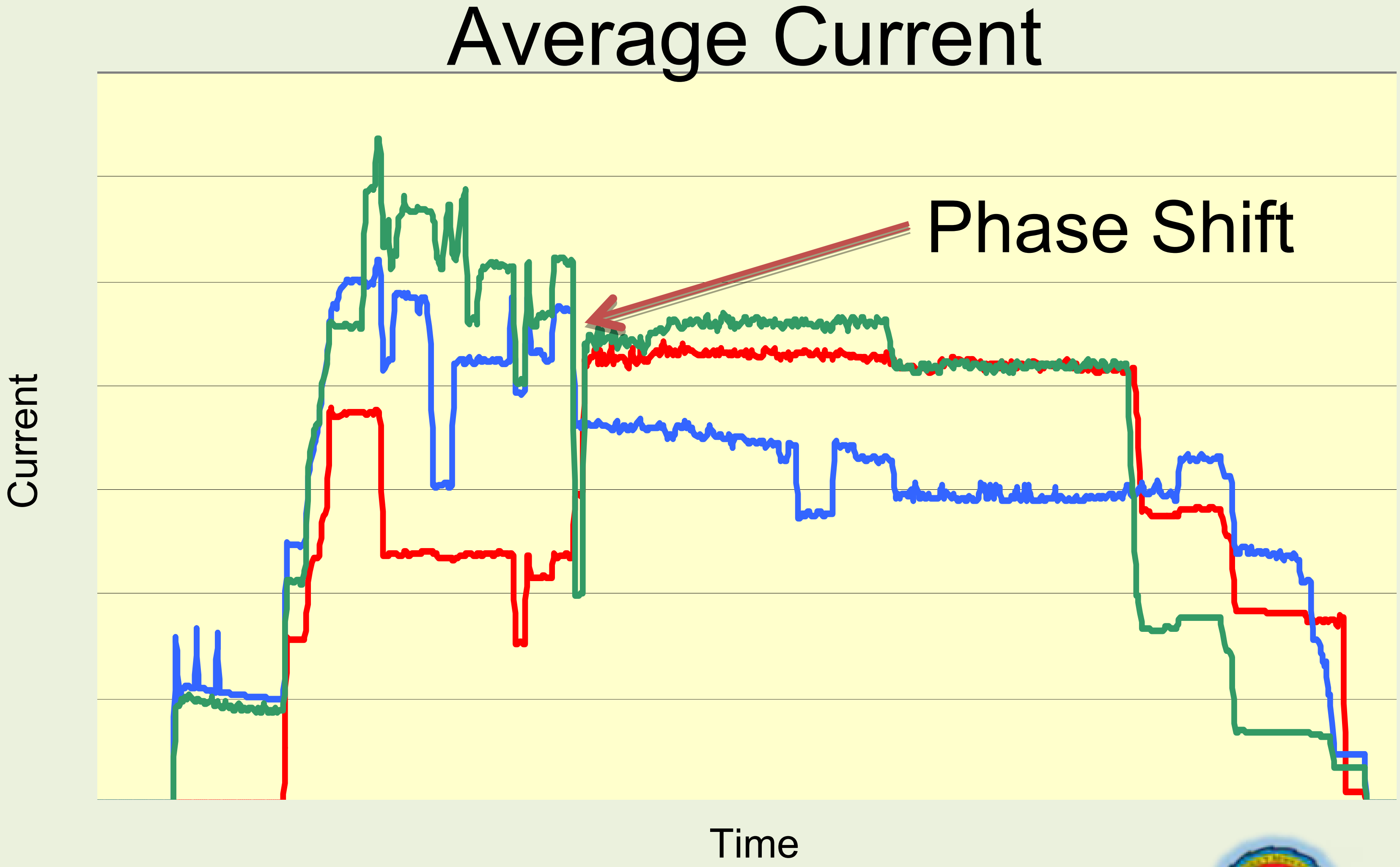
- Auto Load Transfer
- Diagnostics/Prognostics

Objective

Initial Prototype Results

- Developed a prototype system that enabled some safety features as well as automatic load balancing
- The prototype system is a 200A system
- Taken to TOCFEST April 2008 and powered sensitive communications and network equipment

Initial Prototype Results



Defense Acquisition Challenge (DAC)

Army DAC Mission

Test & Evaluate non-developmental items that demonstrate potential to satisfy U.S. Army requirements and would then be procured.

IPMDS Program Summary

The purpose of the IPMDS DAC Program is to purchase intelligent power distribution systems rated at 100 amps and 40 amps and to test these systems to determine if they can meet US Army electrical and environmental requirements. If successful, potential benefits include reduced training and increased reliability of the power grid.

Intelligent Power Management & Distribution

- Utilizing the “Comparative Test to Procure” method
  - Use funding obtained through the DAC program via OSD AS&C and PM MEP to develop and test multiple systems to achieve the program goals.
- Kick-off for the 2009 DAC Programs: November 5th 2008

IPMDS Requirements

- Physical Requirements
  - Weight: Less than or Equal to:
    - 77 lbs (100A), 55lbs (40A)
  - Size: Less than or Equal to:
  - 6.4 ft^3 (100A), 4.91 ft^3 (40A)
- Electric Power Quality
  - Operational Test
  - Automatic Electrical Phase Balance Test

IPMDS Requirements

- Electric Power Quality (cont)
  - Voltage and Frequency Regulation Test
    - 3% Voltage
    - 3% Frequency
  - Compatibility Test
    - Compatibility with current PDISE / DISE

IPMDS Requirements

- Electric Power Quality (cont)
  - Interface Test
  - Endurance Test
    - 250 hrs
  - Short Circuit Test

IPMDS Requirements

- Improper Ground Test
  - Protect and/or shield soldiers from shock hazards and contacting exposed (energized) circuits.
  - Will not energize the output terminals unless the power source is connected correctly to the loads.
  - Visual indicators that clearly show system status and function status

IPMDS Requirements

- Environmental Requirements
  - High Temperature Storage & Operation
    - 160°F (Storage) /140°F (Operation)
  - Low Temperature Storage & Operation
    - -60°F (Storage) / -50°F (Operation)
  - Shock/Vibration

IPMDS Requirements

- Environmental Requirements (Continued)
  - Rain/Humidity
  - Fungus
  - Salt Fog
  - Sand and Dust Intrusion
- Signature Suppression
  - Electro-Magnetic Interference per MIL-STD 461

Intelligent Power Management & Distribution

- As stated in the DAC mission, it is the intent to develop, test and procure the IPMDS systems at the conclusion of this program.

Year 1	Year 2	Year 3
Design & Development	Test & Evaluation	Procure-ment

Potential Down-Select

Down-Select

Bridge to the HI Power Program

Hybrid Intelligent Power

Program Objective

Develop and validate a standard tactical intelligent power management architecture that incorporates source management, demand management, and transient management with plug and play capability to accept any type of available power source while allowing interoperability with legacy equipment.

Bridge to the HI Power Program

- IPM will enable some of the objectives of the HI Power program including:
  - Demand management
  - Interoperability with legacy equipment
- In addition, IPM will enable full utilization of power sources therefore reducing overall fuel consumption

Summary

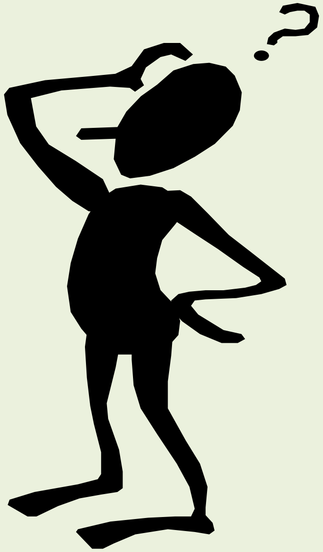
Benefits of IPM

- Reduced time to setup and establish an effective power grid
- Perception of increased power availability
- Maintain high mission readiness
- Decreased fuel consumption
- Safety features to protect Warfighters

Summary

Overall IPM will reduce the training burden on the Warfighter, increase reliability of the power grid, decrease critical mission equipment failures, increase the safety of the power grid and create a more efficient use of power systems.

Questions?



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30kW Exportable Power System for Military Tactical Vehicles

SBIR Topic A05-240
Contract # W56HZV-06-C-0590
Phase II

GS Engineering, Inc.
47500 US Hwy 41
Houghton, MI 49931

Wade Carter – Program Manger

AGENDA

- Military Power Needs
- 30 kW System Overview
- System Performance
- Future Vehicle Applications

30kW Exportable Power System Military Power Needs Addressed

- Increased demand for vehicle systems
- Need for exportable AC and DC power for communications, weapons, medical support and service
- Reduced fuel consumption through higher efficiency power generation
- Updating fleet vehicles with increased power capabilities

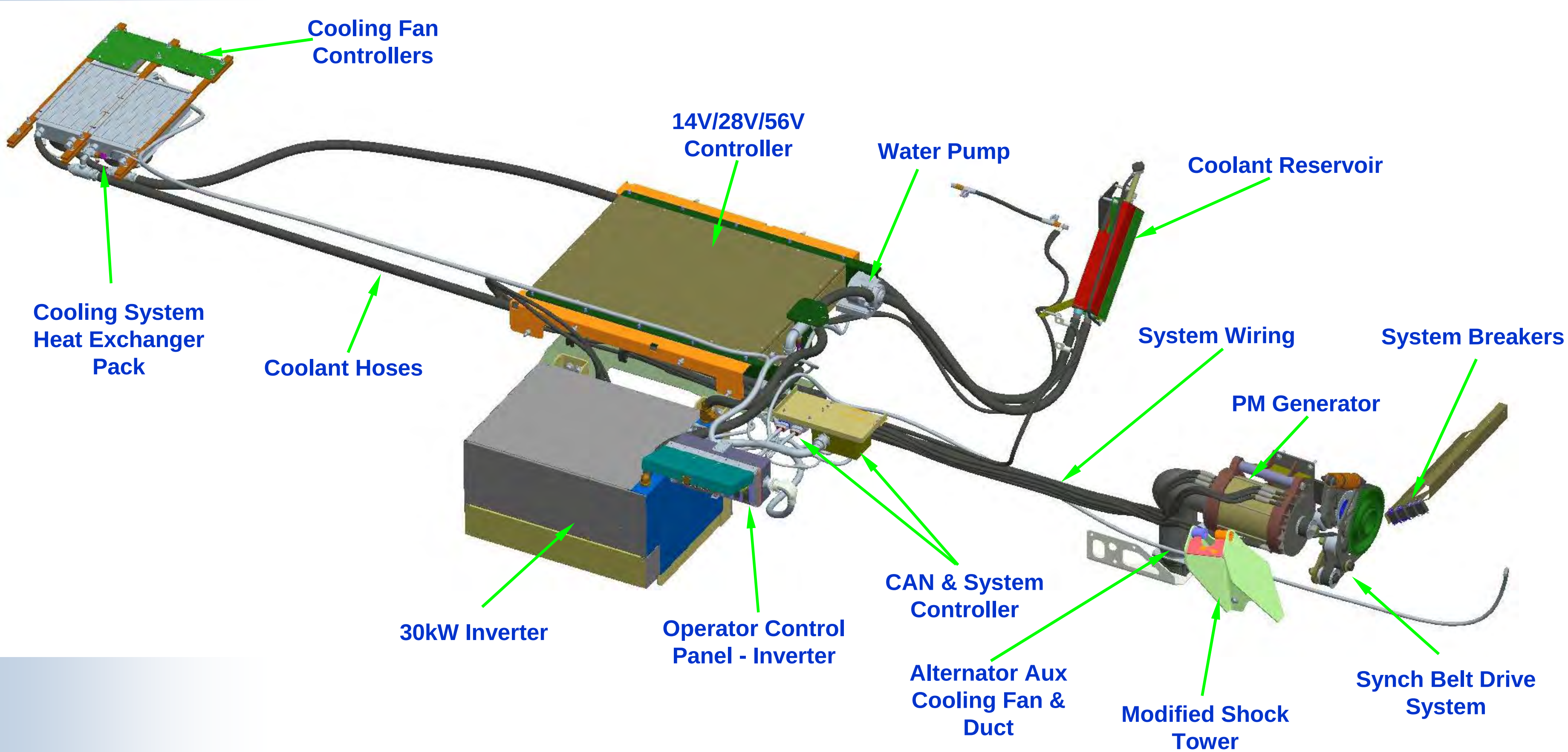
30kW Exportable Power System Project Overview

- **TARDEC NAC – Phase II SBIR Award to GSE**
- **GS Engineering (GSE)**
  - » System Integration, Packaging, Testing and Demonstration
  - » System Control, Operator Interface & Wiring
  - » Liquid Cooling System
  - » Synchronous Belt Drive
- **Technology Partners**
  - » DRS Fermont - 30kW Inverter
  - » Magnetic Applications - PMG & Controller
- **Vehicle - BAE Systems FMTV 5.0 Ton Cargo**

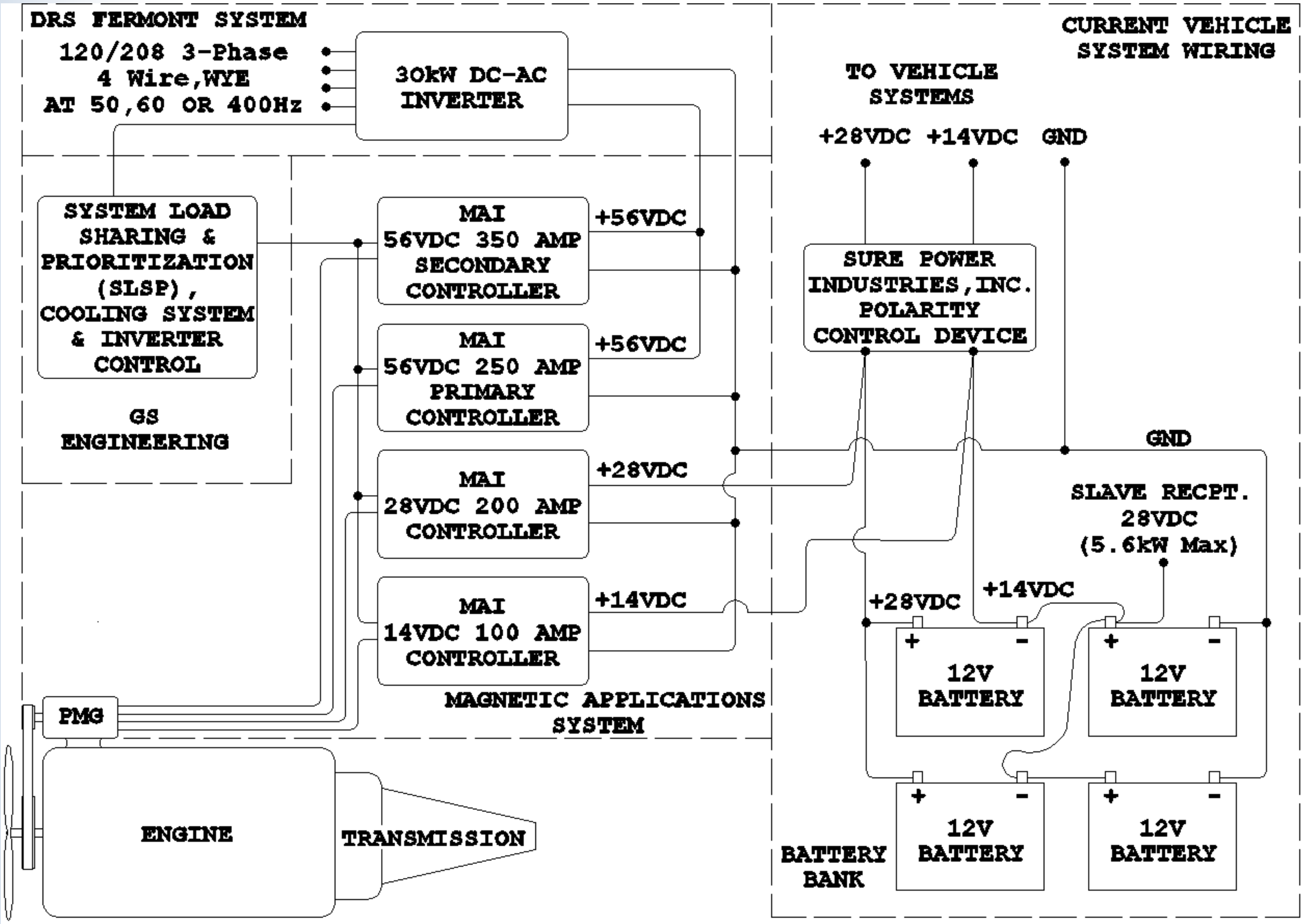
30 kW Exportable Power System
System Key Features

- **Vehicle Power at engine idle - 14V/28V @100A/200A**
- **Exportable AC Power at High Idle**
  - » 29 kW continuous (3-Phase AC at 120/208)
  - » User Selectable Frequency - 50, 60 or 400Hz
- **CANbus controlled system**
- **Operator Interface Panel w/ LCD Display**
- **Inverter technology available for future design**
  - » Compact modular design
  - » Adaptable to DC or PMG Inputs
  - » Selectable output voltage (240/416)
  - » Parallel operation
- **Retro-fit Kit for Fleet Vehicles**

30kW Exportable Power System
System Components



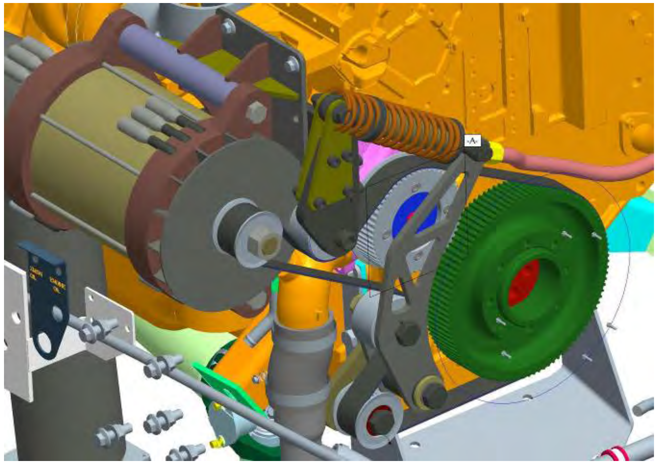
30kW Exportable Power System
System Schematic



30kW Exportable Power System Subsystems

- Synchronous belt drive
- Permanent Magnet Generator (PMG) & Unified Controller
- DC-AC Inverter
- System Controller, Operator Interface & Wiring
- Auxiliary Cooling System

30kW Exportable Power System Synchronous Belt Drive - FEAD



- Synchronous belt system
  - » Direct replacement of CAT C7 Serpentine Kit
  - » Power transmission - 56 hp & 350 lb-ft of torque
- 4.0:1 DR provides 34kW Power
- Adaptable to other engine/vehicle variants
- Designed for future engine start capability

30kW Exportable Power System PMG & Unified Controller

- **PM Generator**
  - » 4 Independent Windings
  - » 3 Separate AC Voltages
  - » 88% Efficiency at High Output
  - » Air-Cooled
- **Unified Controller**
  - » 14VDC 100A at Idle (700 rpm)
  - » 28VDC 200A at Idle
  - » 56VDC 600A at High Idle (1350 rpm)
- **Over Temp Protection**
- **Temperature Compensation**

Alternator & Wiring

14/28/56V Controller

30kW Exportable Power System DC-AC Inverter

- Designed to meet majority of PRECISE Class I AC power quality requirements
- Reduced package
  - » 37% lighter than standard 30kW inverters
  - » Reduced Package Space fits on side of FMTV
  - » 29”L x 16”H x 22” D (13% Reduced Space Claim)
- CAN Controlled
- Broadcasts System Status
- Over Temp Protection
- Liquid Cooled

30kW Exportable Power System Operator Control / Display

HED CAN Controller & Display
- Vehicle Parameters
- Cooling System
- Alternator/Controller (DC System)
- Inverter (Exportable Power)

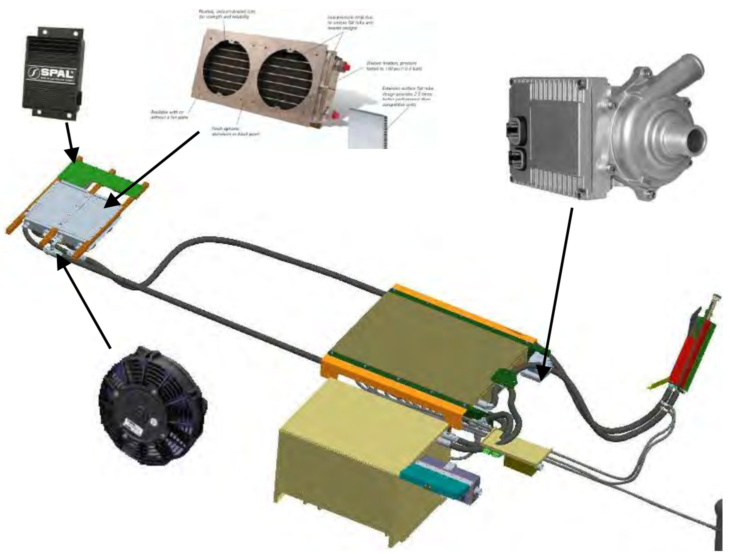
Control Switching
- Inverter Power
- E-Stop
- Frequency Select
- Battle Short
- Contactor Open/Close

Operator Interface Panel

CAN Controller

30kW Exportable Power System Cooling System

- **Closed loop liquid cooling system**
- **Variable speed pump & fans**
  - » Monitor & maintain cooling
  - » Reduced power consumption
  - » Minimized operational noise
  - » Increased component life
- **Expandable design**



30kW Exportable Power System Controller – DC Output

- **Tested to MIL-STD 1332 & 1375**
- **Meets majority of the requirements tested**
  - » Voltage Regulation
  - » Steady-state Stability
  - » Dip & Recovery
    - Meets for 14/28V
    - 56V – 32% vs 30% dip
  - » Rise & Recovery
    - Meets for 14/28V
    - 56V – 3 sec vs 2 sec recovery
  - » Ripple Voltage
  - » Voltage Fluctuations

30kW Exportable Power System DC-AC Inverter Performance

Inverter Specifications

- **Input**
  - » 56VDC Nominal (50-62VDC)
  - » 640A Nominal
  - » +/-20% Voltage < 1sec
- **Output**
  - » MIL-STD-1332B Class 2B
  - » 120/208VAC (3 Phase, 4 Wire w/ Ground)
  - » Power Rating - 30kW
  - » Power Factor - 0.8 lag
  - » Efficiency ~ 83%
  - » 2% Total Harmonic Distortion (THD)

Model Number	318-01-01
INPUT SPECIFICATIONS	
Voltage	56VDC nominal (50-62VDC)
Current	640Amps Nominal
DC Power Disturbances	+/-20% Voltage for less than 1 sec
OUTPUT SPECIFICATIONS	
Applicable Standards	MIL-STD-1332B Class 2B
Configuration	Three Phase, Four Wire plus Ground
Voltage	120/208VAC, 3Ø
Rated Power Factor	0.8 lag
Output Power	30,000 Watts
Output VA	37,500 VA
Rated Output Current	104.2 Amps
Voltage Regulation	1%
Frequency	Selectable: 50/60/400 Hz
Waveform Deviation	5 %
Efficiency at rated load	Better than 83 %
Harmonic Distortion	Better than 2 % single harmonic, 2% THD
Output DC Bias	Better than 0.1V
ENVIRONMENTAL QUALIFICATIONS	
Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC)	MIL-STD-461E Army Ground
Vibration	MIL-STD-810F, Category 10
Audible Noise	70 dBA at 36 inches (0.9 Meters)
Shock (Transit Drop)	MIL-STD-810F, Procedure IV
Operating Temperature	-50°F to +138°F (-45°C to +59°C)
Storage Temperature	-60°F to +160°F (-51°C to +71°C)
Blowing Rain	MIL-STD-810F, 45 degrees, 5 inches per hour (12.7 cm/hr)
Sand and Dust	MIL-STD-810F, Blowing Dust, Blowing Sand 1400mg/cubic meter
Relative Humidity	Up to 95%
PHYSICAL SPECIFICATIONS	
Weight	Less than 200 lbs
Width (Enclosure)	29.0"
Depth (Enclosure)	22.1"
Height (Enclosure)	16.1"
COOLING REQUIREMENTS	
Cooling Mixture	50/50 Glycol-Water
Flow Rate	3 GPM Minimum
Coolant Temperature	149F (65C) Maximum
Power Dissipation into Liquid	4000W
Power Dissipation into Ambient Air	1000W

30kW Exportable Power System
AC Exportable Power Performance

MIL-STD-705 AC Waveform Testing Results						
CHARACTERISTIC PARAMETER	Precise Class I	Utility			DRS FERMONT 30KW INVERTER	Test Method MIL-STD-705
		Class 2A	Class 2B	Class 2C		
a. Voltage characteristics						
1. Regulation (%)	1%	2%	3%	4%	Precise Class I	608.1
2. Steady-state stability (var./bandwidth %)						
(a.) Short term (30 seconds)	1%	1%	2%	2%	Precise Class I	608.1
(b.) Long term (4 hours)	2%	2%	4%	4%	Precise Class I	608.2
3. Transient performance						
(a.) Application of rated load						
(1) Dip (%)	15%	20%	20%	30%	Precise Class I	619.2
(2) Recovery (seconds)	0.5 sec	3 sec	3 sec	3 sec	Precise Class I	619.2
(b.) Rejection of rated load						
(1) Rise (%)	15%	30%	30%	30%	Precise Class I	619.2
(2) Recovery (seconds)	0.5 sec	3 sec	3 sec	3 sec	Precise Class I	619.2
(c.) Application of sim motor load (200% current) (Note[6])						
(1) Dip (%)	30%	NA	40%	NA	Precise Class I	619.1
(2) Recovery to 95% rated voltage (sec)(Note[1])	0.7 sec	NA	5 sec	NA	Precise Class I	619.1
4. Waveform (Note[2])						
(a.) Maximum deviation factor (%)	5%	5%	5%	6%	Precise Class I	601.1
(b.) Maximum individual harmonics (%)	2%	2%	2%	3%	Precise Class I	601.4
5. Voltage unbalance with unbalanced load (%)(Note[3])	5%	5%	5%	5%	Precise Class I	620.2
6. Phase balance voltage (%)	1%	1%	1%	1%	Precise Class I	508.1
7. Voltage adjustment range (%) (min)(Note[4])	-5% +17	+/-10%	-5% +17 (Note[5])	-5 +5%	Not Adjustable	511.1

Notes:

1. The voltage shall stabilize at or above this voltage (not applicable to all sets rated 5 k or below, or 500kW or larger.
2. Specified values are for three-phase output; for single phase add additional 1%.
3. With generator connected for three-phase output and supplying a single line-to-line, unity power factor, load of 25% of rated current and with no other load on the set. (Not applicable for single-phase connections of sets.)
4. For Mode II sets, upper voltage adjustment is +10% of rated voltage. For Mode I sets operating at 50 Hz, upper voltage adjustment may be limited to the nominal voltages show in Table IV, Note 4. (Not included here.)
5. Values shown are for sets rated at 15kW and above.
6. Motor load current was 124%. The load was a 5 hp two stage air compressor connected to 208V (L1-L2).

30kW Exportable Power System TARDEC Demonstration Jan-2009

- Resistive Load – 30kW AC Load Bank
  - » Load Steps
  - » Continuous Operation
- Inductive Load – Chop Saw, 3 HP Air Compressor
- Capacitive Load – Fluorescent Lighting
- Complex Load - Combination

30kW Exportable Power System Potential Future Applications

Military Vehicles

- Any tactical vehicle in need of 30kW power
- “Bolt-on” retrofit for fleet vehicles

Government & Commercial Vehicles

- Disaster Relief
- Homeland Security
- Fire Apparatus
- Logging
- Mining

30kW Exportable Power System
GSE Contacts

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(906) 482-1235 x102

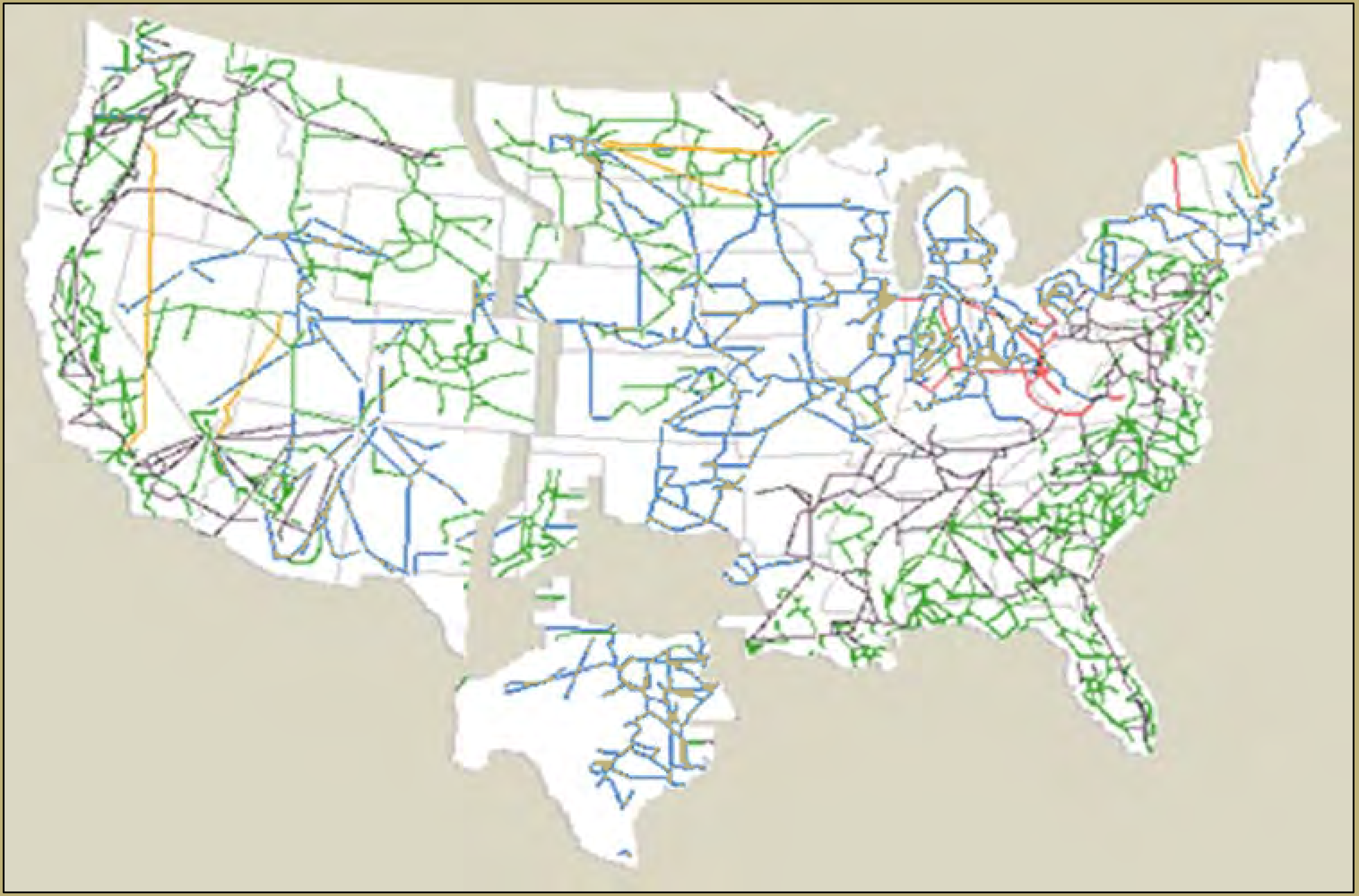
www.gsengineering.com

Micro Grids

Harnessing & Managing Multiple Energy Resources

Big Grids

Serve the Entire Country or Region



Micro Grids

Serve tactical communities

Smart Micro Grids

Why should micro grids be "smart?"

Who threw that?

Smart Micro Grids

Should manage energy sources and loads 24/7

Sources

Smart Micro Grids

Should manage energy sources and loads 24/7

Sources

Loads

Smart Micro Grids

Should manage energy sources and loads 24/7

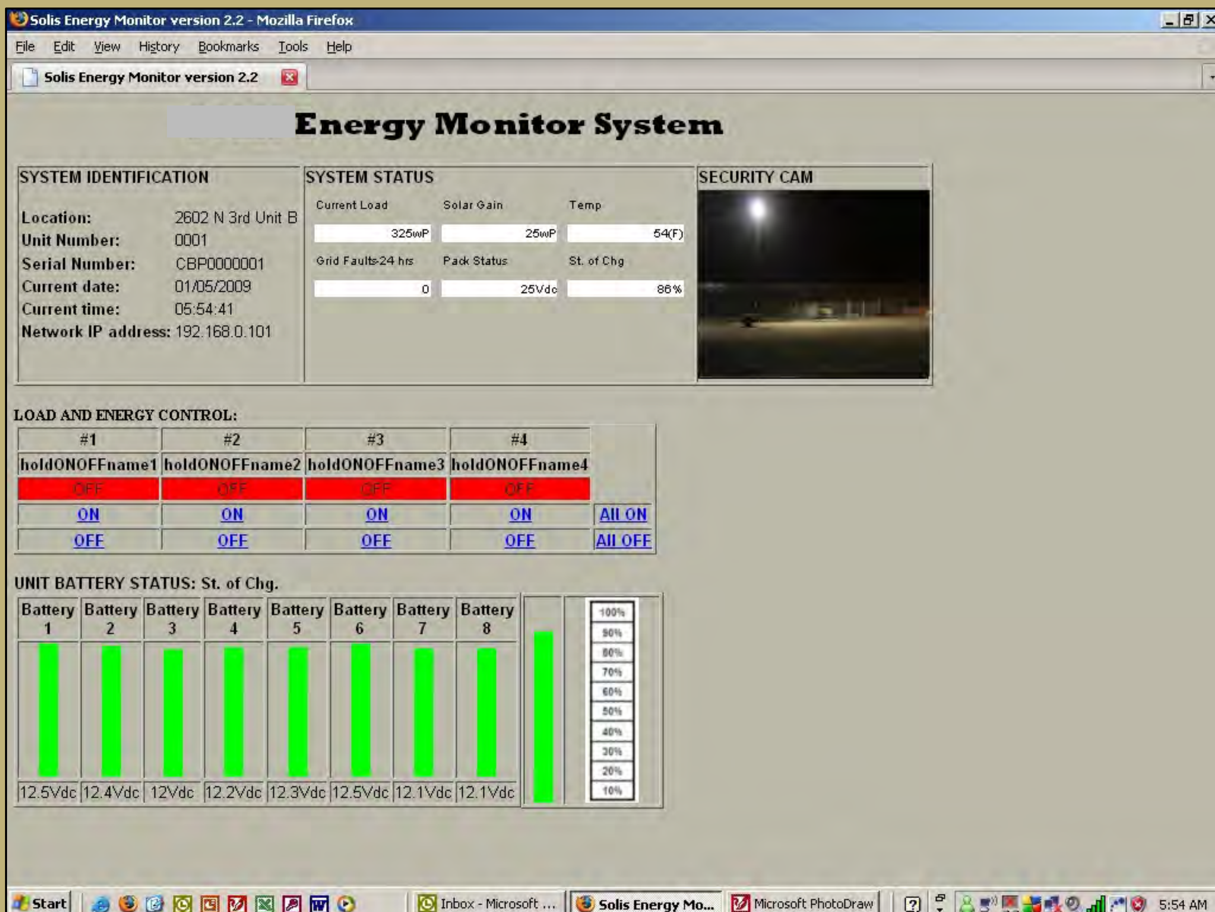
Sources

Energy Management

Loads

Smart Micro Grids

Should provide interactive monitoring & control



From HQ

From the field

Smart Micro Grids

Should communicate status/problems

Smart Micro Grids

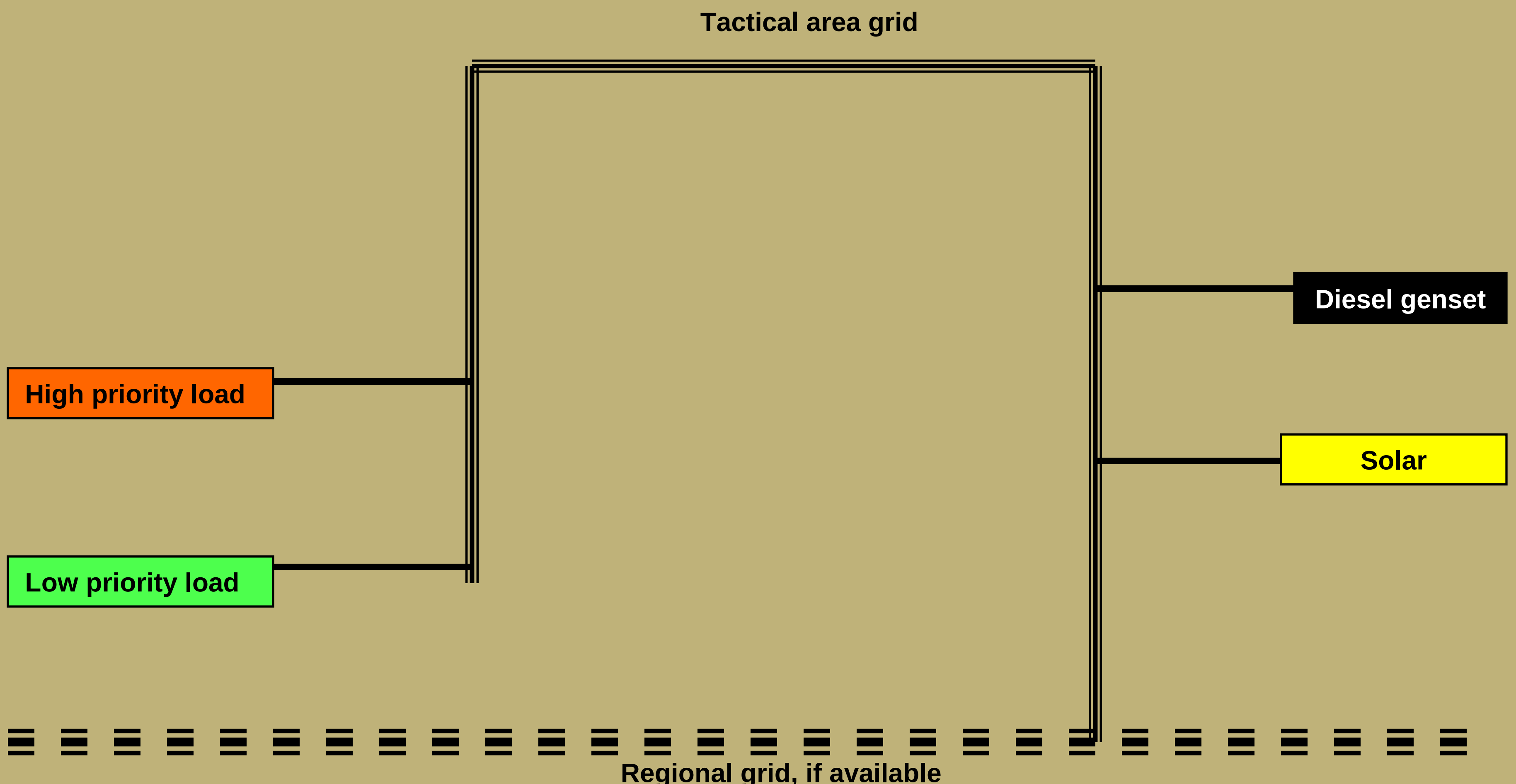
Should prioritize power distribution

Smart Micro Grids

Should employ advanced system security techniques

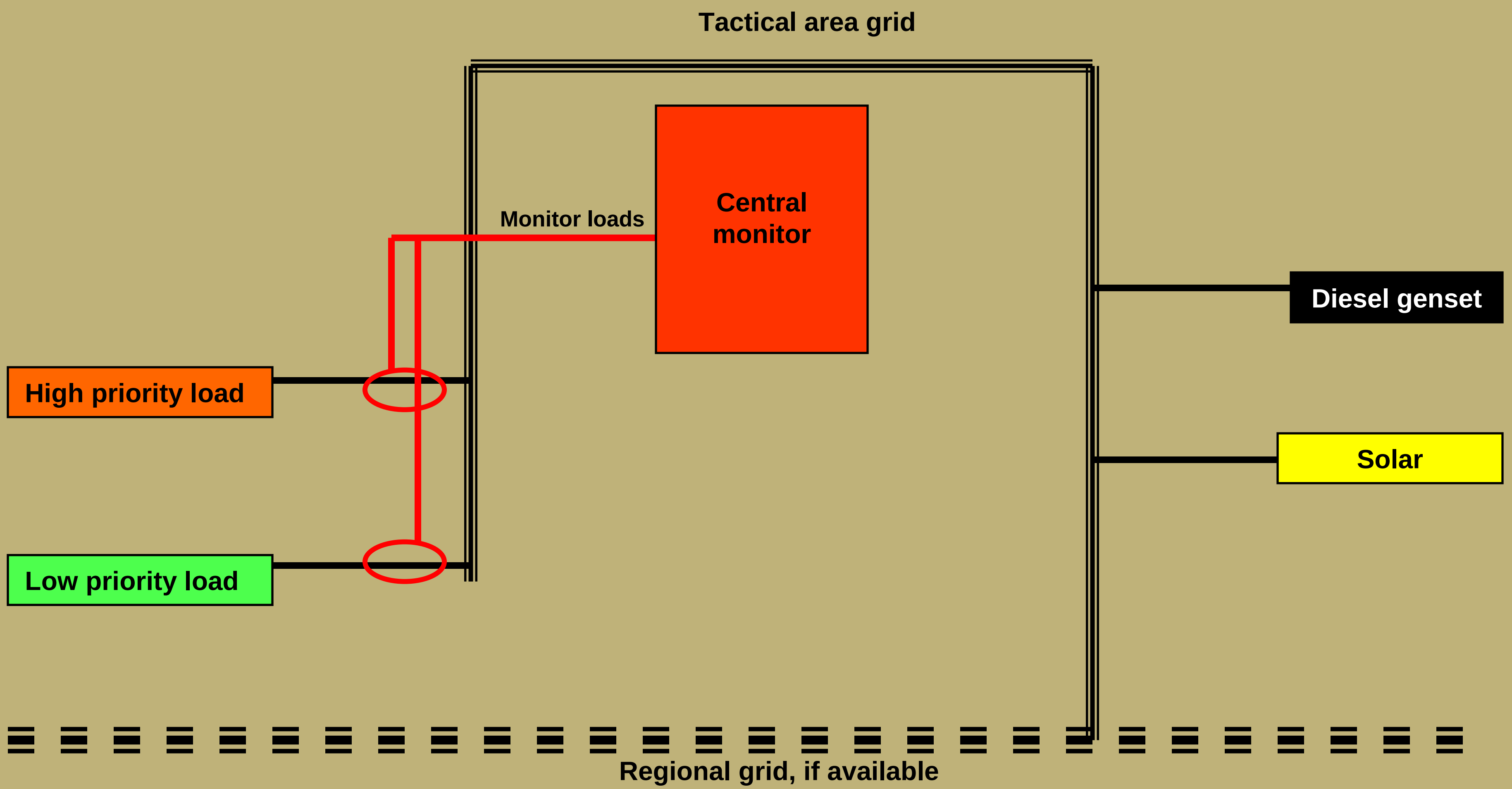
NEST Smart MicroGrid

Patent Pending



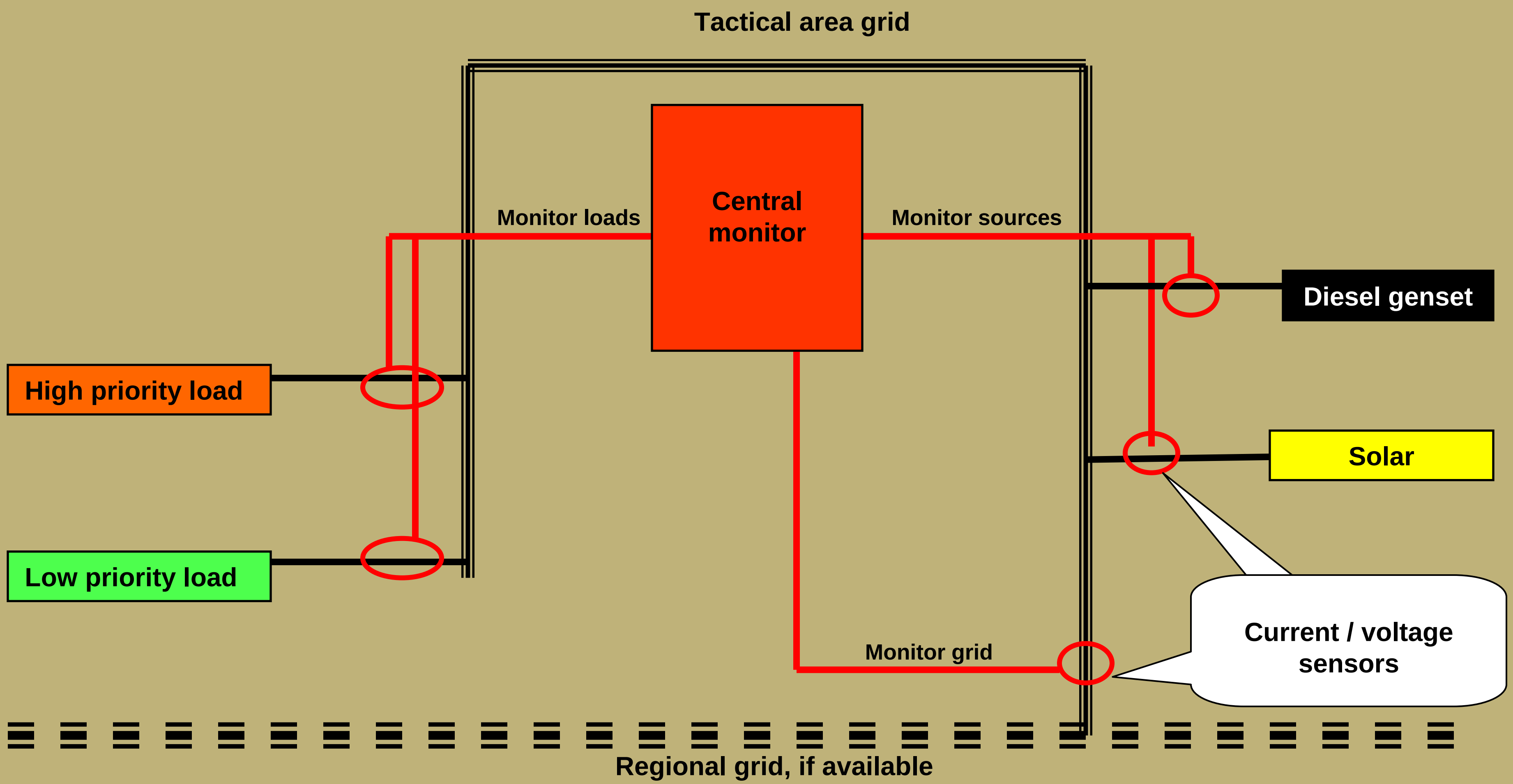
NEST Smart MicroGrid

Patent Pending



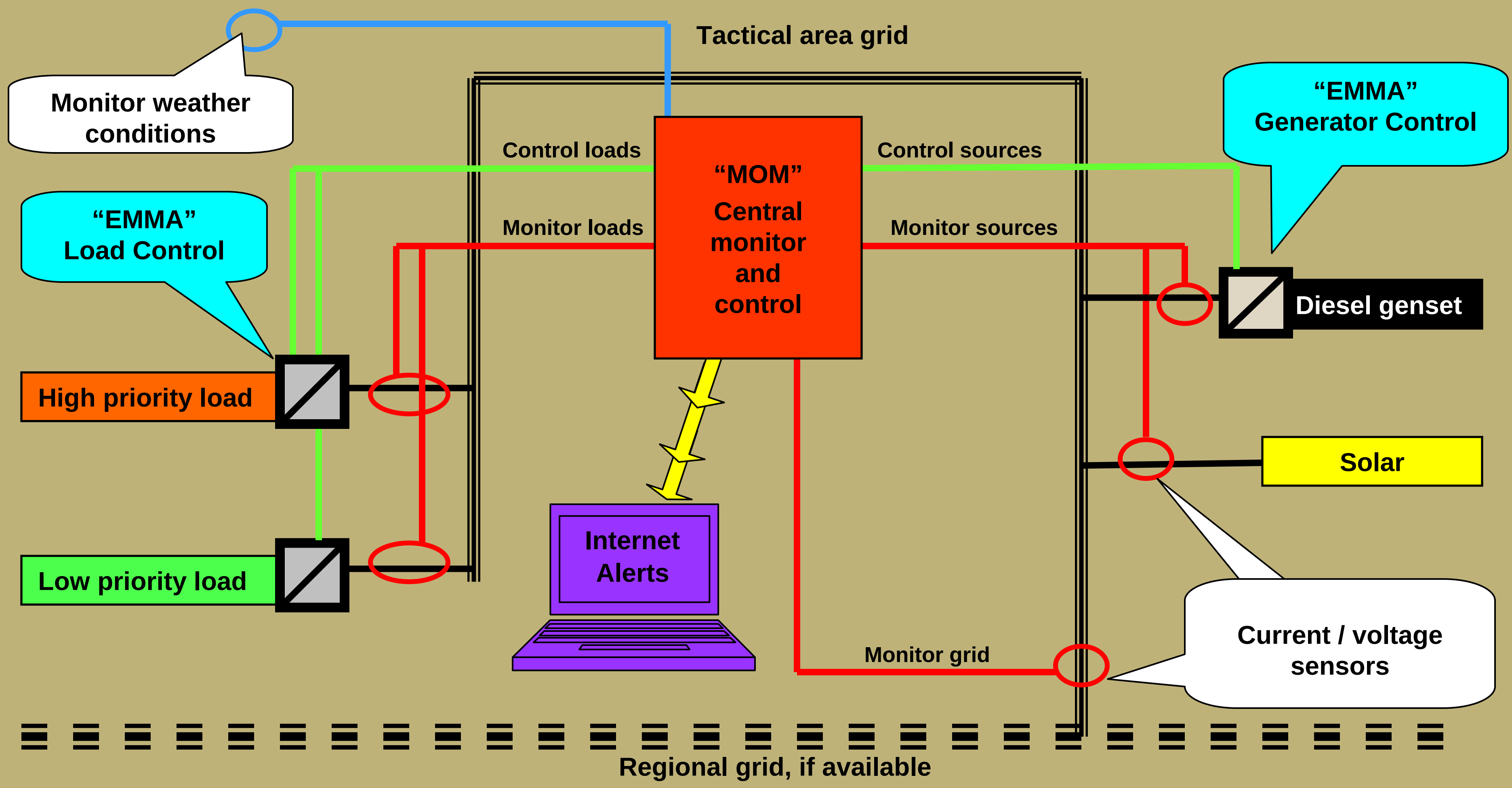
NEST Smart MicroGrid

Patent Pending



NESTSmart MicroGrid

Patent Pending

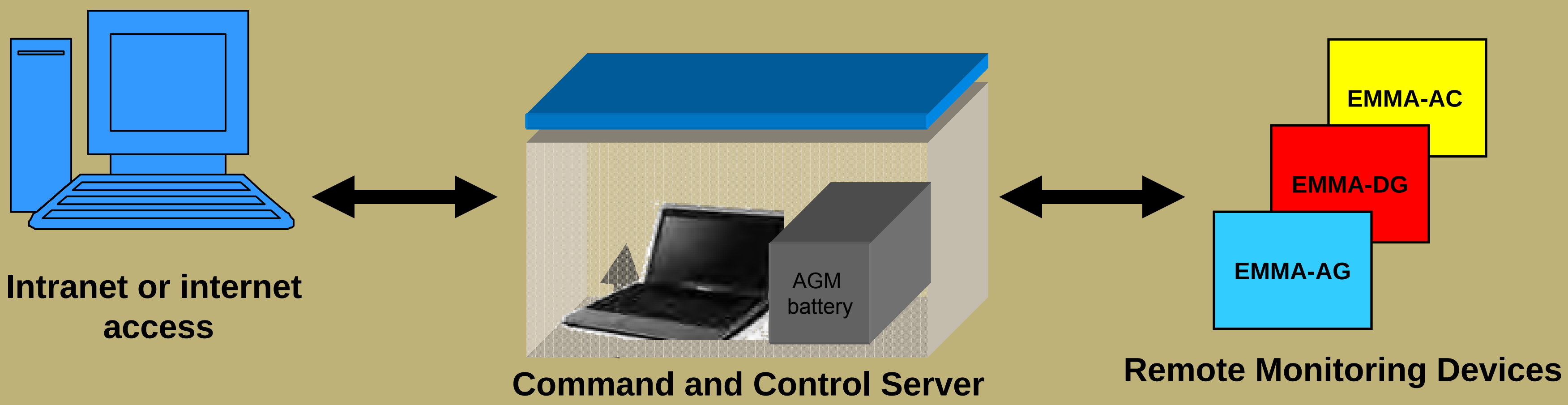


NESTSmart MicroGrid

Patent Pending

MOM

Master Onsite Monitor



NEST Smart MicroGrid

Patent Pending

EMMA

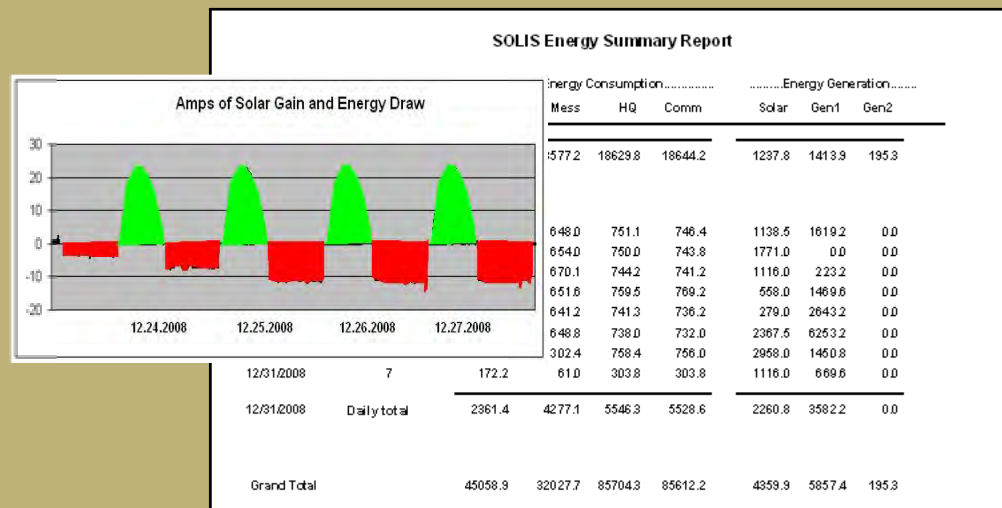
Energy MicroGrid Monitoring Apparatus

NEST Smart MicroGrid

Patent Pending

SOLIS™

Energy Management & Communications

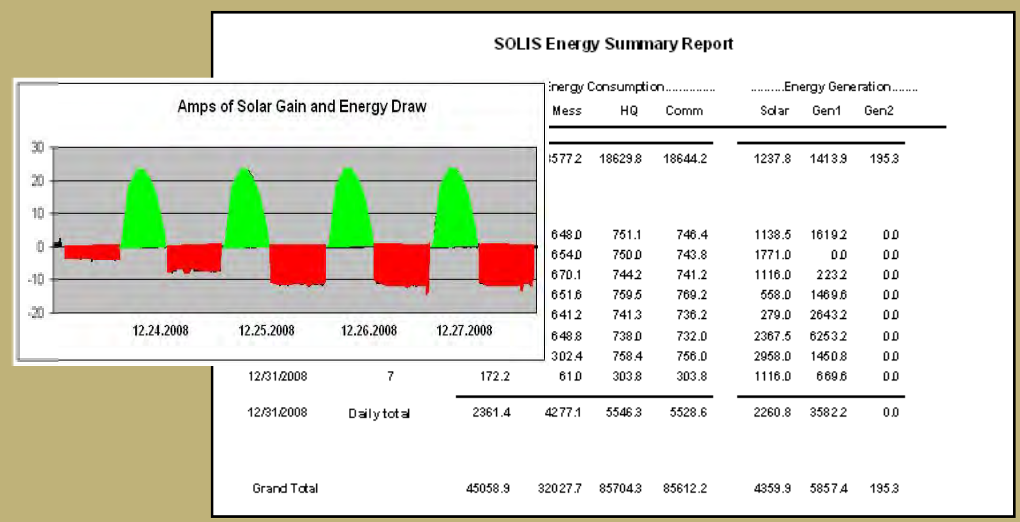


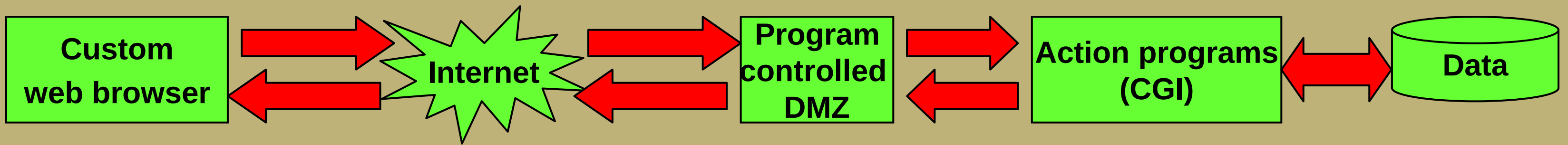
NEST Smart MicroGrid

Patent Pending

SOLIS™

Energy Management & Communications





NEST Smart MicroGrid

Patent Pending

NEST Smart MicroGrid

Patent Pending

MOM-Master Onsite Monitor

EMMA-Energy MicroGrid Monitoring Apparatus

SOLIS™-software and communications

NEST Energy Services LLC

www.nestenergyservices.com

ENERGY SERVICES


The Solinator®

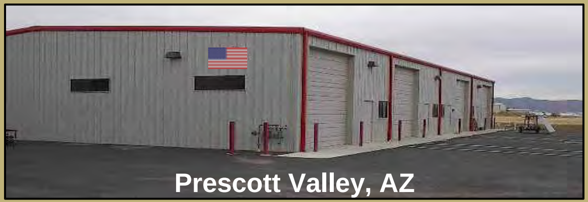

Raptor Surveillance


Solar –powered Light Trailer


Condor Solar Station


Eagle Solar Station

GSA Advantage! www.gsaAdvantage.gov Contract GS-07F-9584S


Prescott Valley, AZ

DOD EMALL www.emall.dla.mil

TOLL-FREE: 877-640-4701

8392 ~ by Edward J. O'Rourke

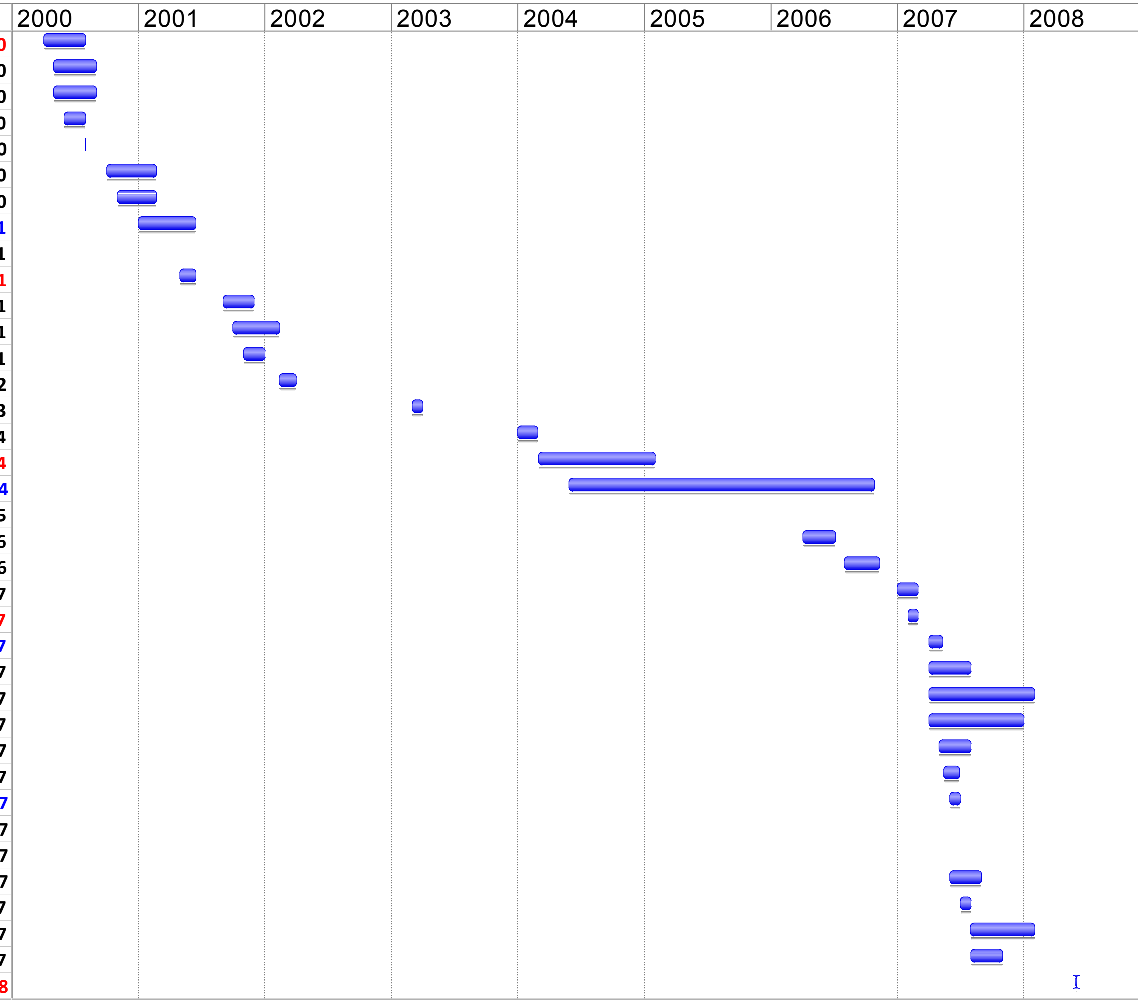
QP-1800 Inverter System – USMC Workhorse

Abstract

- The Iris Technology QuietPower 1800 (QP-1800) has been the workhorse inverter for the Marine Corps for 10+ years now. Iris Technology traces the development history of this rugged and reliable DC/AC 1800W inverter platform from initial deliveries to the current day. The QP-1800 has served with distinction in three conflicts and is widely available in several configurations on multi-year contracts with DLA and GSA.

Development Timeline

ID	Task Name	Start
1	Field trials with 11th Marines	Mon 4/3/00
2	Prototype mods to Inverter 287A101	Mon 5/1/00
3	NATO Cable, 10 ft, 1/0 AWG Designed	Mon 5/1/00
4	Initial military manuals produced PN 287F701	Thu 6/1/00
5	Initial Product Deliveries [303]	Tue 8/1/00
6	Cable safety issues discovered	Mon 10/2/00
7	NATO Cable, 12 ft, 2/0 AWG Designed	Wed 11/1/00
8	Military testing - SPAWAR [324]	Mon 1/1/01
9	NSN Assignments (Initial)	Thu 3/1/01
10	System qualified by SPAWAR for PM INTEL	Tue 5/1/01
11	Initial fielding to PM INTEL	Mon 9/3/01
12	Supplemental Training Document	Mon 10/1/01
13	Alternator overload condition addressed	Thu 11/1/01
14	On-site training for IMEF INTEL operators	Tue 2/12/02
15	Prototype transportation case 287A108	Mon 3/3/03
16	Field Expedient Cable Procedure	Thu 1/1/04
17	Army USACAPOC Support	Mon 3/1/04
18	Military testing - Crane, IN [717]	Fri 5/28/04
19	Bronze Award from DLA / DSCR	Wed 6/1/05
20	Component modification to shock material	Mon 4/3/06
21	Preparation of Product ICD	Tue 8/1/06
22	System qualified by MARCORSYSCOM	Mon 1/1/07
23	GSA / BPA Awarded by USMC [900]	Thu 2/1/07
24	Military testing - Dayton, NY	Mon 4/2/07
25	Redesigned compact transport case 287A108	Mon 4/2/07
26	Revised military manuals produced PN 287F701	Mon 4/2/07
27	Support to USMC to design Quick Start guides	Mon 4/2/07
28	Mounting Plate designed and tested at APG	Tue 5/1/07
29	DTB Rewrite of User Manual	Tue 5/15/07
30	Military testing - Env Assoc	Fri 6/1/07
31	NSN Assignments (Additional)	Fri 6/1/07
32	Bronze Award from DLA / DSCR	Fri 6/1/07
33	Development of Standard Work Instr	Fri 6/1/07
34	Revised grounding label	Mon 7/2/07
35	JEH Rewrite of User Manual	Tue 7/31/07
36	Selection of Manufacturing Partner	Wed 8/1/07
37	Gold Award from DLA / DSCR	Fri 5/30/08

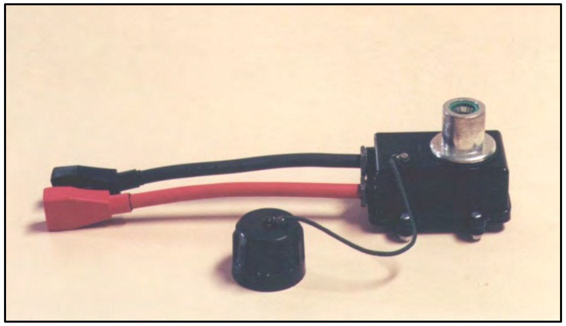


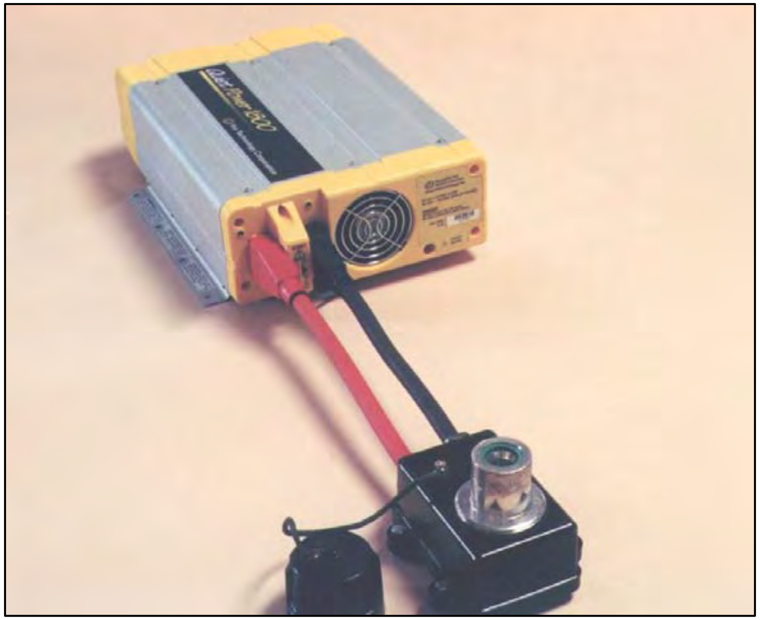
Specifications

- ***Power (Cont / Surge)*** 1800 W / 2900 W
- ***Output Waveform*** True Sine Wave
- ***Input Voltage Range*** 20 - 32 VDC
- ***Weight of Inverter*** 16.5 lbs (7500 g)
- ***Weight of Cables*** 18.0 lbs (8200 g)
- ***Weight of Case*** 20.0 lbs (9100 g)
- ***Size of Inverter*** 15.4 x 11.0 x 4.5 in^3
- ***Size of Cables*** 144.0 x 4.0 x 3.5 in^3
- ***Size of Case*** 22.1 x 17.9 x 10.4 in^3
- ***Operating Temp*** -20 / +60 °C (-4 / +140 °F)
- ***Storage Temp*** -30 / +70 °C (-22 / +158 °F)

Note: Low Temperature (-20 °C) Operation

History ~ Cables

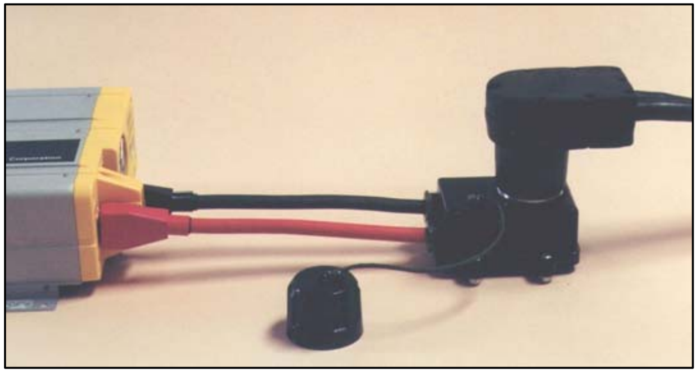




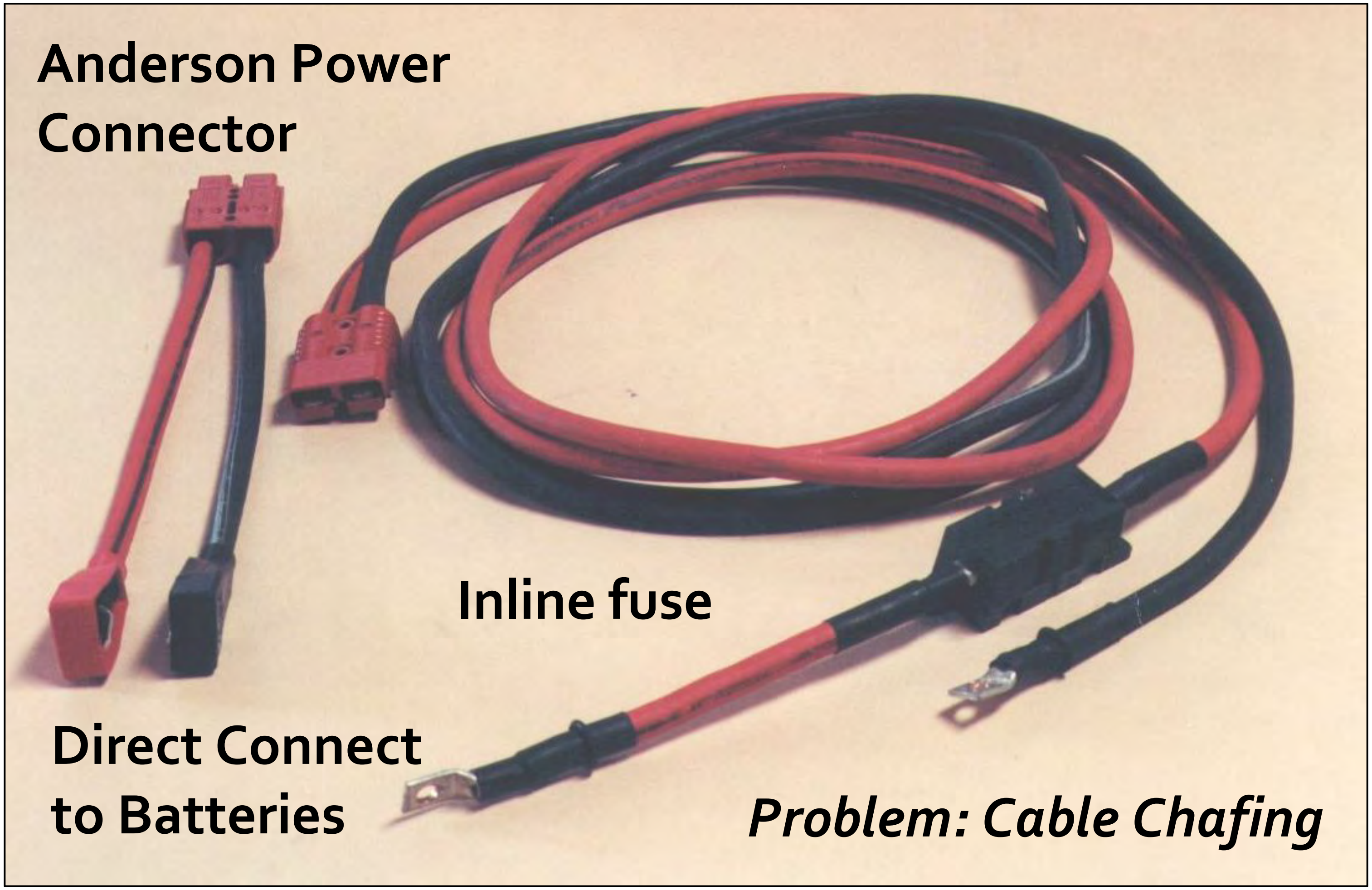
SLAVE Receptacle

Promote use of standard SLAVE Jump Start Cable (also, save weight and cost)

Problem: Modification of Existing Required Hardware



History ~ Cables



History ~ Cables

Hi-Flex SLAVE Cable
Problem: Durability

NATO SLAVE
QP-1800 Cable
PN 287A106

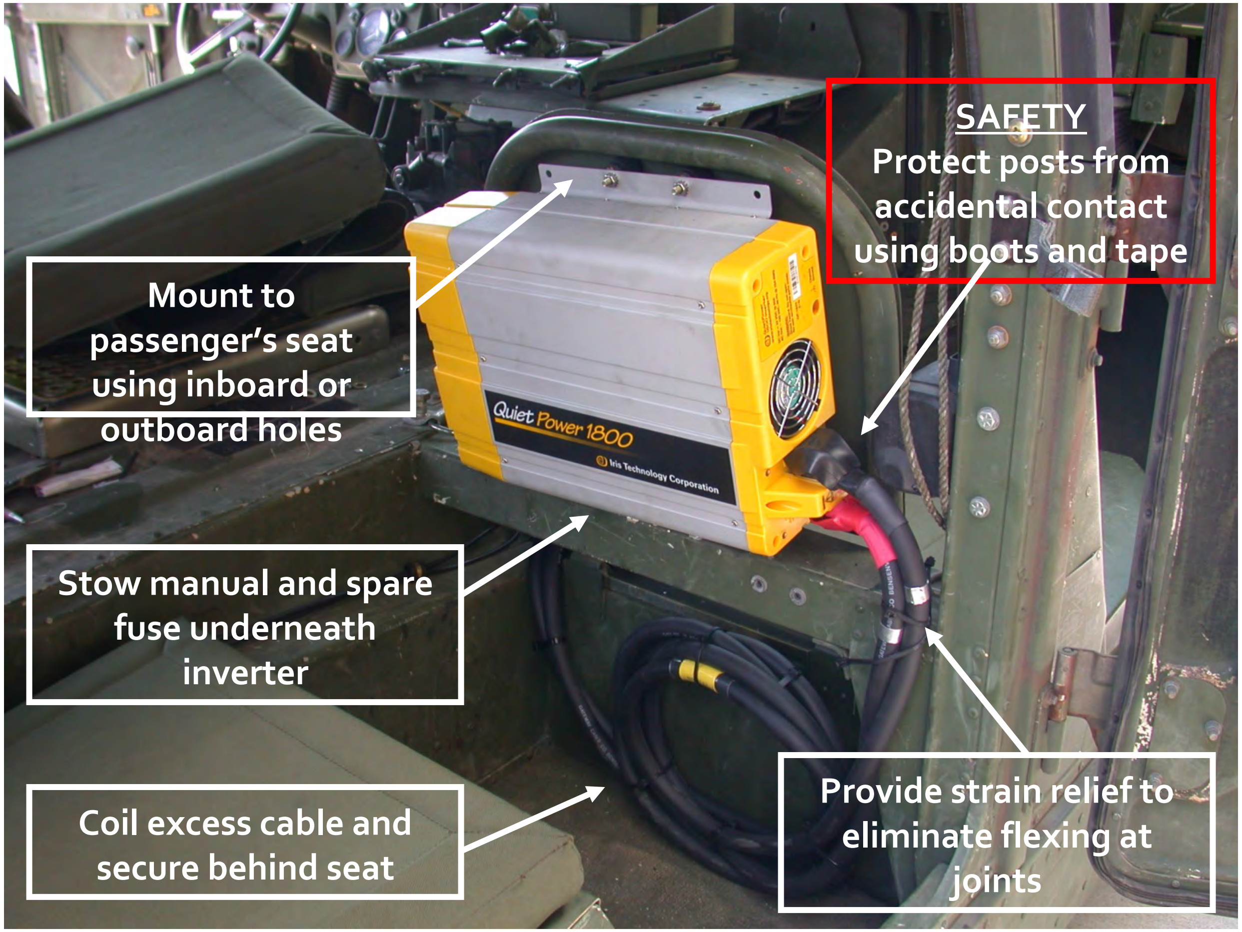
History ~ Cases

Is / OUTSIDE
22.1" x 17.9" x 10.4"
(560 x 455 x 265 mm)

Was / OUTSIDE
24-13/16" x 19-3/8" x 13-7/8"
(63 cm x 49.2 cm x 35.2 c

USACAPOC Install

United States Army
Civil Affairs and Psychological Operations Command



Vibration Testing

Transportation Testing

Power Tidbits

Volume 4 Issue 1 (14 June 2008) // pm_eps@nmci.usmc.mil

"Fielding of the QP-1800 began during the 3RD Quarter FY08. The distribution plan is provided in Appendix A of the QP-1800 Fielding Plan (FP 11460A, PCN 132 114600 00) dated 28 September 2007.

"The QP-1800 DC/AC Inverter System consists of the Inverter (NSN 6130-01-496-6448), Carrying Case (NSN 7050-01-551-0600), and NATO cable (NSN 6150-01-497-2515). Vibration Isolators and one spare fuse are provided with each Inverter. The QP- 1800 is a semi-ruggedized inverter that connects to a military vehicle 24 volt DC (VDC) power system through the supplied NATO slave cable and converts 24 VDC (vehicle power) to 115 VAC (True Sine Wave), 60 Hz at 1800 Watts(W).

"... The QP-1800 Inverter System is a SAC 1 Type 2 allowance item and can be procured from Iris Technology Corp., via GSA contract GS-07F-0131N or from DLA using the listed above.

USMC Reference

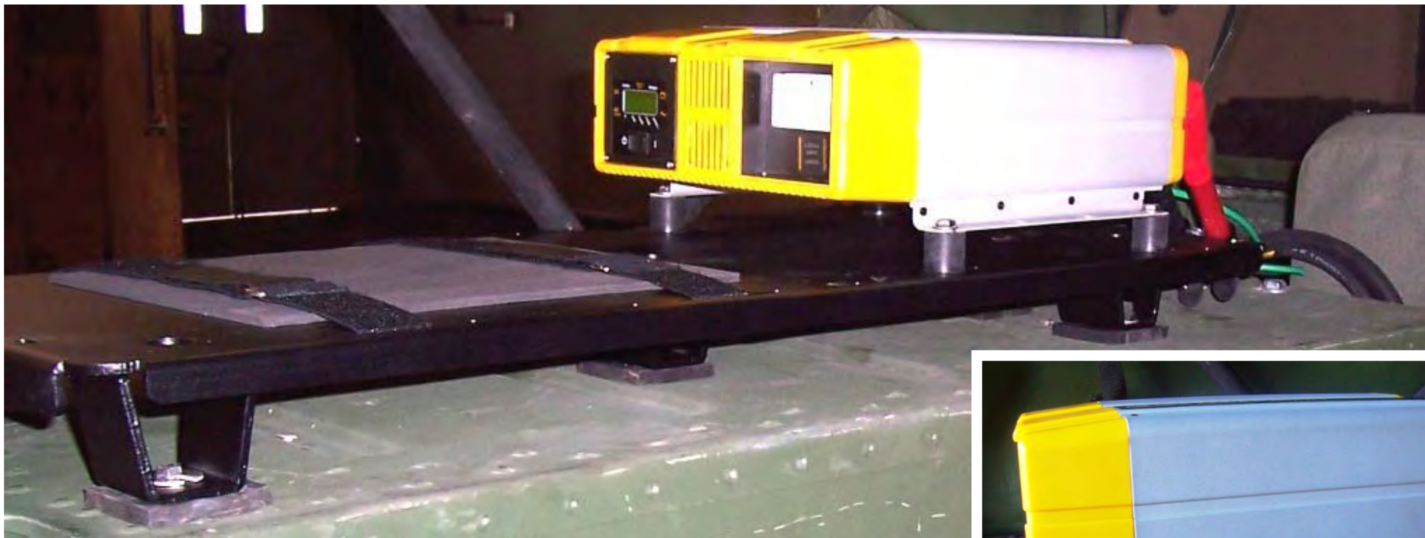
QP-1800 Inverter System

- *TAMCN - H0004*
- *NSN - 6130-01-552-6350*
- *ID - 11460A*
- *SAC - SAC 1*
- *Warranty – Two years*

Publications

- *TM 11460-OR/1 PCN 500 114600 00*
- *SL-3-11460A PCN 123 114600 00*
- *Job Aid (refer to page 13 of this newsletter)*

QP-1800 Mounting



"MI 11460-OI/1 provides instructions for installing the QP-1800 in non-armored HMMWV's using the vehicle mounting bracket or directly to the top of the wheel well.

"When the wheel well contains air conditioning components, use of the vehicle mounting bracket is MANDATORY. Vibration isolators are MANDATORY regardless of the method of installation used."

Applications

Open Contract Vehicles

- GSA / FSS
  - GS-07F-0131N
- USMC / BPA
  - M67854-07-A-5022
- DSCR / IDIQ
  - SPM4LG-08-D-0018

Questions

- Equipment on display in Booth 314

Power Management for Heavy Tactical Vehicles

Presented to:

NDIA Joint Service Power Expo

May 7, 2009

Chris Rogan, P.E.
Penn State ARL

Penn State University Applied Research Lab

- Established by U.S. Navy in 1945
- Designated a University Affiliated Research Center (UARC) in 1988
- Largest research unit within PSU with more than 1,200 faculty and staff
- Approximately $150M in research funding in FY2008
- Role: serve as trusted agent for DoD
- Mission: Research, Tech Transfer, Education
- University Resources: College of Engineering, PA Transportation Institute, Materials Research Lab

Penn State ARL

ARL is primarily a science and technology-based laboratory with leadership in the following core competencies:

- Acoustics
- Guidance and control
- Power / energy systems
- Hydrodynamics, hydroacoustics, propulsor design
- Materials and manufacturing
- Navigation and GPS
- Communications and information
- Systems Engineering
- Graduate education

Power System "Needs" for Heavy Tactical Vehicles

- Improved reliability – power whenever it's needed
- More power available during 'normal operation' – i.e., power for air conditioning, C4ISR, CREW, IED countermeasures, lighting
- More power / longer operation during 'silent watch'
- Reliable engine starting
- Reduced logistics burden
- Lower lifecycle costs
- Simplified maintenance and diagnostics

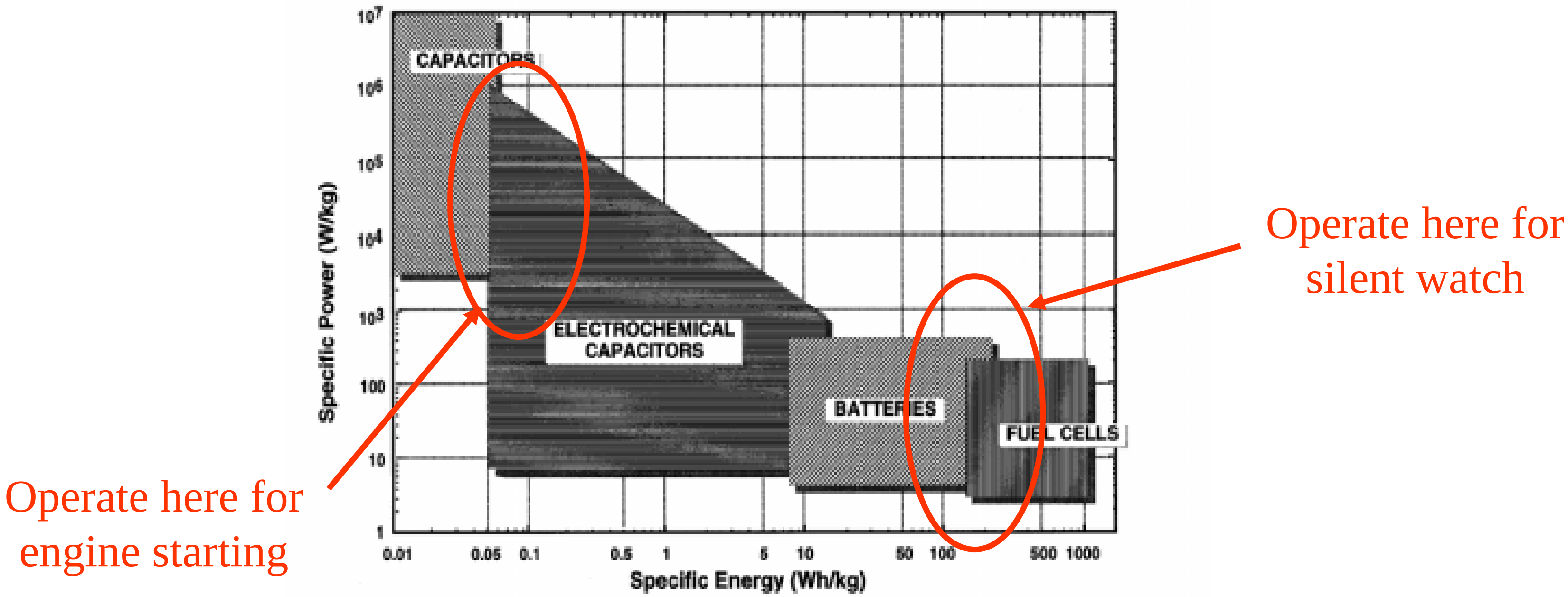
Battery graveyard in Kuwait

Primary Power Management System (PPMS)

- Common vehicle power & energy architecture
- Configurable for specific missions
- Split energy storage system
  - Ultracapacitor for vehicle starting
  - Deep cycle batteries for silent watch
- Hydraulically-driven generator for high power drive & accessory loads
- Planetary Gear Starter
- Integrated power management & control
- Integrated CBM+
- VCS monitoring and control

Split Energy Storage System Design Benefits

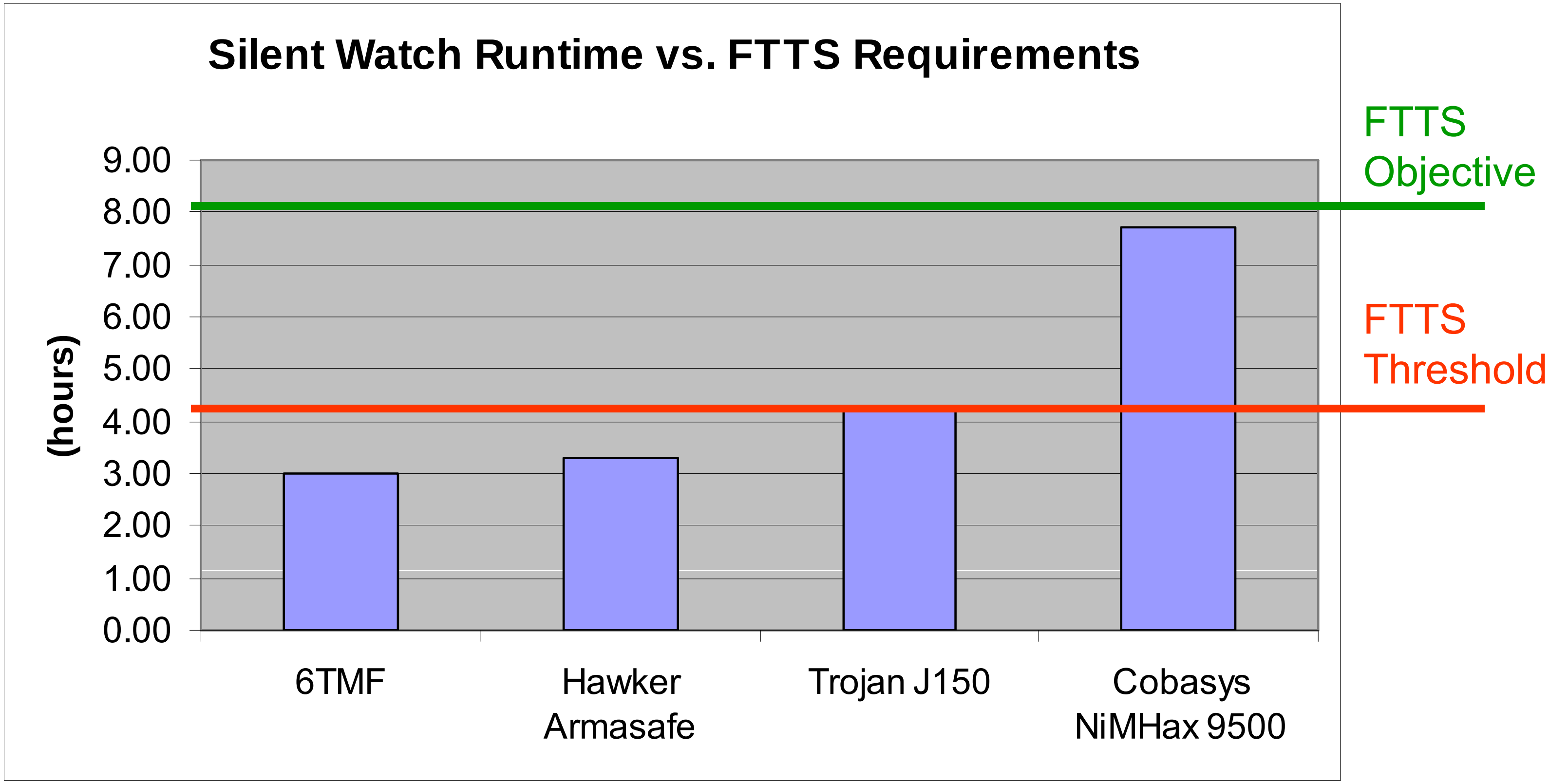
- Separate the two different power requirements
  - High <u>power</u> for engine starting (more CCAs)
  - High <u>energy</u> for silent watch (deep cycle application)
- No battery exists that can be optimized for both functions
  - Use appropriate technology for each requirement



Split Energy Storage System Design Benefits

- Utilize ultracapacitors for engine starting
  - Ultracaps rated for 100K's of cycles
  - More reliable starting than batteries (even w/ battery monitoring)
- Use the appropriate battery technology for specific silent watch requirements
  - One vehicle configuration regardless of battery chemistry
  - Lead acid => inexpensive, sufficient energy for most missions
  - Li Ion, NiMH => for missions that require longer or higher power silent watch
  - Could integrate fuel cells as they become available in future

Energy Storage for Silent Watch



Silent watch runtime estimates based on 60A loading @ 24VDC, with battery pack of equivalent size/weight to that of (4) 6TMF batteries

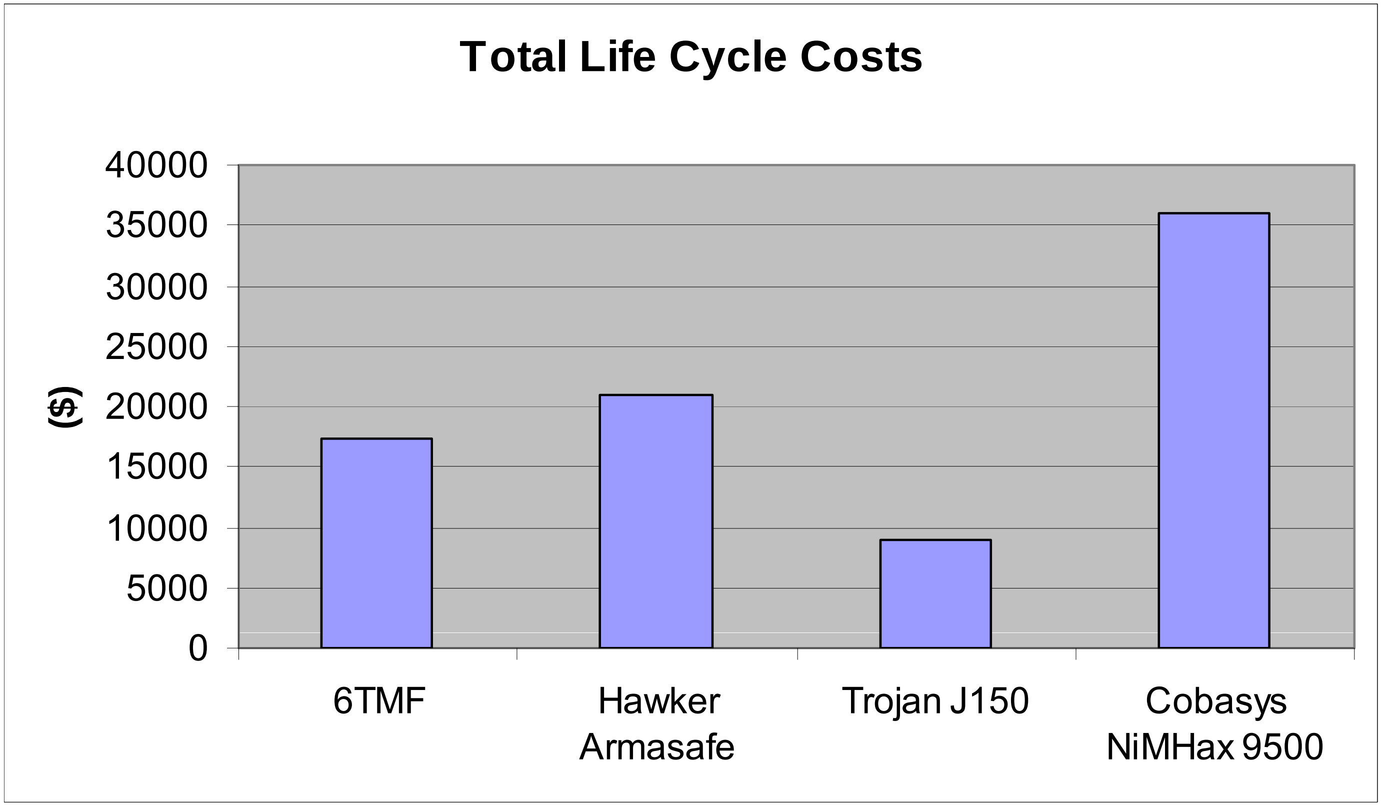
6TMF

Hawker Armasafe

Trojan Lead Acid Deep Cycle Battery

CobaSys NiMHax 9500

Energy Storage for Silent Watch



Lifecycle costs based on 25 year vehicle lifetime with two high intensity conflicts and 6000 charge/discharge cycles.

6TMF

Hawker Armasafe

Trojan Lead Acid Deep Cycle Battery

CobaSys NiMHax 9500

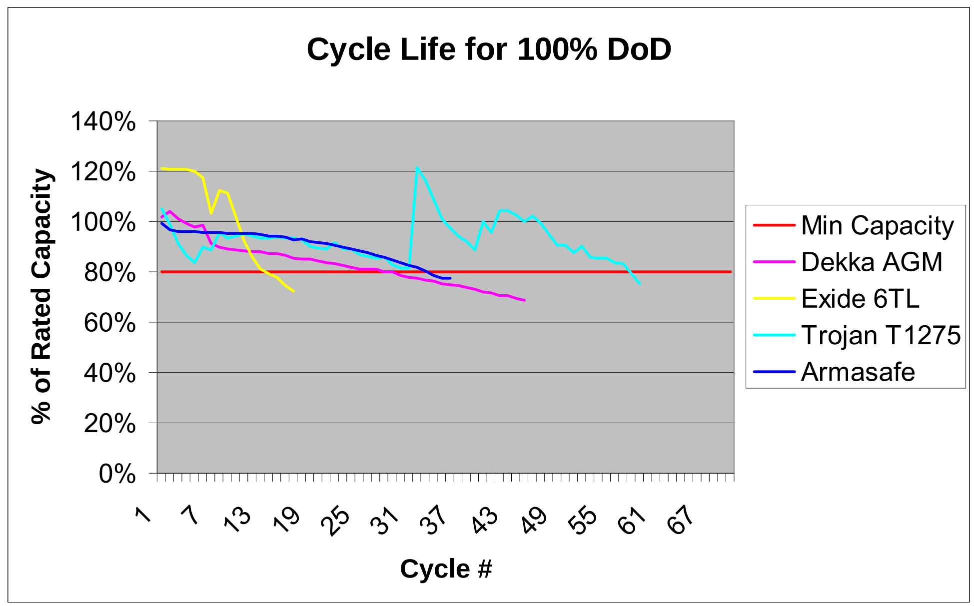
Deep Cycle Battery Testing

Purpose

- Test and characterize silent watch run-time under different operating conditions
- Characterize battery lifetime (lifecycle costs) based on operating cycles

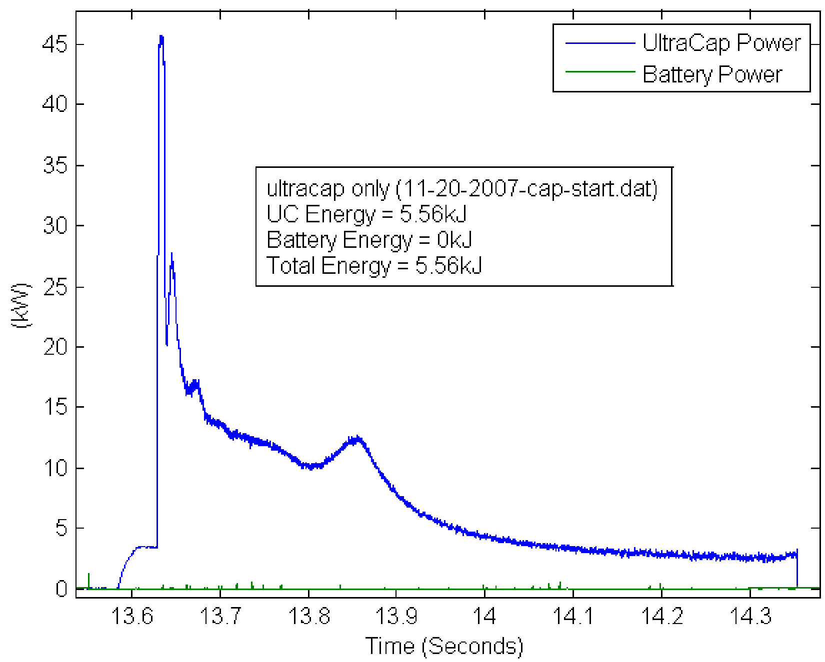
Battery test station

- 4 electronic load banks and power supplies
- LabVIEW software-controlled
- Run 4 independent load profiles simultaneously
- Equipped with a freezer and high temp chamber for testing at environmental extremes



Currently cycling 6T-style flooded lead acid batteries from Axion Power

Energy Storage for Engine Starting



ESMA 28V Ultracap
(provided by KBI)

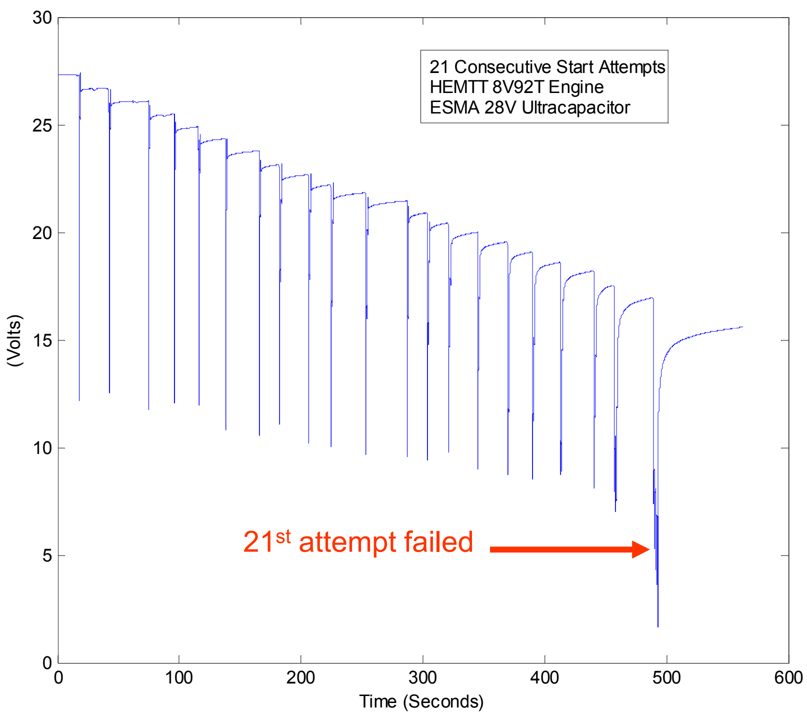
- Peak power plotted comparable or better than that of four 6T lead acid batteries
- Less affected by low temp's (compared to batteries)
- Easy to accurately measure ultracap SOC
- Ability to recharge rapidly

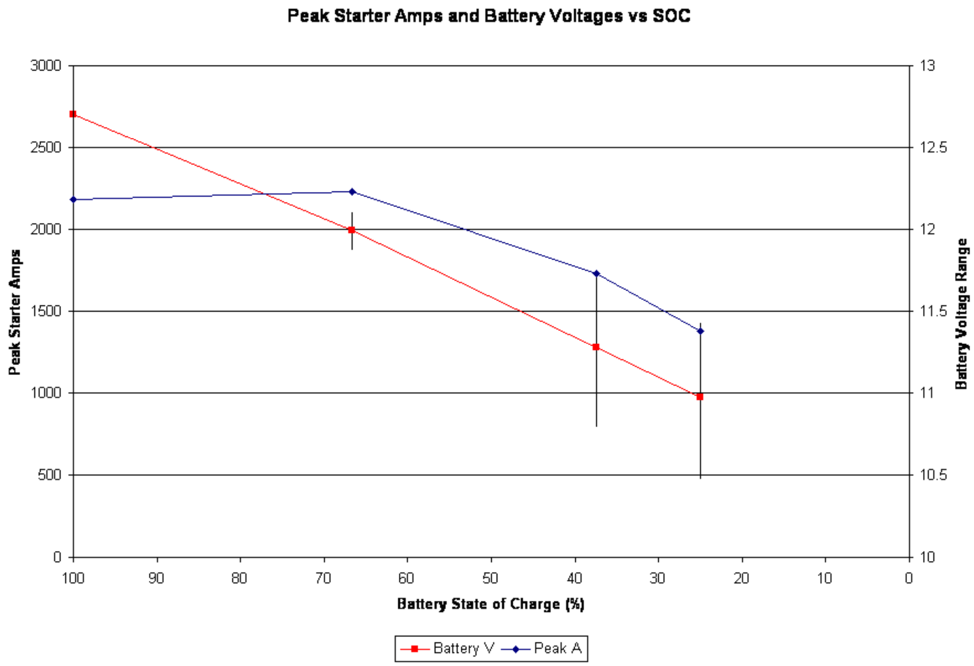
Energy for Engine Start
… some numbers

- Energy required to crank 8V92T @ 50^{o}F ~ 6KJ
- Energy stored in ESMA 28V Ultracap ~ 120KJ
- Energy stored in Hawker Armasafe 4-pack ~ 17,300KJ
- An engine crank @ 50^{o}F requires:
  - 5.0% of total energy in ESMA ultracap
  - 0.035% of the total energy in Hawker 4-pack

- **Question:** If stored energy is > 6KJ, will vehicle start?
- **Answer:** Yes, if sufficient power can be delivered

Energy for Engine Start





Ultracapacitor

- ESMA Cap ~ 120KJ
- Energy to start ~ 6KJ
- Per energy calcs, should get ~ 20 starts

Batteries

- Battery's ability to deliver power decreases with SOC
- Also affected by age/health

Energy for Engine Start

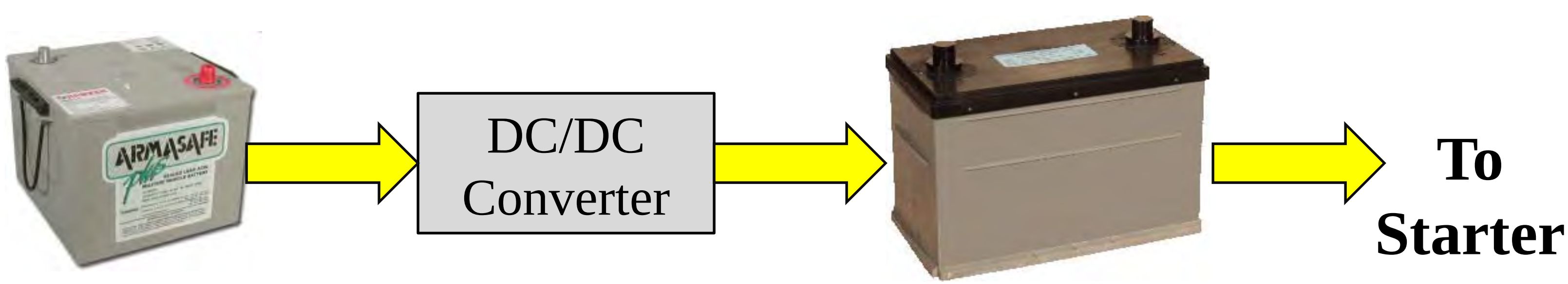
Battery SOC vs. Power

• Battery's ability to deliver power is reduced as SOC falls, and as batteries age

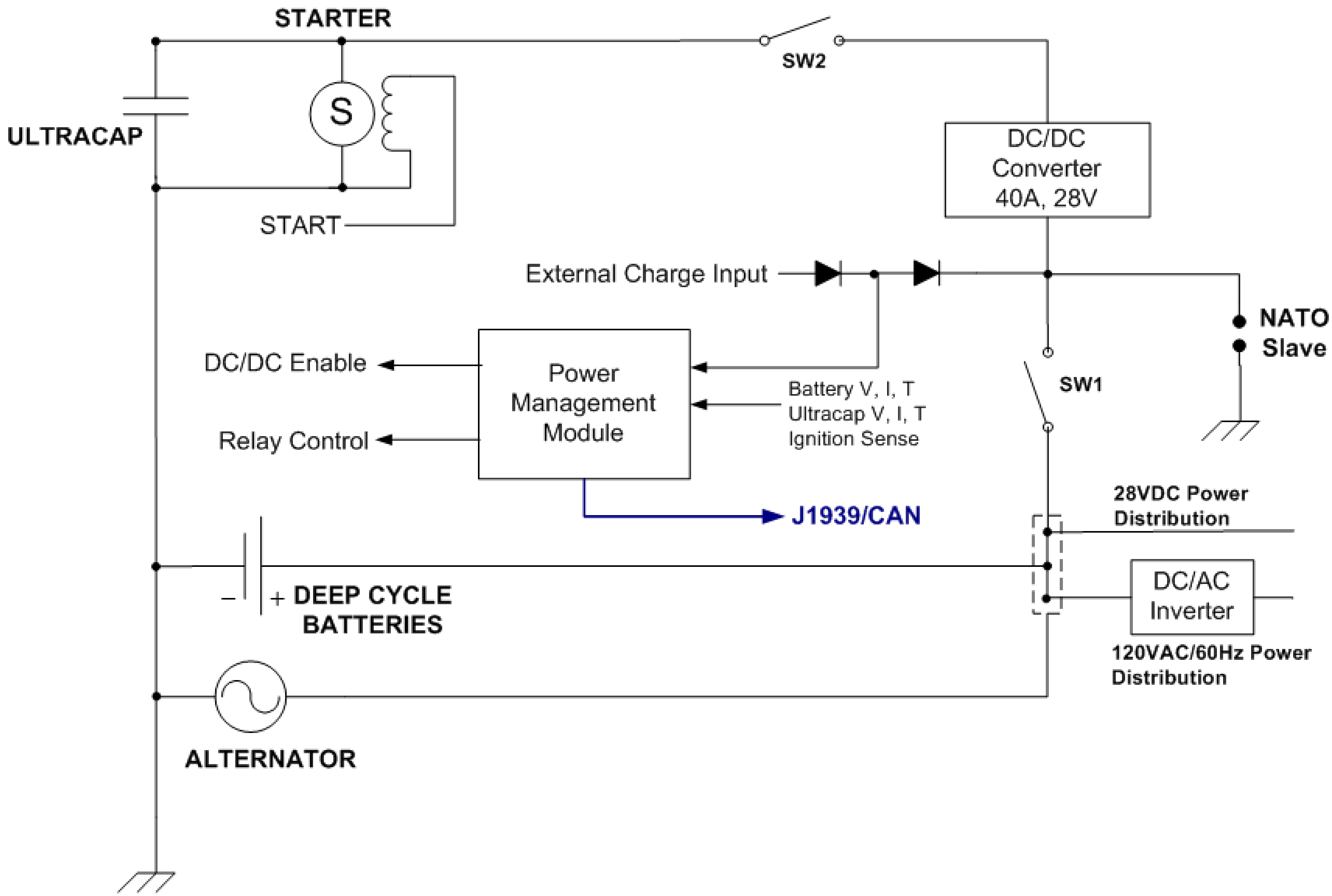
• Below 25% SOC may not be able to crank engine

- But battery pack still has much energy remaining

• **Solution:** use batteries to charge ultracap using DC/DC converter, ultracap delivers power needed to start vehicle



PPMS Architecture

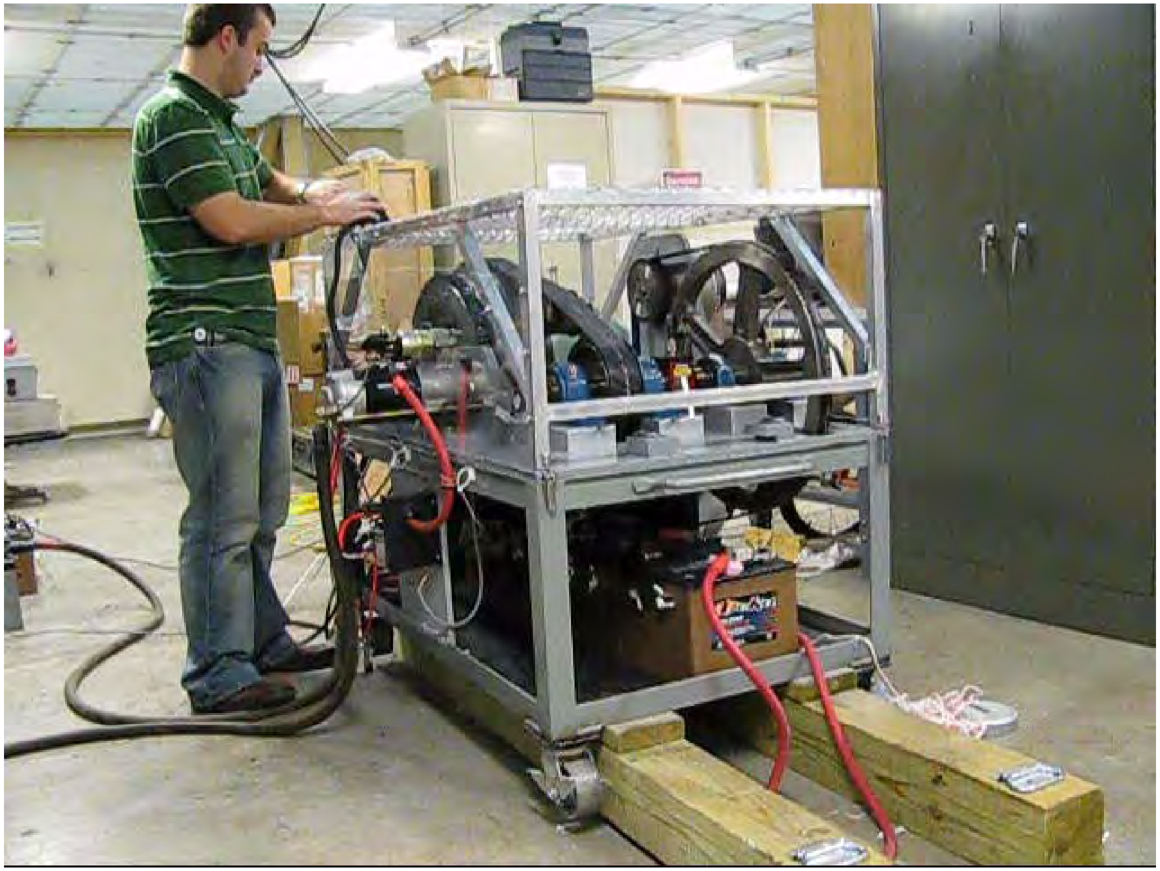


HILTEC Test Bench

Hardware-in-the-Loop Test & Evaluation Center

Purpose: simulate engine starting under a wide range of conditions in order to evaluate performance of engine starters and energy storage devices

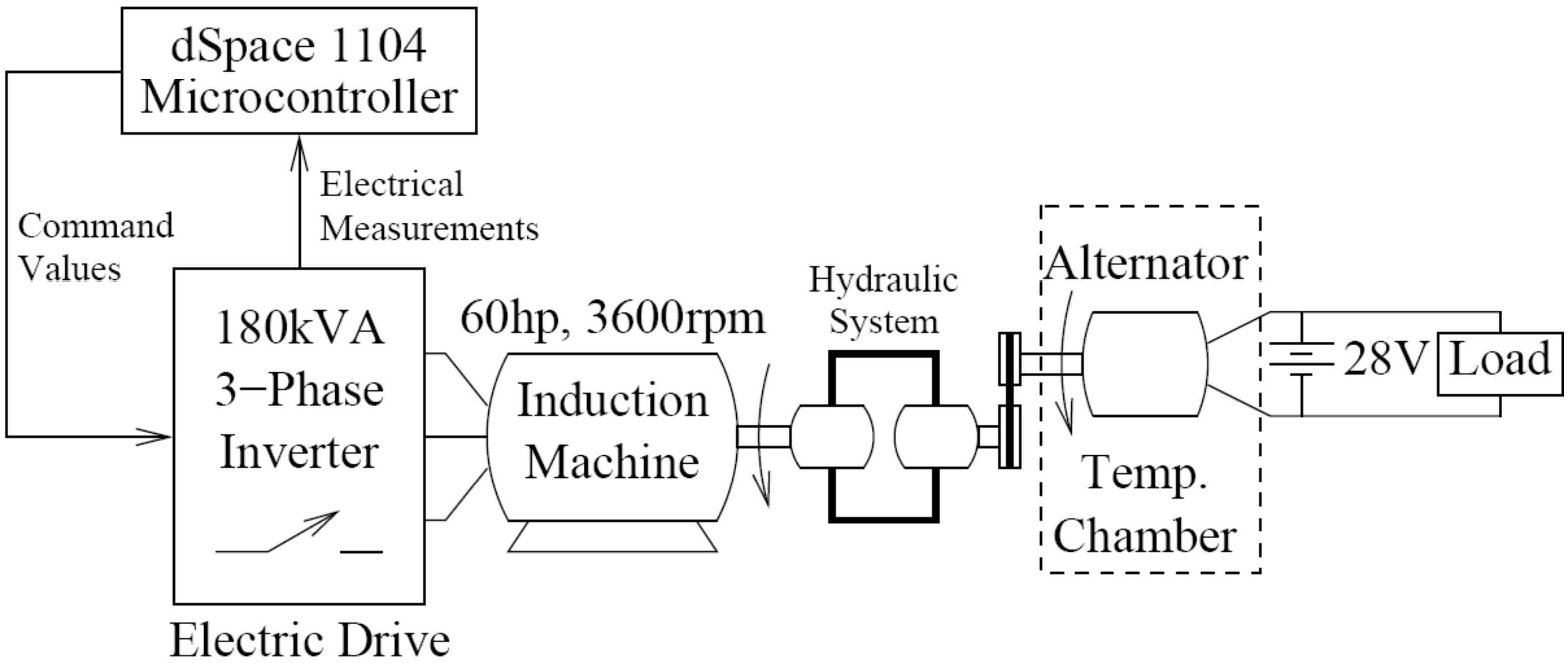
- Electric motors for assist/oppose torque
- Matlab Simulink models can be used to emulate different size engines



Hydraulic Power Generation

- Concept: install hydraulically-driven generator on vehicle for supplying high power loads
  - In place of large belt-driven alternators
- Benefits:
  - Alternator output is temp dependent, performance spec'd at 72F, but typically degrades at higher temps
  - Hydraulics allow flexibility of placement, can move alternator out of engine compartment
  - Not tied to engine speed (taken off PTO)
  - Low cost APU capability
  - Reliable operation, minimal maintenance required

Alternator Testbed



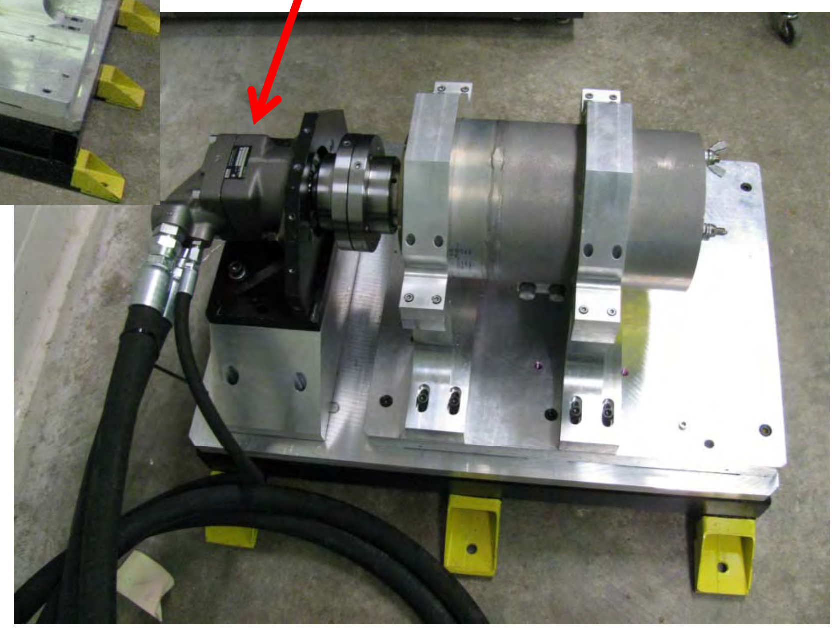
Purpose:

- Test alternators for performance vs speed, temperature

Alternator Testbed

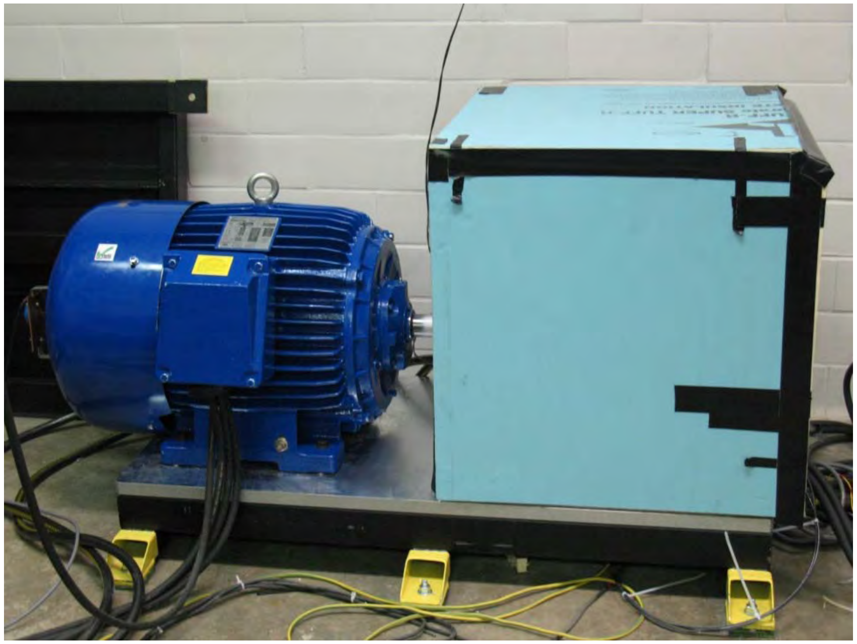
- 10 gallon reservoir
- Air-cooled heat exchanger with ¼ hp motor

Parker F11-019-HU-SV-T Hydraulic Motor
- 30kW mechanical power @ 8000rpm in spec'd system



Eaton 70360 Hydraulic Pump
- Manually-Controlled Displacement
- 48kW continuous hydraulic power @ 3600rpm

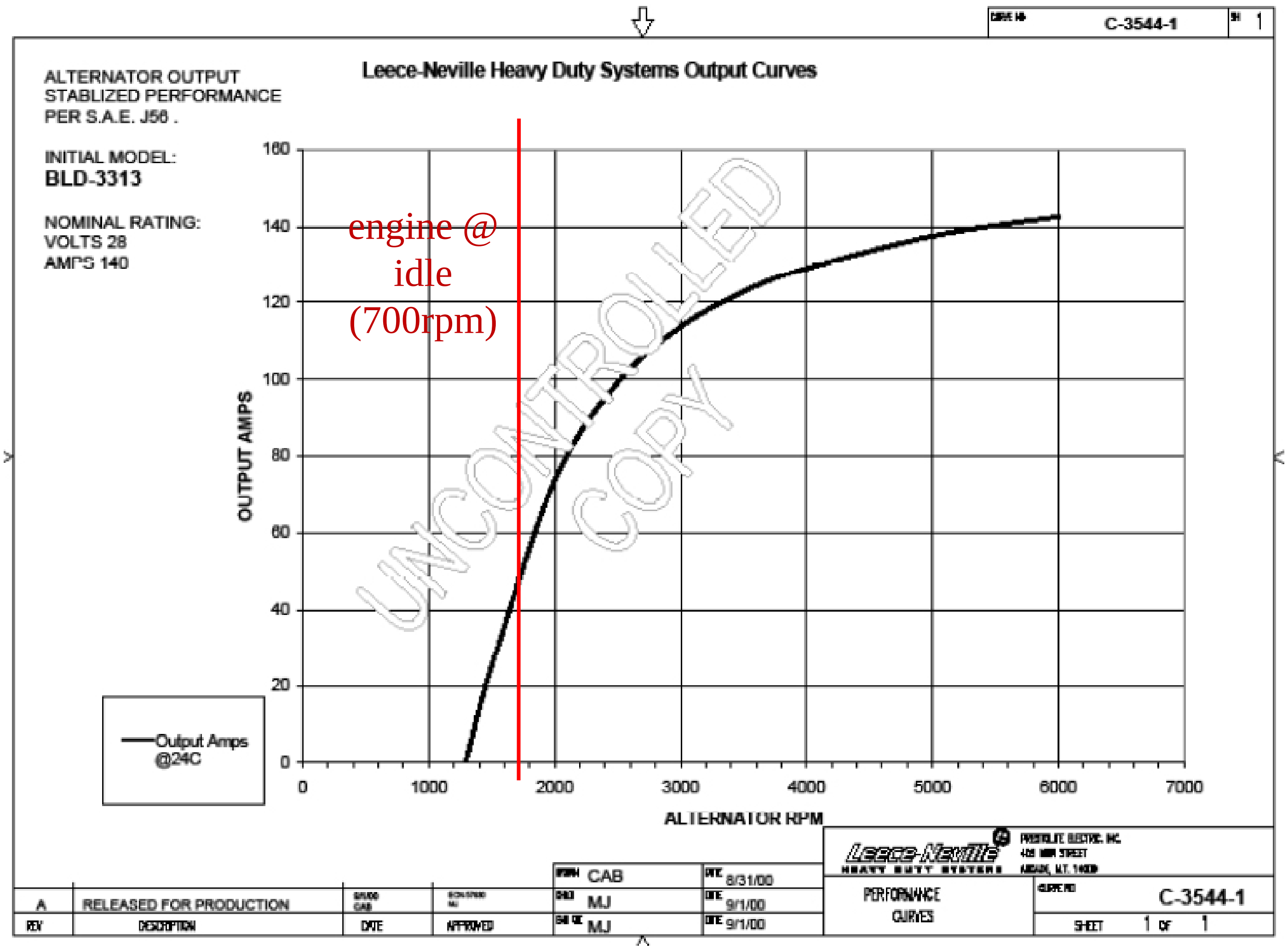
Alternator Direct Drive Testing



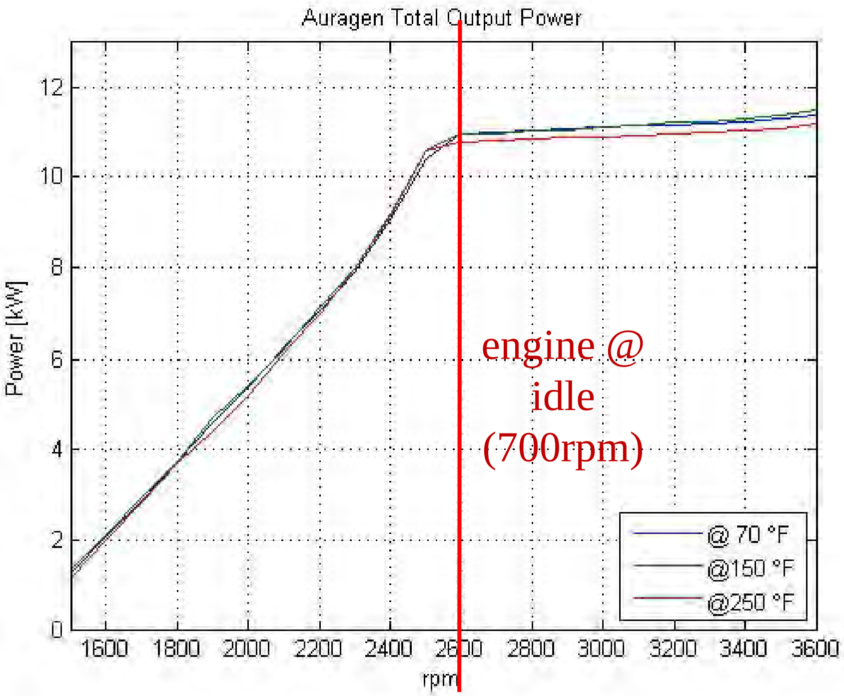
- Conducted prior to hydraulics implementation
- Alternator enclosed in heat chamber (70-250F)
- 400A DC load banks
- **Alternators tested:** Prestolite SF252, AuraGen TANGEN G8500YC, EMP Power 450
- **Yet to be tested:** Prestolite C-3544-1 (baseline), Niehoff 1602-1

Prestolite C-3544-1

140 amps (per spec)

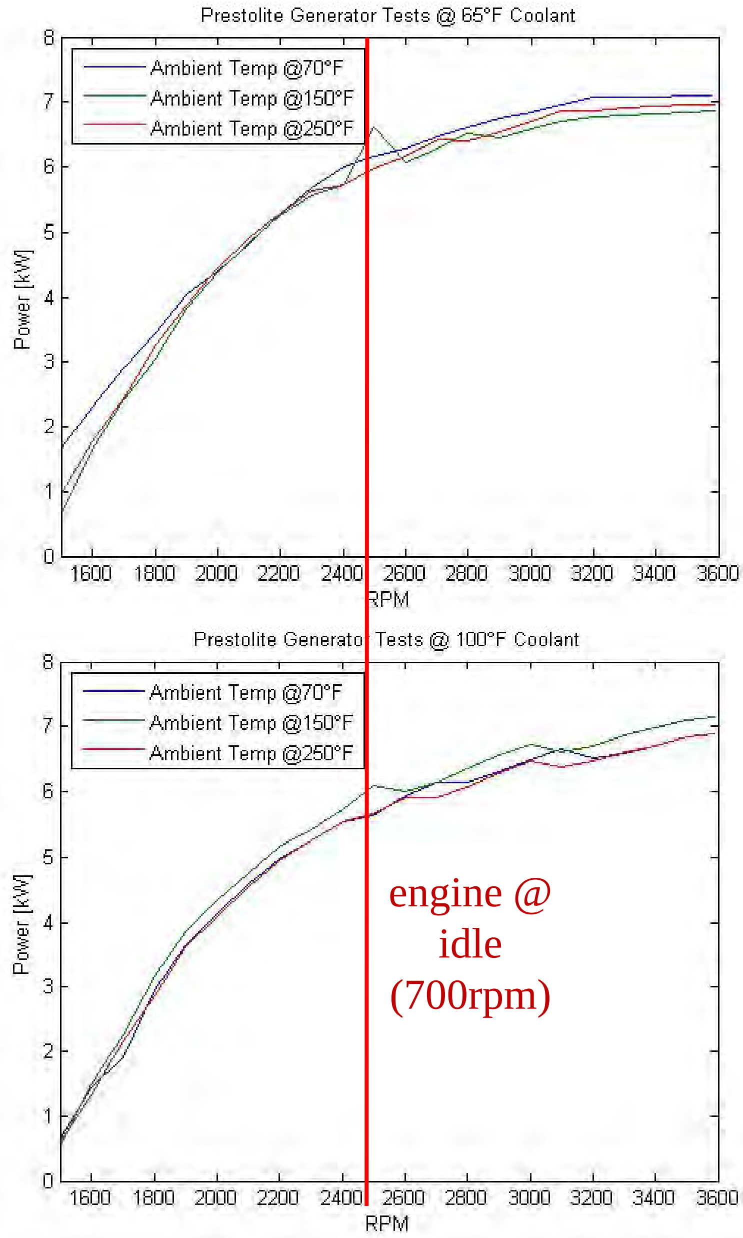


AuraGen TANGEN G8500YC



- Dual 8500W alternators with inverter charger system
- 500A @ 28VDC, 2x33A @ 240VAC
- Curve to right is DC power only
- Little degradation in power output at high temps

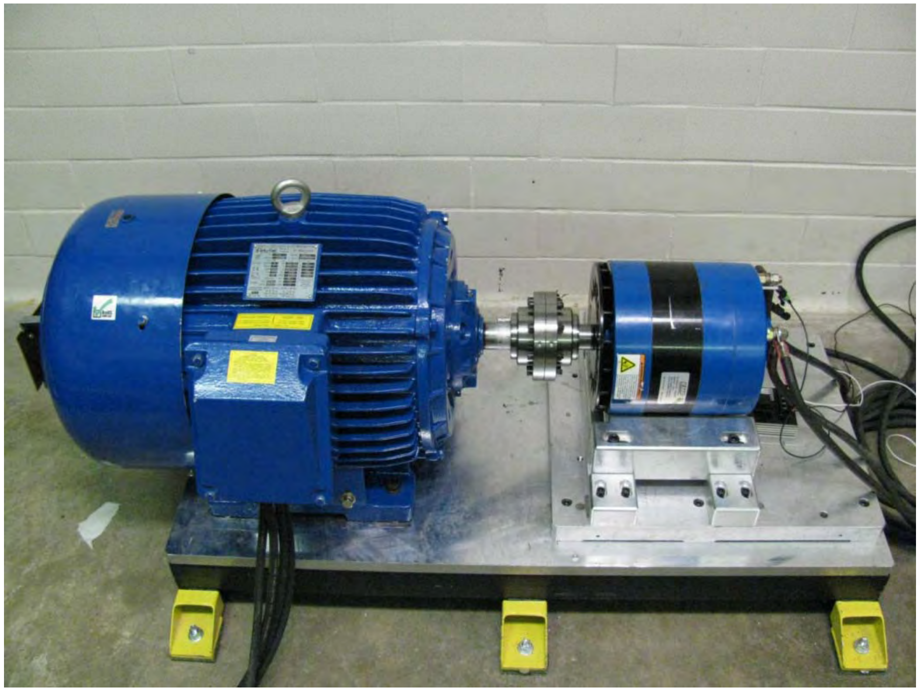
Prestolite SF252

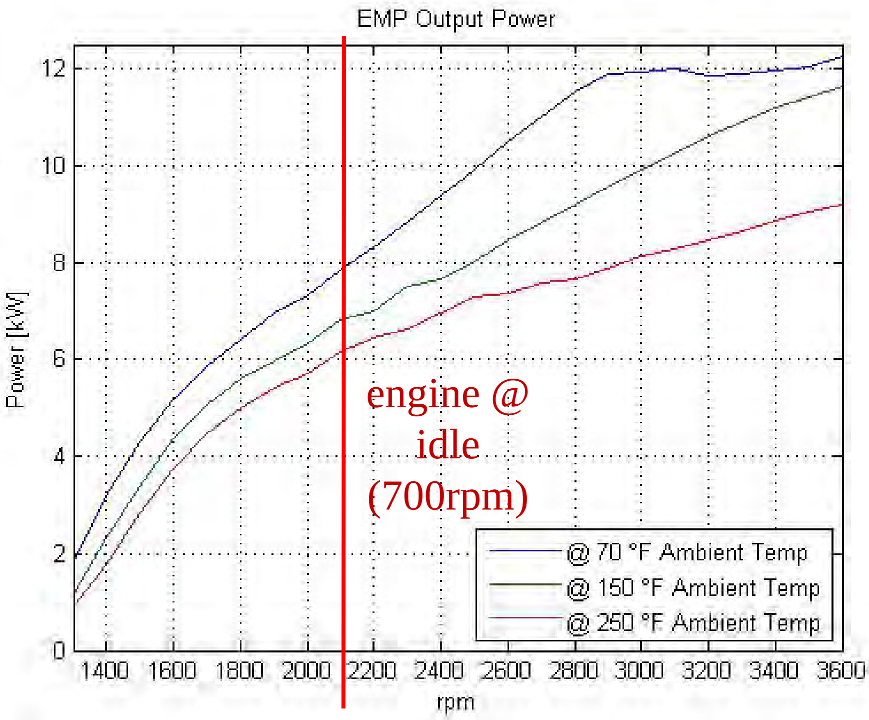


- 300A @ 28VDC
- Brushless, water-cooled AC generator, integrated rectification
- Need to test at 212F coolant temp

EMP Power 450

PENNSTATE ARL





- 450A @ 28VDC
- Brushless, air-cooled alternator

CBM and On-Vehicle Sensor Integration

CBM applied to existing vehicle data sources

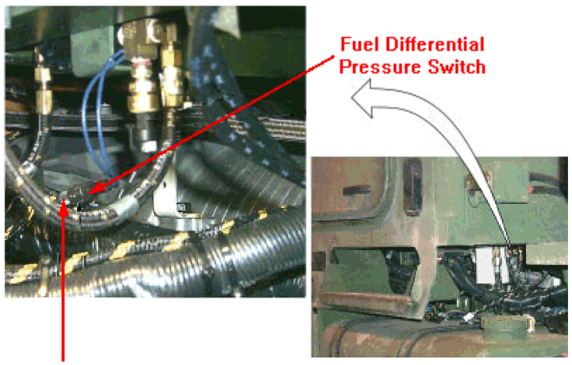
- Open data sources: J1939, J1708
- Proprietary data sources: ADM diagnostic messages, ADM operational parameters

CBM applied to new sensors

- Engine oil condition analysis
- Engine oil level
- Transmission oil level
- Coolant sensor level
- Hydraulic system
- Fuel level
- Fuel filter condition
- Air filter condition
- Tire pressure monitoring
- Brake wear monitoring

CBM applied to power system components

- Alternator V, I, T
- Battery V, I, T, SOC, SOH
- Ultracap V, I, T, SOC



Vehicle Control System

Hardware agnostic

- Software developed using Microsoft XNA Game Studio
- VCS tied to vehicle CANbus backbone
- Control of PPMS, display system operational parameters, display CBM updates, etc

Conclusions

- Penn State modeling /evaluation capabilities:
  - Hardware-in-the-Loop for simulated engine starting
  - Battery Test Station for cycle life & performance evaluation
  - Alternator Test Station for power vs. speed, temperature characterization
- PPMS and CBM+ solutions being implemented on HEMTT A2 Wrecker
- Technologies available today can provide a means to meet present day power demands
- System architecture will allow for rapid implementation of future technology improvements

Questions / Comments

- **For more info, contact:**

  - Chris Rogan, Penn State ARL
    cmr109@psu.edu
    (814)865-7337
  - Brian Murphy, Penn State ARL
    bjm206@psu.edu
    (814)865-9036
  - John Johnson, PM-HTV, TACOM
    john.w.johnson@us.army.mil
    (586)574-6924

Acknowledgement:
This work was supported by the US Army TACOM, PM Heavy Tactical Vehicles, SFAE-CSS-TV-H, Contract Number N00024-02-D-6604

Thanks to following companies who have donated equipment for this program:
AuraGen, Prestolite, EMP, Axion Power, Deka, KoldBan Inc, Nippon, Korry

Maximizing Power from the Stock Alternator Using a Practical Constant Speed Drive

Fallbrook Technologies Inc.

- **Small Business**
  - Delaware C Corp.
  - < 60 employees
- **Company Footprint**
  - Headquartered in San Diego, California
  - Engineering center based in Austin, Texas
  - Branch sales office in Detroit, Michigan
  - Manufacturing in Leitchfield, Kentucky
- **Fallbrook is the Company, NuVinci is the Brand**

What Is The Problem With Engine Driven Accessories?

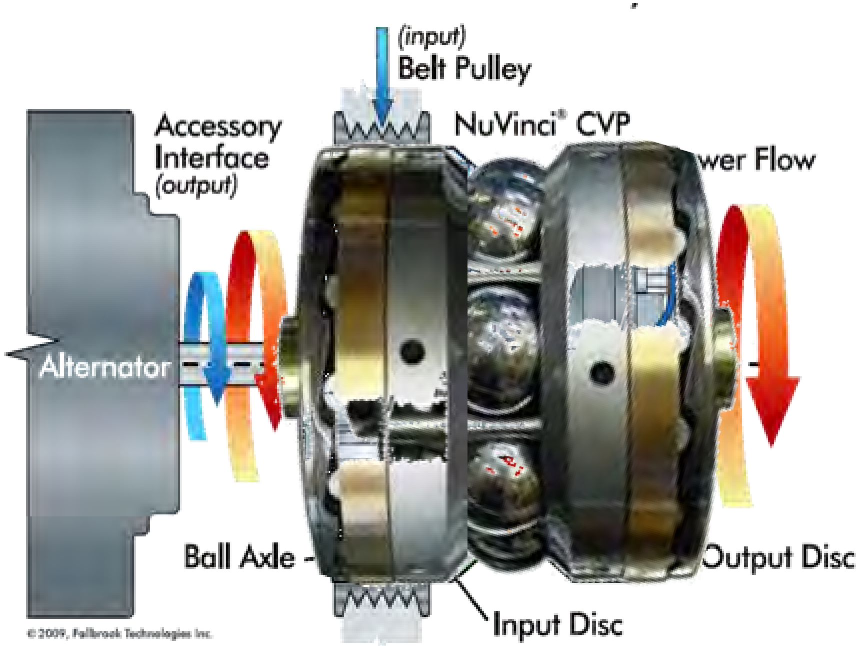
- **Accessory Speed Is Tied To Engine Speed.**

- **The Impact to the Alternator is Measurable.**
  - Lower Power at Idle: Alternators do not make their rated electric power, while idling.

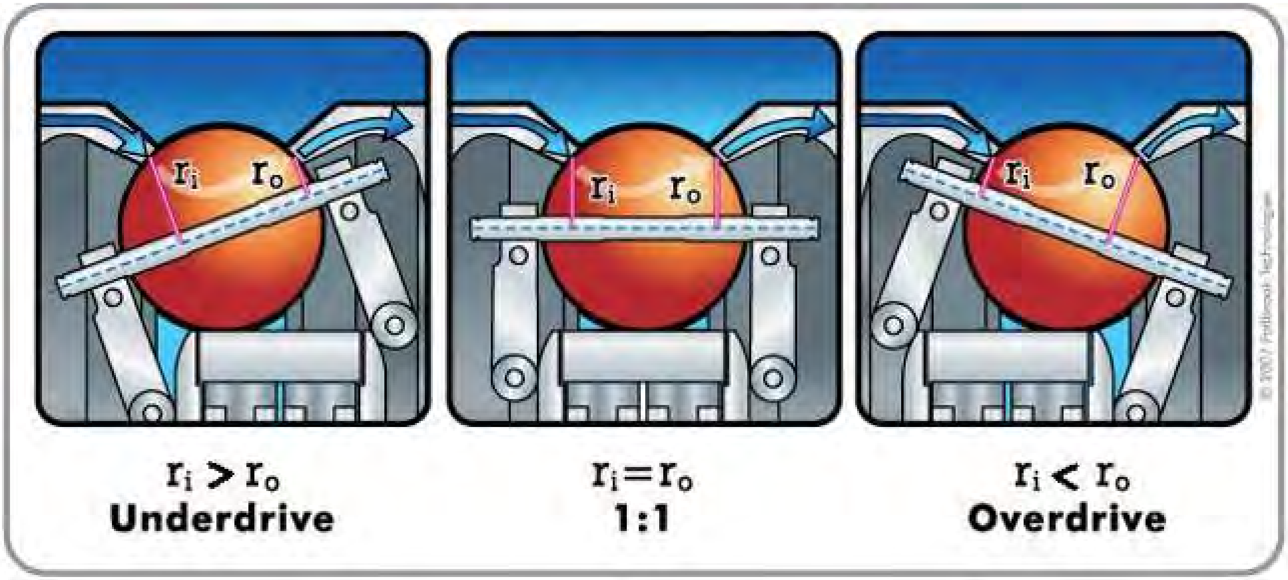
The Application of Fallbrook's *NuVinci* Technology as a Continuously Variable Accessory Drive (CVAD)

The *NuVinci* Code: Principles of Operation

- **Employs a set of rotating and tilting balls between input and output discs**
- **Torque is actually transferred through a thin layer of "traction" fluid (no metal-to-metal contact)**
  - Technical term is "elastohydrodynamic lubrication", or EHL
  - Fluid development partner is Valvoline



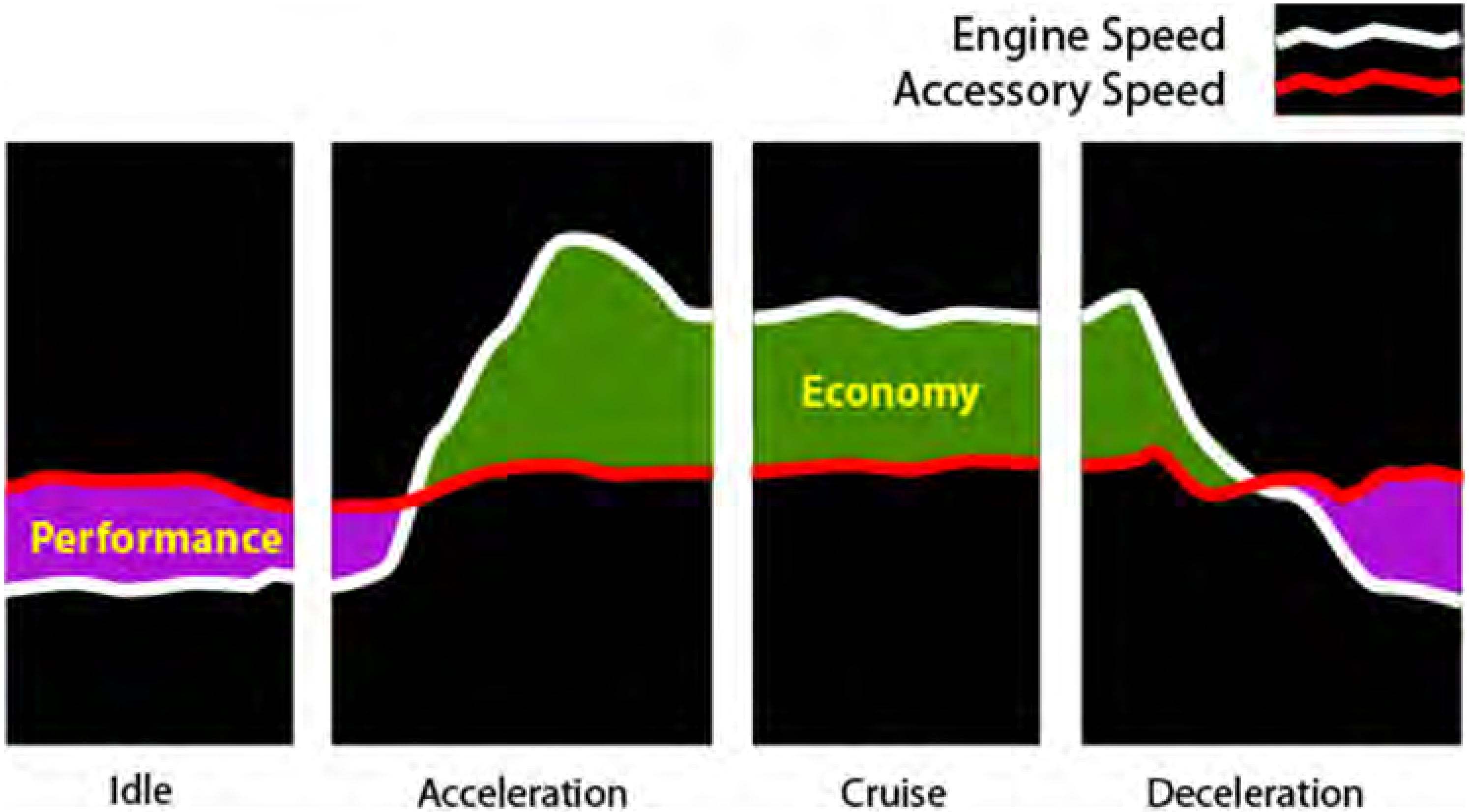
The *NuVinci* Code II: How it Works



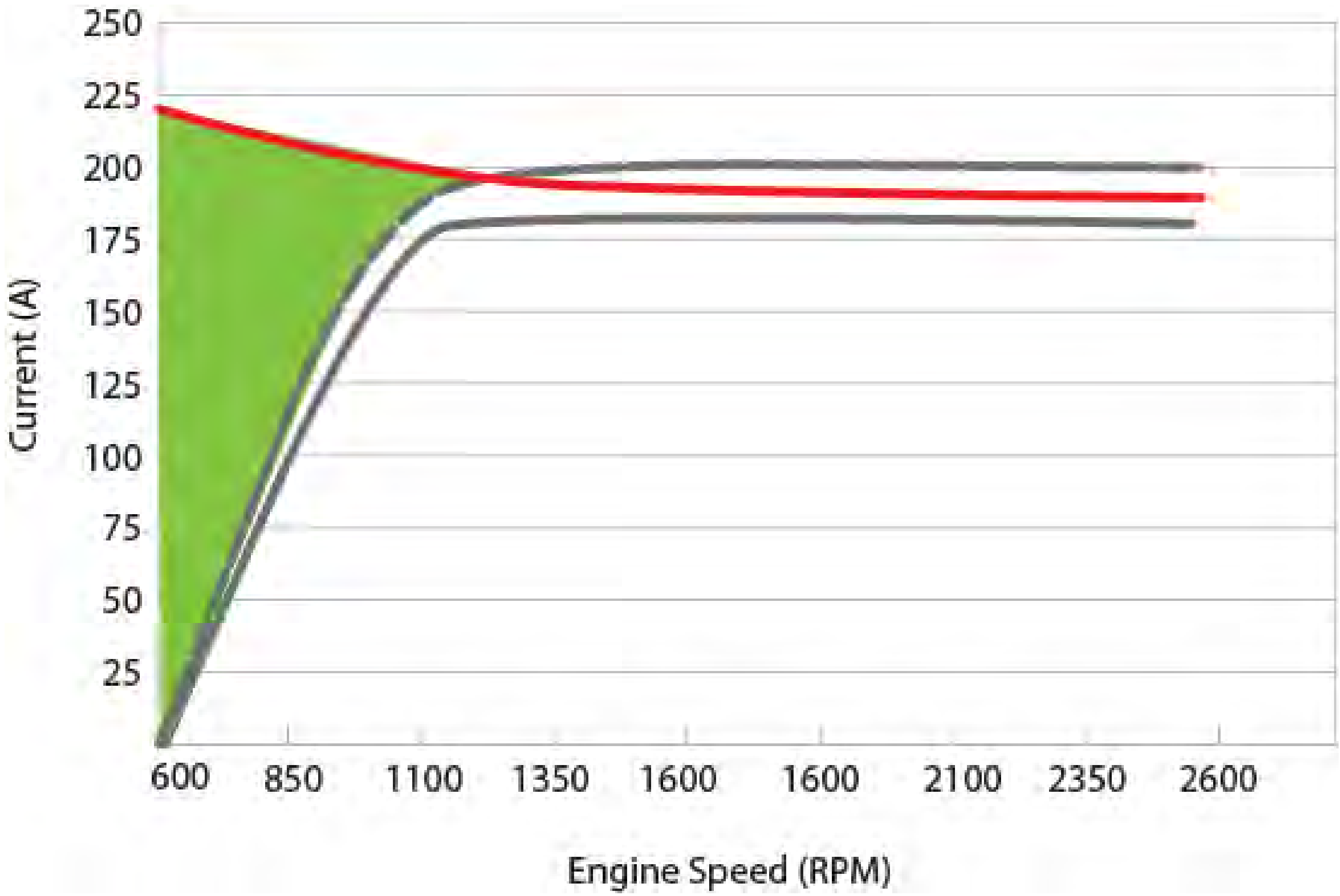
Speed ratio changes with contact radii ratio (r_i/r_o)

- **The axis of rotation of the balls is tilted to change its distance from input and output rings, which vary speed ratio**

Alternator Speed is Now Free From Engine Speed



Power at Idle.
CVAD on the Alternator

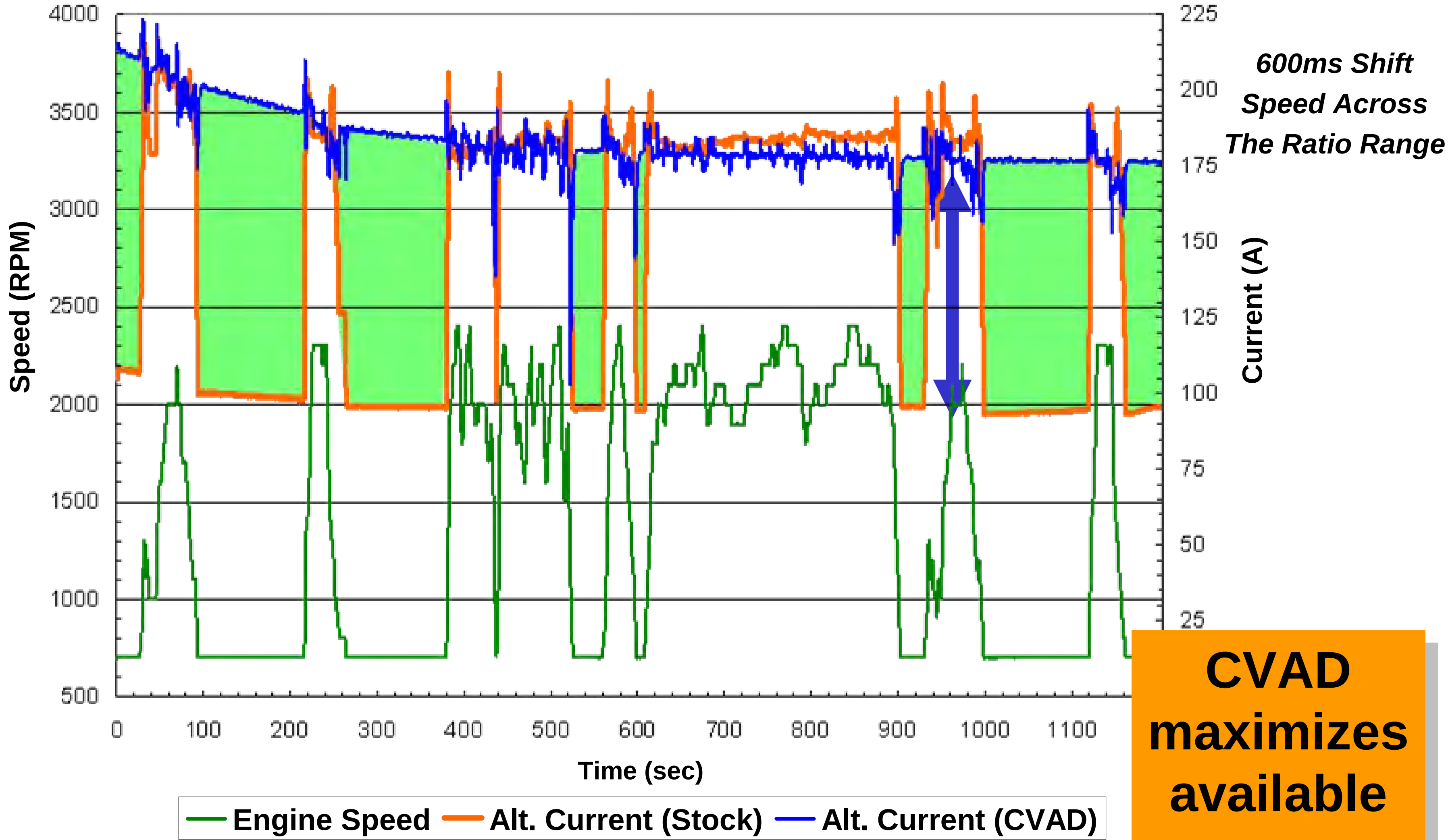


Power at Idle: Demonstration of a Continuously Variable Planetary (CVP) Transmission Technology to Drive an Alternator

FALLBROOK TECHNOLOGIES

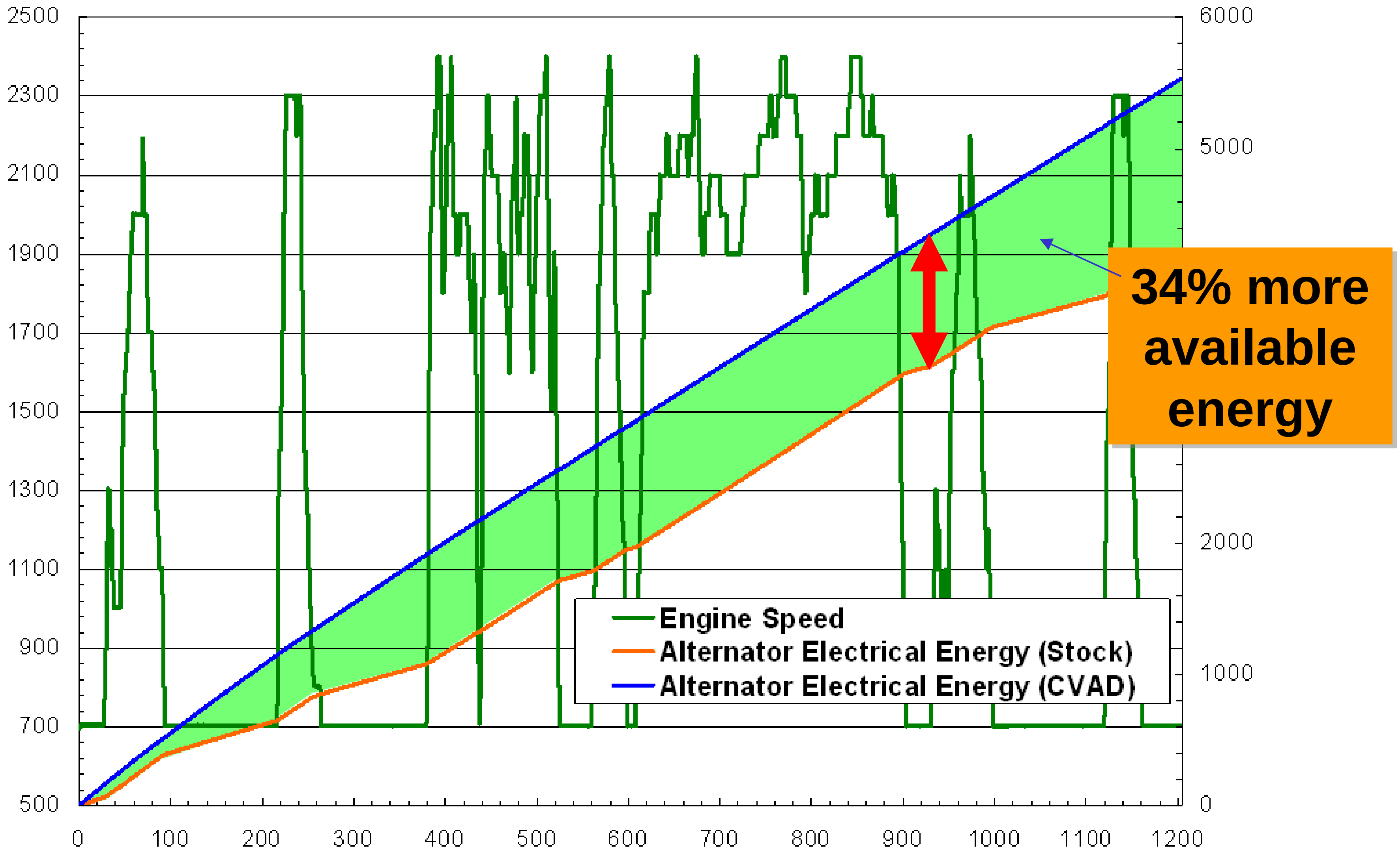
- **The Program:**
  - In 2007, U.S. Army wanted Fallbrook to explore the use of a CVP as a CVAD to address this issue as found in the fleet of Tactical Wheeled Vehicles:
    - Increasing power demand of C4 Systems (Command, Control, Communications and Computers)
    - Vehicle duty cycle inherent with high level of low speed (engine RPM) conditions
    - An alternative to the use of higher amp alternators that are:
      - Higher cost
      - Increase in weight
      - System Economy Considerations (Fuel, Range, Battery Life)
        - Fuel and range affect combat power
- **Program Requirements:**
  - Output maximum available alternator current at any engine speed
  - Maintain alternator output speed of 2400 RPM with dynamic engine RPM input
    - +/- 100 RPM output allowance
  - Manage engine compartment temperature levels of 200º F (93º C)
  - Package on the beltline with little or no modification to the vehicle.

CVAD Alternator – Improved Performance

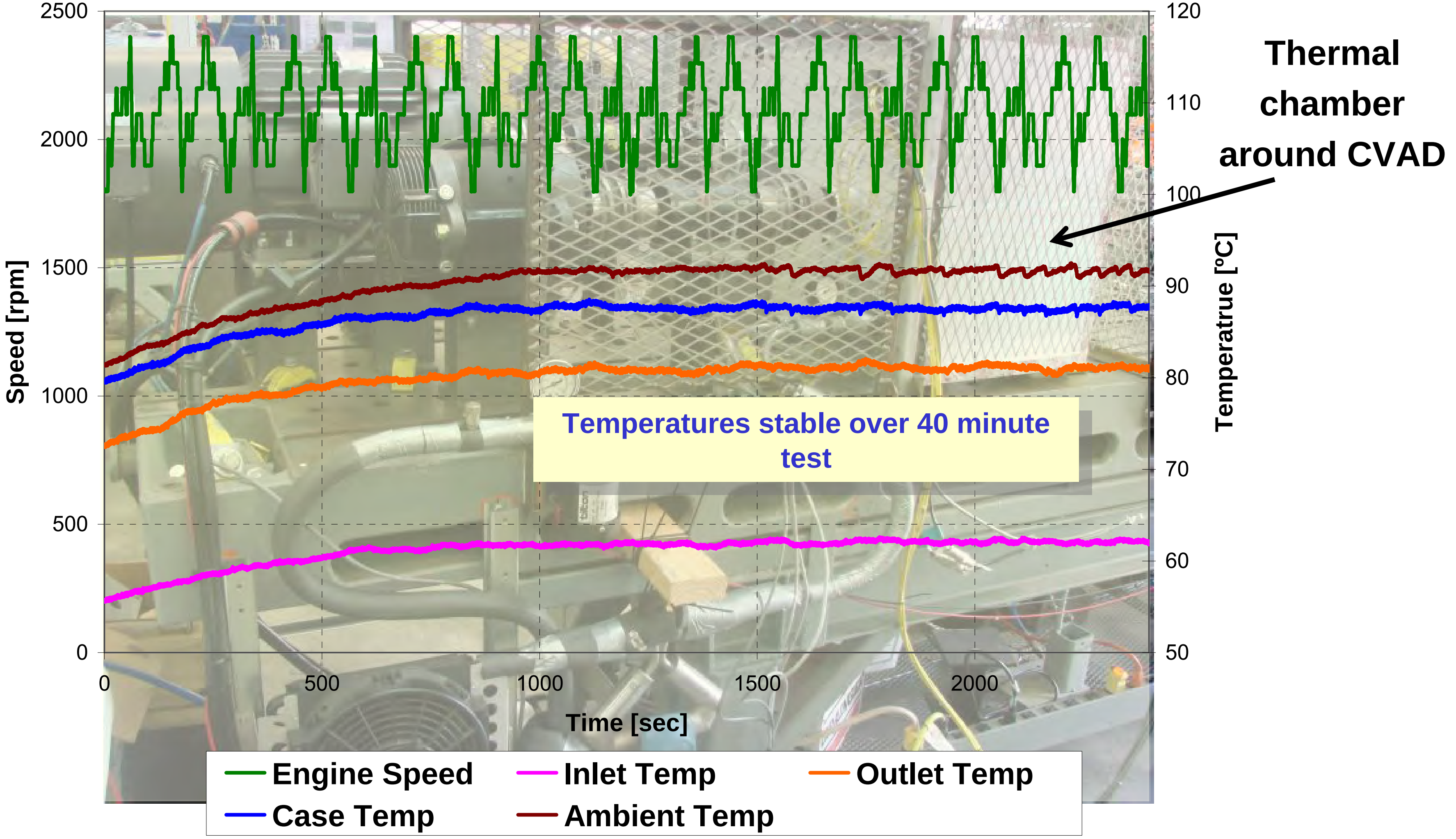


CVAD maximizes available power

CVAD Alternator – Improved Performance

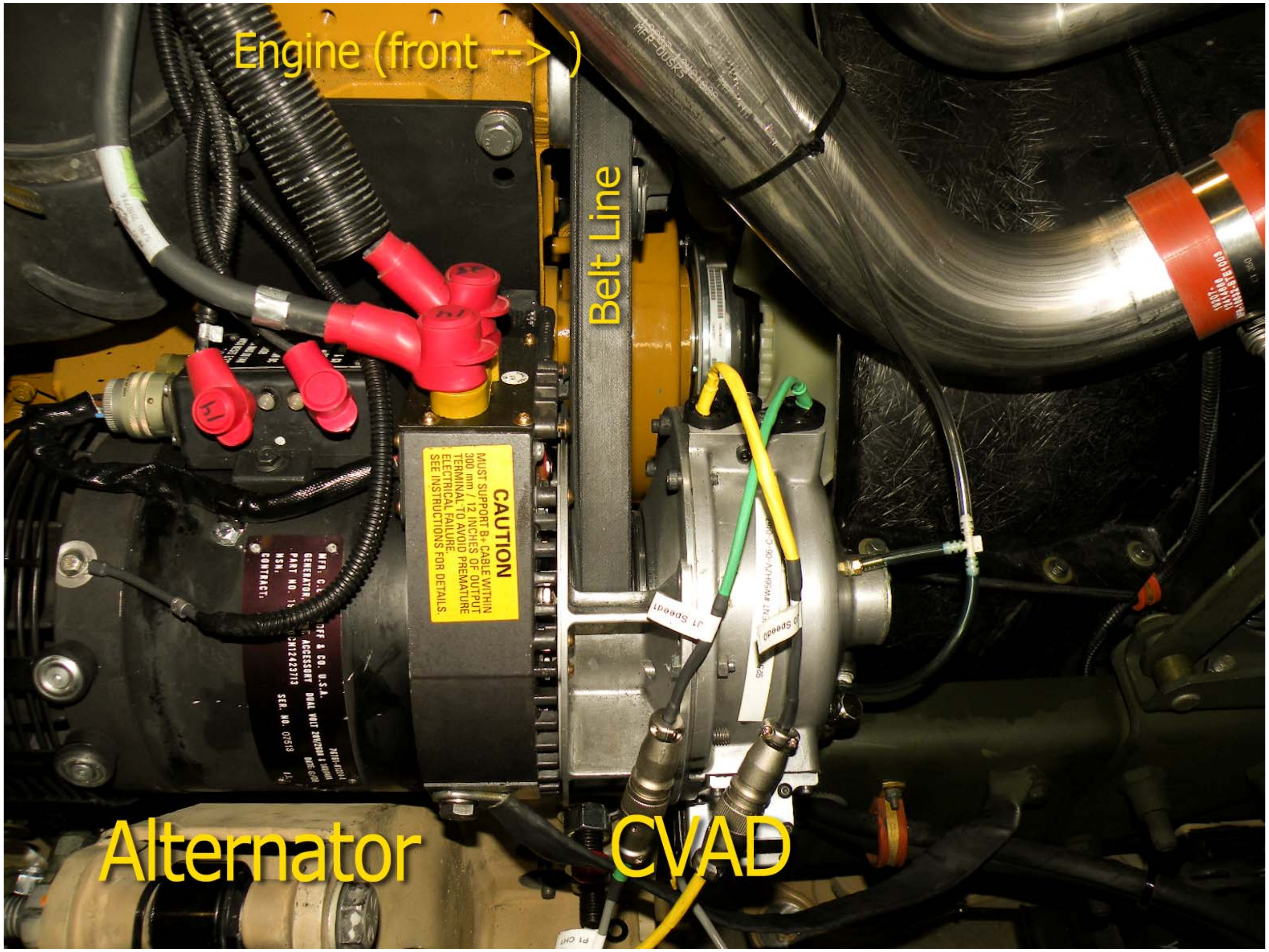


The *NuVinci* CVAD Solution on Alternator
The Results – Thermal Stability



Power at Idle:
The *NuVinci* CVAD Solution on the Alternator

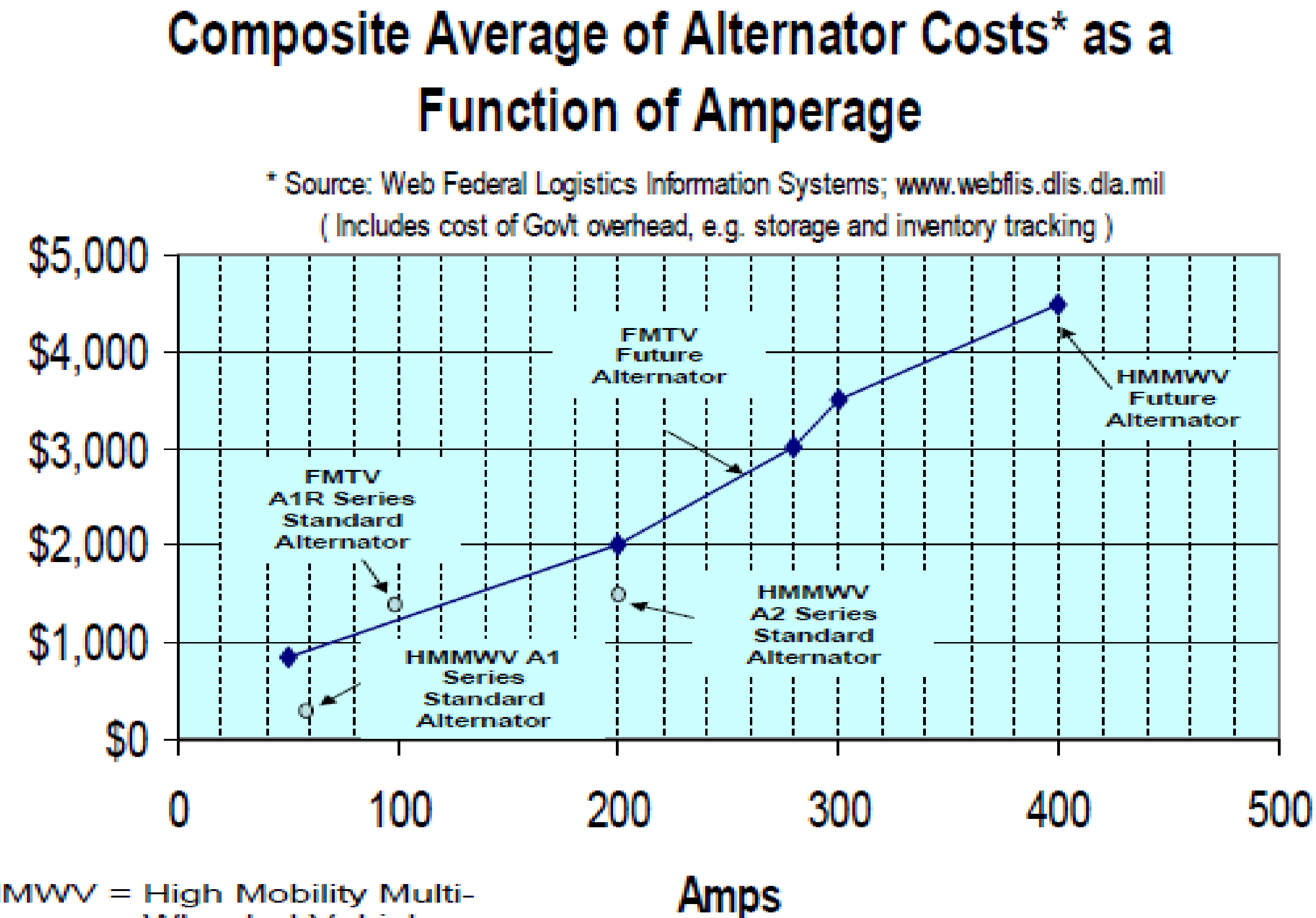
Power at Idle.
The *NuVinci* CVAD on the Alternator



Video

FALLBROOK®
TECHNOLOGIES

Military Vehicle Alternator Cost Chart



HMMWV = High Mobility Multi-Wheeled Vehicles
FMTV = Family of Medium Tactical Vehicles

More Power At Idle With CVAD Costs Less

- **Assuming 175 A is the required "power at idle."**
  - The current alternator provides 90A
  - Alternatives include…
    - A bigger alternator – for example some 400A alternators can make 175A at idle
      - Cost is roughly $4,000
    - A different/newer alternator technology
      - Also expensive
    - Hydrostatically Driven Alternator from PTO
      - Not very efficient
      - Noisy
    - Fast Idle
      - Consumes fuel, loud, more exhaust
      - Reduces engine and accessory life
    - CVAD
      - Current alternator ($2,000) + CVP and controller ($1,000*) = $3,000
      - **$1,000 savings per installation**

*Estimated cost based on volume production

Additional Benefits

- **Alternator Application**
  - Reduce Battery Replacements
  - Reduce Battery Size
  - Eliminate Belt Hop
- **Crank Shaft Application**
  - Reduce the Torque Required to Start the Engine
    - Improve starter life
    - Reduce the Amp draw from the battery
    - Great for engine start/stop systems
  - Increase in Accessory Life
  - Attenuate Engine Torsionals Imparted on the Belt
- **Easy Integration**
  - Co-Axial and Compact U-Drive or Thru-Drive
  - Doesn’t require special tooling to install on vehicles.
- **Smooth and Quiet**
  - Easy to control
  - Transparent to the user

In Summary the *NuVinci* CVAD Offers

- A practical, economical and adaptable CVT technology.
- Technical canvas for engineers to create solutions never before thought possible.

CVAD Production Starts in Q1 2010

Beta Units available for evaluation in Sept 2009
(A limited number available to qualified recipients)

FALLBROOK®
TECHNOLOGIES

Thank You!

For More Info: www.nuvinci.com

8392 ~ by Edward J. O'Rourke

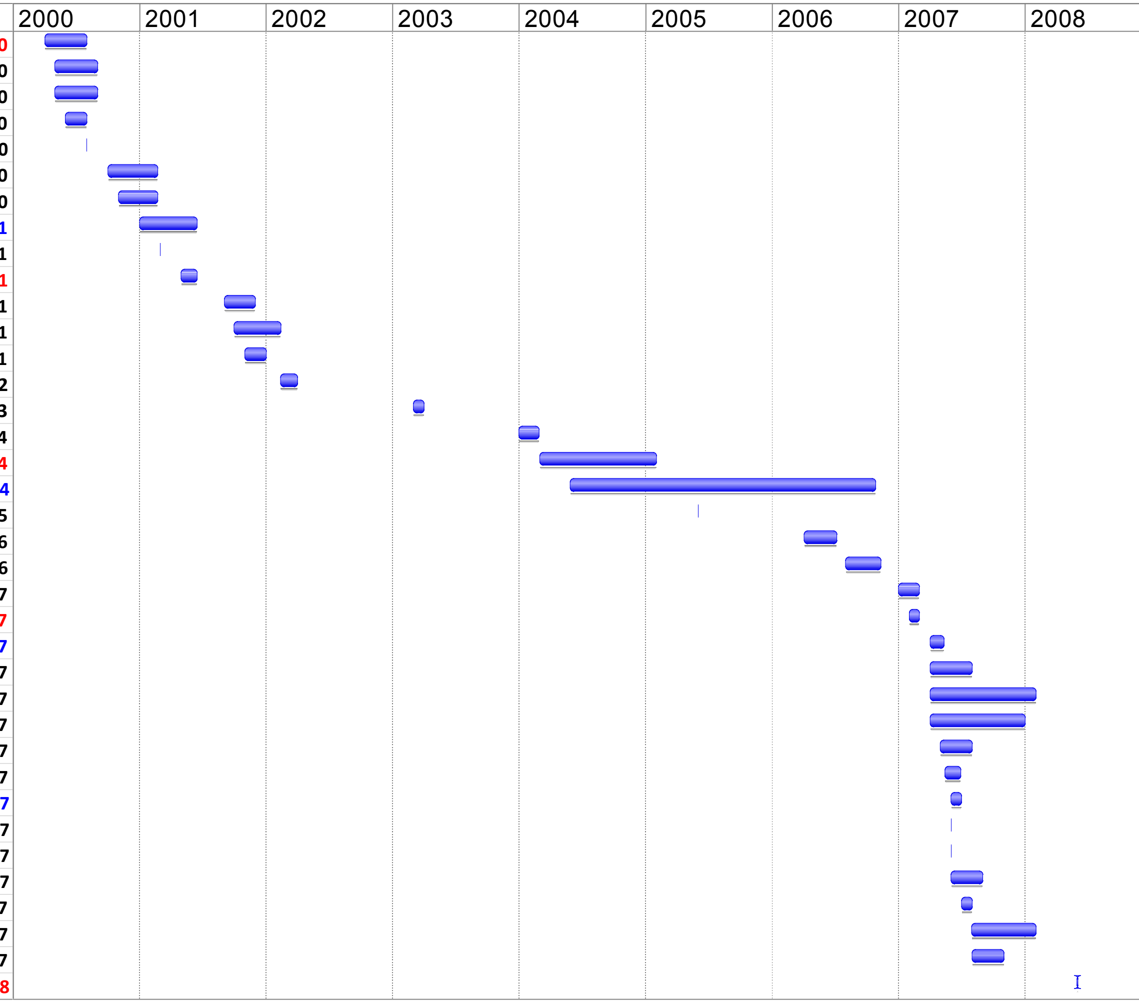
QP-1800 Inverter System – USMC Workhorse

Abstract

- The Iris Technology QuietPower 1800 (QP-1800) has been the workhorse inverter for the Marine Corps for 10+ years now. Iris Technology traces the development history of this rugged and reliable DC/AC 1800W inverter platform from initial deliveries to the current day. The QP-1800 has served with distinction in three conflicts and is widely available in several configurations on multi-year contracts with DLA and GSA.

Development Timeline

ID	Task Name	Start
1	Field trials with 11th Marines	Mon 4/3/00
2	Prototype mods to Inverter 287A101	Mon 5/1/00
3	NATO Cable, 10 ft, 1/0 AWG Designed	Mon 5/1/00
4	Initial military manuals produced PN 287F701	Thu 6/1/00
5	Initial Product Deliveries [303]	Tue 8/1/00
6	Cable safety issues discovered	Mon 10/2/00
7	NATO Cable, 12 ft, 2/0 AWG Designed	Wed 11/1/00
8	Military testing - SPAWAR [324]	Mon 1/1/01
9	NSN Assignments (Initial)	Thu 3/1/01
10	System qualified by SPAWAR for PM INTEL	Tue 5/1/01
11	Initial fielding to PM INTEL	Mon 9/3/01
12	Supplemental Training Document	Mon 10/1/01
13	Alternator overload condition addressed	Thu 11/1/01
14	On-site training for IMEF INTEL operators	Tue 2/12/02
15	Prototype transportation case 287A108	Mon 3/3/03
16	Field Expedient Cable Procedure	Thu 1/1/04
17	Army USACAPOC Support	Mon 3/1/04
18	Military testing - Crane, IN [717]	Fri 5/28/04
19	Bronze Award from DLA / DSCR	Wed 6/1/05
20	Component modification to shock material	Mon 4/3/06
21	Preparation of Product ICD	Tue 8/1/06
22	System qualified by MARCORSYSCOM	Mon 1/1/07
23	GSA / BPA Awarded by USMC [900]	Thu 2/1/07
24	Military testing - Dayton, NY	Mon 4/2/07
25	Redesigned compact transport case 287A108	Mon 4/2/07
26	Revised military manuals produced PN 287F701	Mon 4/2/07
27	Support to USMC to design Quick Start guides	Mon 4/2/07
28	Mounting Plate designed and tested at APG	Tue 5/1/07
29	DTB Rewrite of User Manual	Tue 5/15/07
30	Military testing - Env Assoc	Fri 6/1/07
31	NSN Assignments (Additional)	Fri 6/1/07
32	Bronze Award from DLA / DSCR	Fri 6/1/07
33	Development of Standard Work Instr	Fri 6/1/07
34	Revised grounding label	Mon 7/2/07
35	JEH Rewrite of User Manual	Tue 7/31/07
36	Selection of Manufacturing Partner	Wed 8/1/07
37	Gold Award from DLA / DSCR	Fri 5/30/08

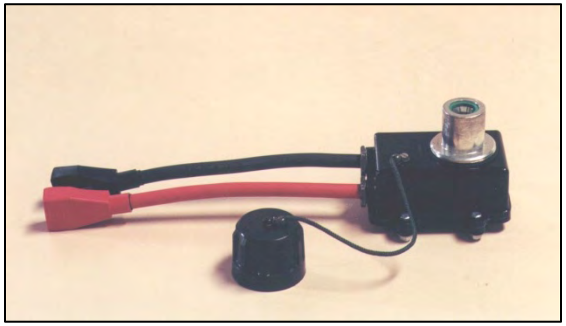


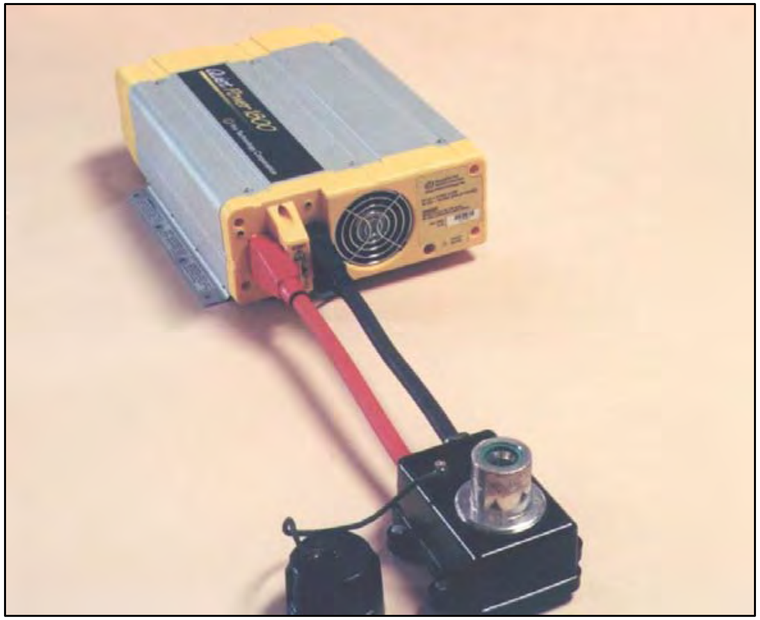
Specifications

- ***Power (Cont / Surge)*** 1800 W / 2900 W
- ***Output Waveform*** True Sine Wave
- ***Input Voltage Range*** 20 - 32 VDC
- ***Weight of Inverter*** 16.5 lbs (7500 g)
- ***Weight of Cables*** 18.0 lbs (8200 g)
- ***Weight of Case*** 20.0 lbs (9100 g)
- ***Size of Inverter*** 15.4 x 11.0 x 4.5 in^3
- ***Size of Cables*** 144.0 x 4.0 x 3.5 in^3
- ***Size of Case*** 22.1 x 17.9 x 10.4 in^3
- ***Operating Temp*** -20 / +60 °C (-4 / +140 °F)
- ***Storage Temp*** -30 / +70 °C (-22 / +158 °F)

Note: Low Temperature (-20 °C) Operation

History ~ Cables

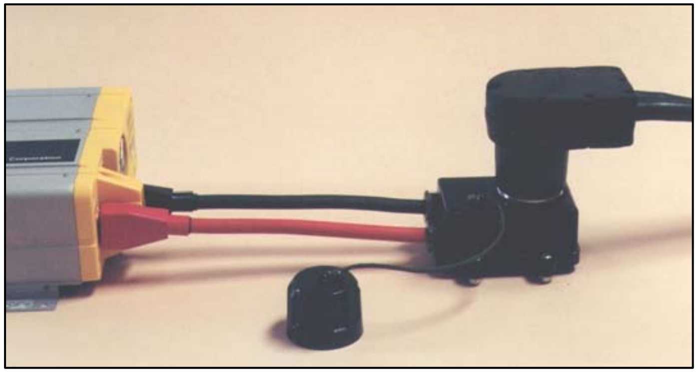




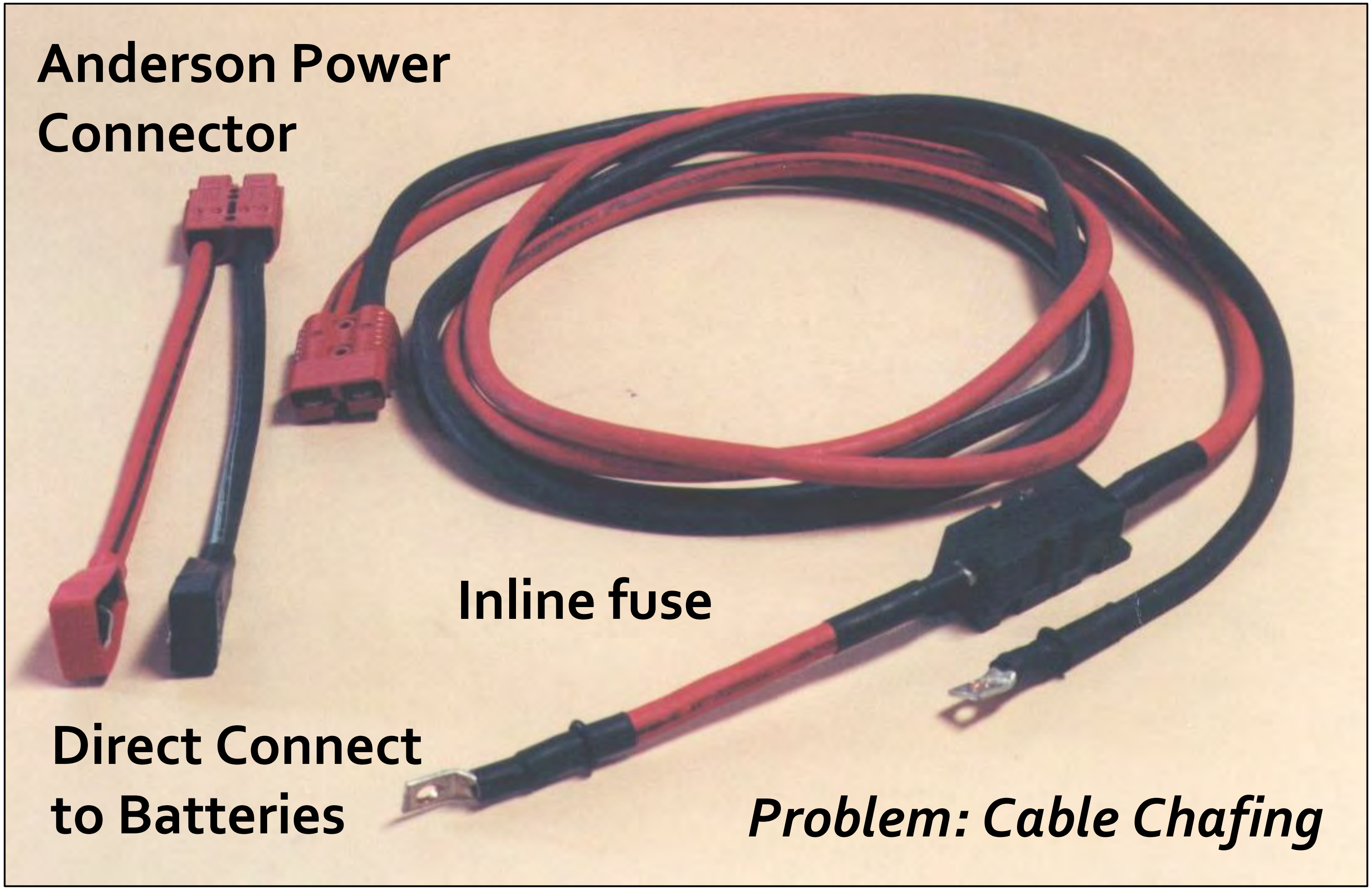
SLAVE Receptacle

Promote use of standard SLAVE Jump Start Cable (also, save weight and cost)

Problem: Modification of Existing Required Hardware



History ~ Cables



History ~ Cables

Hi-Flex SLAVE Cable
Problem: Durability

NATO SLAVE
QP-1800 Cable
PN 287A106

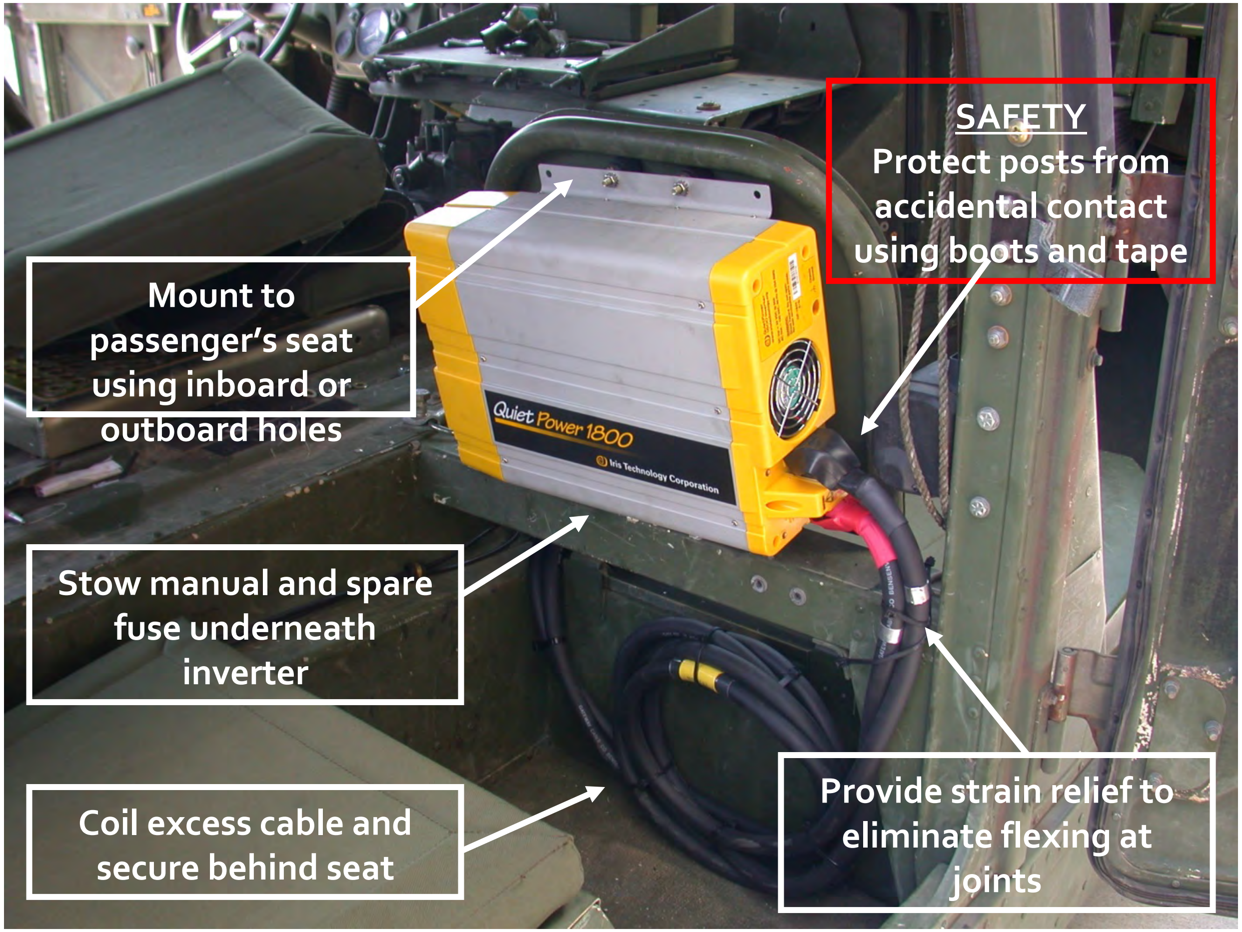
History ~ Cases

Is / OUTSIDE
22.1" x 17.9" x 10.4"
(560 x 455 x 265 mm)

Was / OUTSIDE
24-13/16" x 19-3/8" x 13-7/8"
(63 cm x 49.2 cm x 35.2 c

USACAPOC Install

United States Army
Civil Affairs and Psychological Operations Command



Vibration Testing

Transportation Testing

Power Tidbits

Volume 4 Issue 1 (14 June 2008) // pm_eps@nmci.usmc.mil

"Fielding of the QP-1800 began during the 3RD Quarter FY08. The distribution plan is provided in Appendix A of the QP-1800 Fielding Plan (FP 11460A, PCN 132 114600 00) dated 28 September 2007.

"The QP-1800 DC/AC Inverter System consists of the Inverter (NSN 6130-01-496-6448), Carrying Case (NSN 7050-01-551-0600), and NATO cable (NSN 6150-01-497-2515). Vibration Isolators and one spare fuse are provided with each Inverter. The QP- 1800 is a semi-ruggedized inverter that connects to a military vehicle 24 volt DC (VDC) power system through the supplied NATO slave cable and converts 24 VDC (vehicle power) to 115 VAC (True Sine Wave), 60 Hz at 1800 Watts(W).

"... The QP-1800 Inverter System is a SAC 1 Type 2 allowance item and can be procured from Iris Technology Corp., via GSA contract GS-07F-0131N or from DLA using the listed above.

USMC Reference

QP-1800 Inverter System

•TAMCN - H0004

•NSN - 6130-01-552-6350

•ID - 11460A

•SAC - SAC 1

•Warranty – Two years

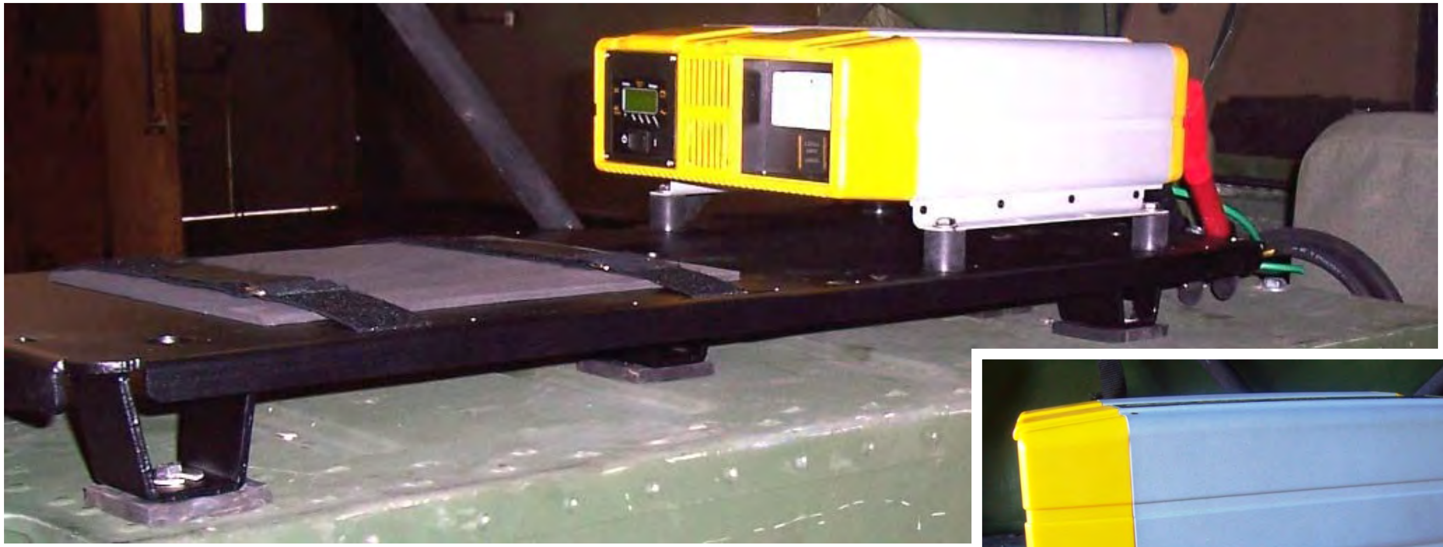
Publications

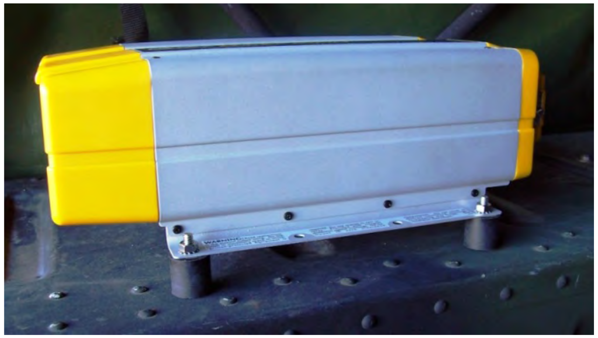
•TM 11460-OR/1 PCN 500 114600 00

•SL-3-11460A PCN 123 114600 00

•Job Aid (refer to page 13 of this newsletter)

QP-1800 Mounting





"MI 11460-OI/1 provides instructions for installing the QP-1800 in non-armored HMMWV's using the vehicle mounting bracket or directly to the top of the wheel well.

"When the wheel well contains air conditioning components, use of the vehicle mounting bracket is MANDATORY. Vibration isolators are MANDATORY regardless of the method of installation used."

Applications

Open Contract Vehicles

- GSA / FSS
  - GS-07F-0131N
- USMC / BPA
  - M67854-07-A-5022
- DSCR / IDIQ
  - SPM4LG-08-D-0018

Questions

- Equipment on display in Booth 314

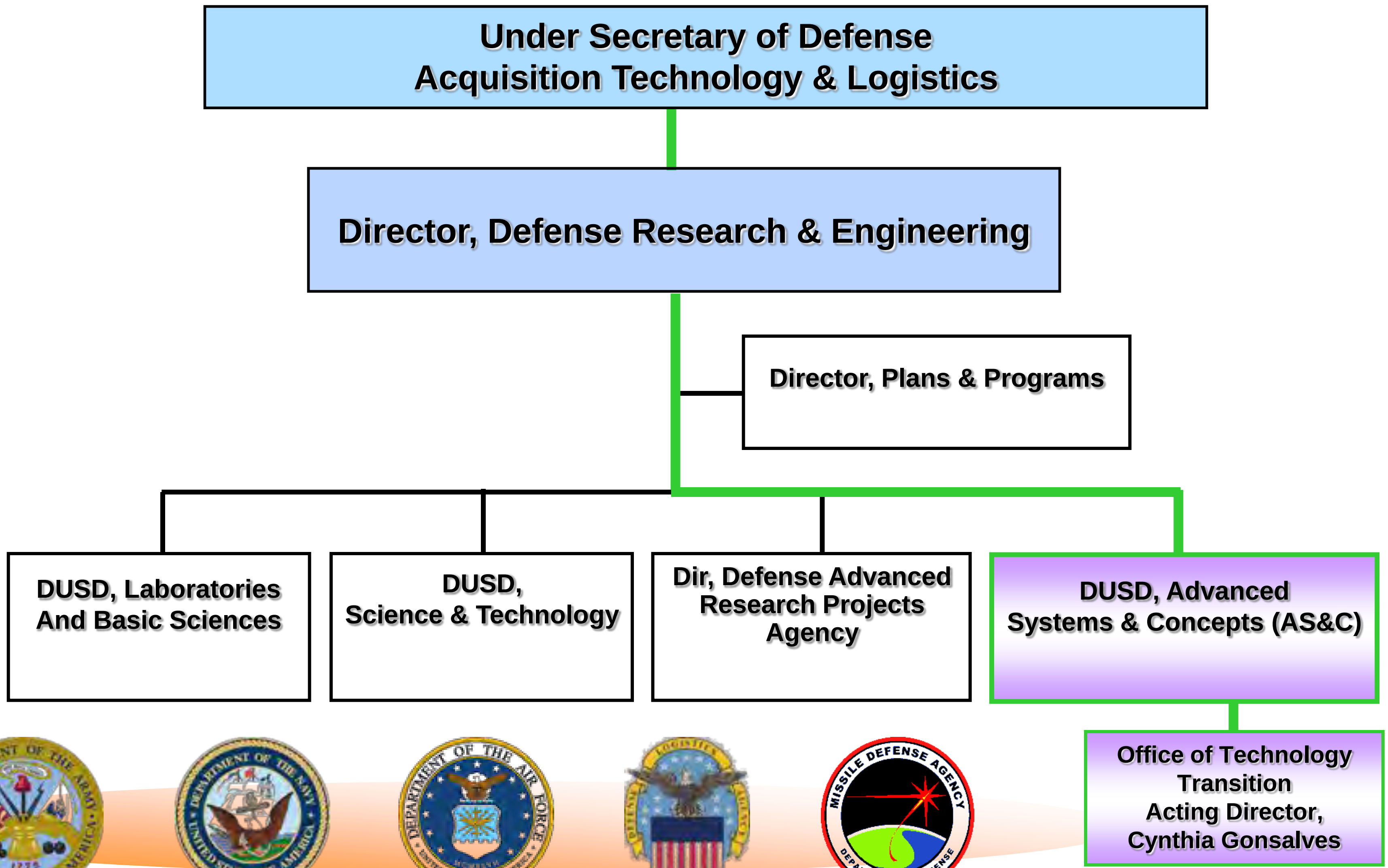
OSD Manufacturing Technology Overview
New Orleans, LA
5 May 2009

Adele Ratcliff
Director, Manufacturing Technology
703-607-5319
adele.ratcliff@osd.mil
5 May 2009

Topics

- Organization
- Manufacturing Readiness Level (MRL)
- GAO Study on Manufacturing Readiness
- DoD Strategic Plan
- Manufacturing S&T Program (OSD D-Line)
- Industrial Base Innovation Fund (IBIF)
- American Reinvestment and Recovery ACT (ARRA)
- Summary

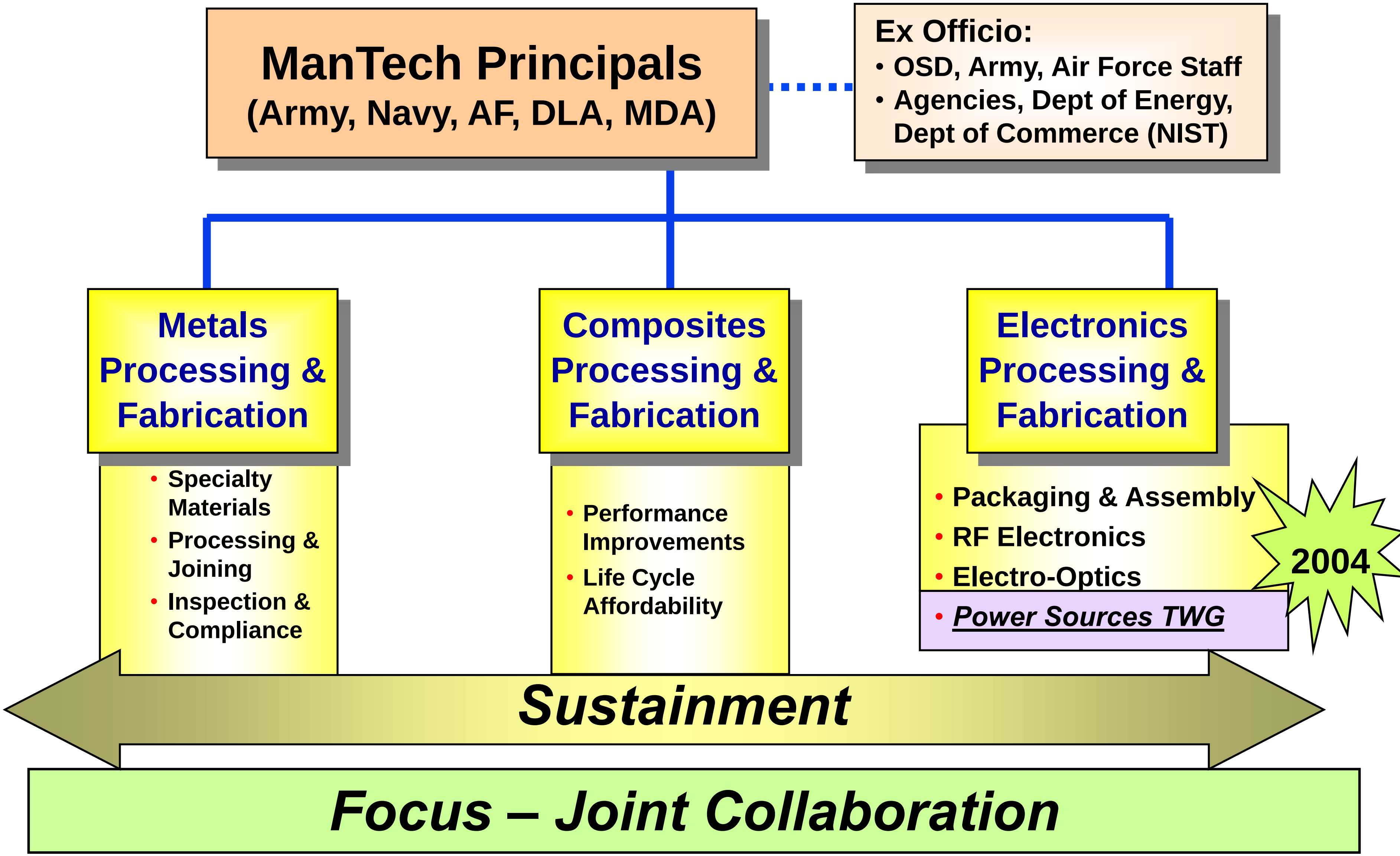
AT&L Chain of Command



Manufacturing Technology (ManTech)

- *ManTech is critical for moving disruptive technologies into disruptive capabilities*
- *If you can't build it, build it affordably, reliably, and in a timely manner, you don't have IT.*
- *To have true capability, must be able to move beyond the prototype "One-Off"*
    - *Operates Under Title 10 (Section 2521)*
        - *Manufacturing process* investments that provide product performance, operational, & affordability improvements
    - *All About Affordable & Timely Equipping of the Warfighter*
        - Defense essential needs beyond normal risk / interest of industry
        - Pervasive needs across systems, platforms, or components
    - *Transition of Validated Technology*
        - Scale-up of processes for S&T, ATDs, IR&D, & ACTD products
        - Focus: Manufacturing <u>process</u> investments, not <u>product</u> design

Joint Defense ManTech Panel (JDMTP)



MRL - Background

Immature technology & unstable manufacturing processes are major acquisition drivers

- Recent GAO study of 72 programs: RDT&E costs up by 42% with schedule slippage of 20%

Manufacturing Readiness Levels (MRL) Developed

- Common Standard and framework for identifying, communicating, and managing manufacturing risks
- Establish and promote manufacturing risk management as basic principal of technology development and acquisition programs
- Establish DoD standard for manufacturing readiness to support decision makers at key milestones
  - Milestone A – MRL4
  - Milestone B – MRL 6
  - Milestone C – MRL 8
  - FRP Decision – MRL 9
- Support the development and maintenance of necessary knowledge and skills within the DoD workforce to support this best practice already used by key U.S. defense industries

Equip the DoD Enterprise with Knowledge Based Approach to Manufacturing Risk Management - Standard, Tools, and Training

Manufacturing Activities

- DOD 5000.2 signed 2 December 2008 by AT&L
- Collaboration within OSD to align manufacturing activities to existing acquisition and technical reviews
- Integrate Manufacturing Readiness activities into the Systems Engineering Process
- Defense Acquisition Guidebook (DAG) – being updated to reflect increased focus on mfg early in acquisition development (TDS and Acq Strategy)

All MR products are available at **www.dodmrl.org**

GAO Study
MRL & Integration RL Implementation

- A 12 to 14 month review to examine the manufacturing aspects of the acquisition process & the potential benefits that could be derived from manufacturing & integration readiness levels
- GAO plans to look at DOD's initiatives, & commercial sector companies & their practices for comparative purposes
- OSD in-brief Monday, 11 January 2009
- OSD, Services/Agencies
- Industry Participants Wanted
- Any volunteers from the audience??? More to Come..

ManTech Strategic Plan (MTSP)

- Congressionally directed by NDAA 2008 language
- The DoD ManTech Strategic Plan was signed by AT&L March 2009
- Strategic messages:
  - Strong, positive support for ManTech program in all camps; recurring calls for bold thinking
  - <u>Affordability</u> remains an overarching concern
  - Institutional focus on "Manufacturability" is strategically important--keep championing the Manufacturing Readiness Assessment (MRA) concept
  - Workforce concerns are pervasive; responsibility for solution sets not clear

Strategic Thrusts

Defense Industrial Base

RELIABLE COST EFFECTIVE SUFFICIENT

Defense Manufacturing Enterprise

DoD ManTech Program

Strategic Thrust 1

Effective Management and Delivery of Processing & Fabrication Technology Solutions

Strategic Thrust 2

Active Support for

A Highly Connected and Collaborative Defense Manufacturing Enterprise

Strategic Thrust 3

Active Support for

A Strong Institutional Focus on Manufacturability and Manufacturing Process Maturity

Strategic Thrust 4

Active Support for

A Healthy, Sufficient, and Effective Defense Manufacturing Infrastructure and Workforce

A balance between ManTech's core program responsibilities and active support for broader defense manufacturing enterprise needs

ManTech Strategic Plan (MTSP)

- The plan:
  - Emphasizes affordability as a "focusing theme"
  - Leverages existing program strengths--much is going well
  - Expands the focus on 21st Century trends and a global, collaborative context for framing ManTech investments-- *joint/crosscutting capabilities & enablers are key*
  - Provides direction for model-based & network-centric approaches to enhance common operating pictures, product data exchange, supply chain integration
  - Postures the ManTech program as a strategically important tool for DoD leadership priorities in S&T, acquisition, and sustainment

FY 2009 ManTech Budget

RDT&E-Defense Wide	*Dollars in Thousands*			
Appn Line: Various	**Approp Delta:**	**+$49,300**	**+$46,200**	**+$78,800**
MANTECH	**Budget**	**House**	**Senate**	**Conference**
Appropriations	**$197,955**	**$247,255**	**$244,155**	**$276,555**
Army –Industrial Preparedness (0708045A)	$69,084	$89,884	$78,284	$91,084
Air Force – ManTech (0603680F)	$39,729	$43,729	$42,729	$45,329
Air Force – Industrial Preparedness(0708011F)	$0	$6,000	$0	$4,800
Navy – Industrial Preparedness (0708011N)	$56,681	$63,181	$56,681	$61,881
DLA – Industrial Preparedness (0708011S)	$20,480	$32,480	$44,480	$55,280
Defense (PE 060368D8Z)	$11,981	$11,981	$21,981	$18,381
	Auth Delta:	**+$16,000**	**+$52,700**	
Authorizations	**$197,955**	$213,955	$250,655	
Army –Industrial Preparedness (0708454A)	$69,084	+78,084	+80,084	
Air Force – Industrial Preparedness (0603680F)	$39,729	+43,729	+39,729	
Air Force – Indust Prepared. BA 7	$0	+3,000	$0	
Navy – Industrial Preparedness (0708011N)	$56,681	+56,681	+58,381	
DLA – Industrial Preparedness (0708011S)	$20,480	+20,480	+50,480	
Defense Wide (PE 0603680D8Z)	$11,981	+11,981	+21,981	

Defense-Wide Manufacturing Science and Technology Program - Overview -

Program Motivation:

- Responds to Section 241 of NDAA 2006 and GAO reports on acquisition program cost drivers
- Identify and transition advanced manufacturing processes and technologies that would achieve significant productivity and efficiency gains within the defense manufacturing base

Product: mature or lower risks manufacturing processes that can transition to programs of record, industry, or follow-on maturity programs

Execution Approach: Air Force Manufacturing Technology Program

Customer: Industrial Base, Programs of Record, and follow-on maturity programs

Measure of Success:

- Decreased production costs or time to production
- Increased affordability – unit costs and life cycle costs
- Improved operational availability – mean time between failure reduced
- Accelerated application of emerging technologies

Defense-Wide Manufacturing Science and Technology Program - Funding -

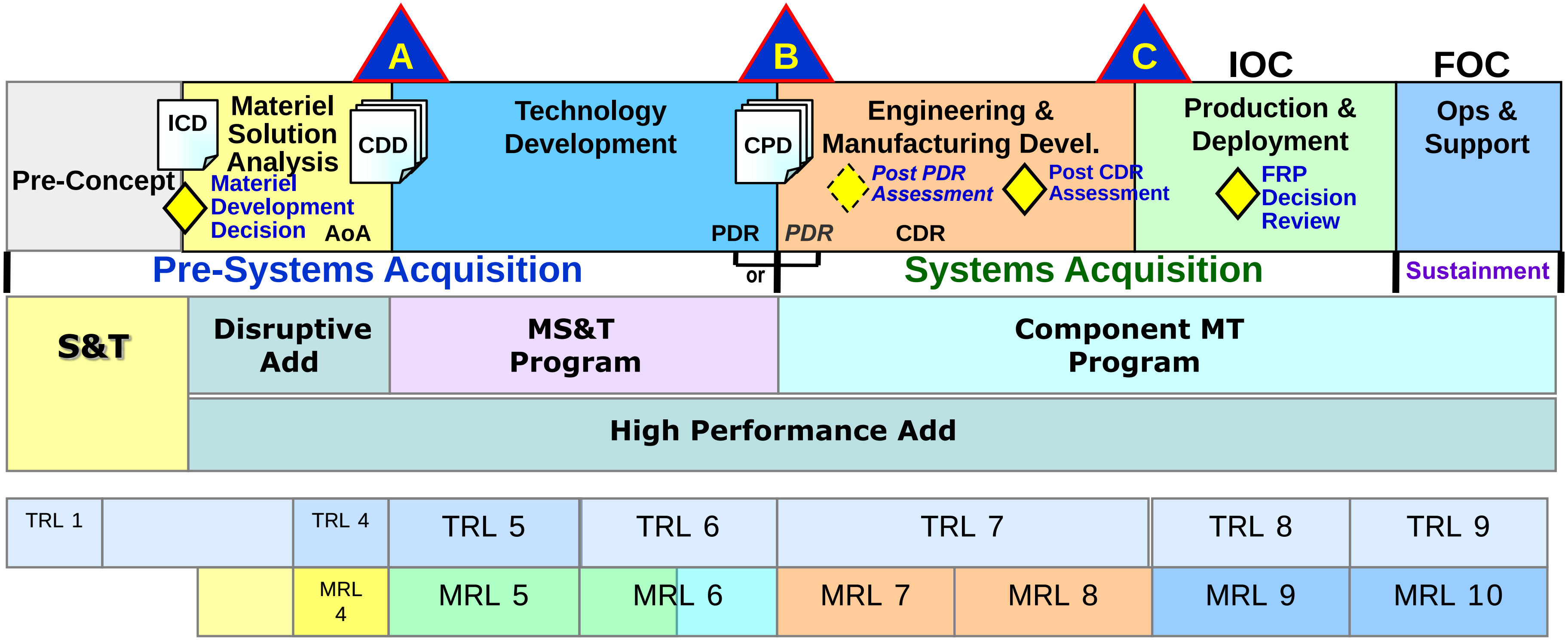
Dollars in thousands	FY 09 PBR	FY 09 Appropriation	FY 10 PBR
PE 0603680D8Z	$11,981	$18,280	$14,638

- Take risks that components/agencies can not take within respective portfolio
  - modeling and simulation, production processes for emerging warfighting technologies
- Inform DoD wide policy via manufacturing demonstrations and pilots
  - new 3D technical data, new manufacturing process data files
- Address cross-cutting manufacturing issues and opportunities
  - no ownership issues e.g. lead free

- FY 09 Congressional adds and status
  - High Performance Manufacturing
    - National Constituent add
    - Launching efforts in
      - Next generation tools for model based manufacturing enterprise
      - Model based manufacturing enterprise tools to support Future Combat System

Manufacturing Maturity Targets

- Core MS&T targets Technology Readiness Levels (TRLs) and Manufacturing Readiness Levels (MRLs) of 5 to 6
- High Performance Manufacturing focuses on “above the shop floor” issues and targets TRL/MRL from 3 +
- Disruptive Manufacturing targets TRL/MRL of 3 to 4



Selection Criteria

1. Basic ManTech Tenet *(a Go/No-Go Decision)*

- Enhances manufacturability / producibility of a process or component
- Beyond reasonable / normal industry risk
- Requirement is defense-essential or defense-unique

By:
- **Improving an Existing Manufacturing Processes**
- **Establishing a New Manufacturing Process**
- **Exploiting Business Practices**
- **Expediting Transition of Emerging Technology**

2. Joint Service, Cross-Cutting Impact

- Multi-service, multi-system applications
- Enterprise issues beyond the ability of a single service to address
- Stimulate early development of manufacturing processes
  - Warfighting capability, cost, cycle time benefits do not have to be firm yet

3. Implementation

- Path towards transition during and after the proposed program
  - Implementation not required immediately after a program
  - Next step may be a service MT program

Defense-Wide Manufacturing Science and Technology Program - Technical Goals -

• FY09 Technical Goals - Continued 4 core technical initiatives and 2 congressional adds

- Ceramic Matrix Composites Manufacturing Initiative
- Low Observable Materials Manufacturing Initiative
- System-on-chip Manufacturing Initiative
- Prosthetic and Orthotics Manufacturing Initiative
- High Performance Manufacturing R&D - congressional add
- Disruptive Manufacturing – congressional add

•FY 10 Strategic Goals

- Strengthen linkage to Industry and S&T communities – Emerging S&T Technologies, DARPA, Technology Focus Teams, National Defense Industrial Association (NDIA)

•FY10 Technical Goals

- Launch new-start projects in materials, electronics, and model based enterprise manufacturing

MS&T FY09/FY10 Strategic Themes

- Directed Energy (offensive and defensive)
- Survivability
  - Ballistic protection
  - Low observable structures & transparencies
  - Countermeasures
- Disruptive Green and Energy Technologies
  - Power & Energy
    - Li-Ion battery
    - Solar cells
    - Fuel cells
  - Lead free solder
  - Nano for electronics
  - Fuel efficiency
    - Advanced structures
    - Propulsion
  - Environmentally friendly manufacturing
- Manufacturing Best Practices
  - Model Based Enterprise, Lean, supply chain visibility, network centric manufacturing...

Standing Technology Focus Team (TFT) Proposal

- Standing TFTs on big areas
  - Provide the top 5-6 objectives for respective technology areas in the 1st year
    - Target date for reaching objectives is 5-10 years out
  - Revalidate the objectives and deep dive in 1 or 2 areas, each subsequent year
  - Brief results to the DSTAG

We have performed assessments in big areas. We need to continue to populate websites and get info out.

Big Areas

- **Advanced Electronics ($520M)**
- **Advanced Materials ($340M)**
- **Information Systems ($1.870B)**
- **Robotics & Autonomous Systems ($100M)**
- **Human Systems ($440M)**
- **Sensors & Surveillance ($980M)**
- **Energy & Power ($620M)**
- **Space?**
- **Directed Energy?**

- ✓ **Electronics**
- ✓ **Materials (Meta/Thermal Mgmt/Energetic Mat)**
- ✓ **Info Systems (Info Assurance/Networks/SW)**
- ✓ **Robotics/Autonomy**
- ✓ **Human Systems (Accel Learning)**
- ✓ **Sensors (Thru the Wall and IRFPAs)**
- ✓ **Energy & Power (Thermal Mgmt)**

Industrial Base Innovation Fund (IBIF)

•The Department of Defense Appropriation Act for Fiscal Year 2008, Pub. L. 110-116, provided $24 million for the Industrial Base Innovation Fund (IBIF) in the Research, Development, Test and Evaluation, Defense-Wide appropriation.

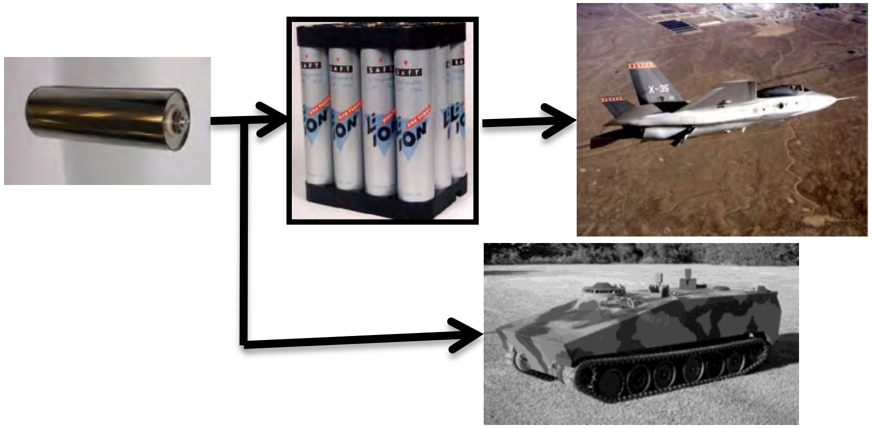
•The conferees provide $24 million for the Industrial Base Innovation Fund to ensure that investments are made to address shortfalls in manufacturing processes and technologies in support of the Department's long-term and short-term needs

•This program is being executed through the Defense Logistics Agency's Manufacturing Technology Budget

•Of the $24 million provided by Congress, almost 20% ($4.625 million) was allocated to Power and Energy proposals

FY08 IBIF - UHP Li-ION TECH FOR THE JSF/DE APPL’NS (SAFT America, Inc)

SAFT UHP **JSF MODULE** **F-35**



HYBRID ARMORED VEHICLES

PROBLEM

- Evolving Power Needs of the F-35 JSF Aircraft with Short Circuit Current in excess of 4,000 A RESULT: Thermal Runaway Destruction of Battery and Aircraft

OBJECTIVE or SOLUTION

- Industrialize the robust VL5U cell technology to eliminate the weak Glass to Metal seal in the JSF cell design. Provides increased low temperature performance margin, a producible cell design, and reduced acquisition cost.

APPROACH

- Transition the VL5U cell development technology to production.
- A: Optimize mixing and coating for thin electrodes, reduce variability in electrode calendering and winding, & use production welding
- B: Optimize cell weight and bussing and validate abuse tolerance
- C: Incorporate VL5U cell in JSF Module and validate performance

BUSINESS STRATEGY

- **Joint:** AFRL/RZPS and USA RDECOM/TARDEC
- **Execution:** USAF
- **Performing Organization(s):** Air Force Research Laboratory/RZPS
- **Projected Start Date and Duration**: 26 Sep 08 (21 Months)

Funding ($K)	FY08	FY09	FY10	FY11	Total
OSD ManTech	$1,400	$0	$0	$0	$1,400
USA ManTech	$0	$0	$0	$0	$0
PM	$0	$0	$0	$0	$0
Industry	$360	$0	$0	$0	$360
Total Annual	$1,760	$0	$0	$0	$1760

COTR: John Erbacher (937-255-2372)

LEVERAGED EFFORTS

- AF UHP Technology & USA Prototype VL5U Cell Developments
- Industrialized VL5U Cell and Design will be incorporated in the JSF and Hybrid Armored Vehicle Development Programs.
- Other Opportunities Include Tri Service DE Applications & USA FCS

BENEFITS / WARFIGHTER RELEVANCE

- A Robust 270 V JSF Battery
- Short Circuit Protection
- Low Temperature Increased Performance Capability
- Reduced Parts Count (TBD)

IMPLEMENTATION

- Army: Hybrid Armored Vehicles for FCS
- Navy: JSF Carrier Variant
- Air Force: JSF and DE Development Programs

FY08 IBIF - Press Upgrades for the Thermal Battery Cells
EaglePicher Technologies, Joplin MO

Problem:

- Thermal battery manufacturing relies on hydraulic presses to form the pellets that form thermal battery cells. Tight control of pressing parameters is critical to achieving acceptable yield and performance.
- Existing presses at EP require enhancement to achieve better pellet yields and quality

Hydraulic presses used to make thermal battery pellets will be upgraded with modern controllers and measuring devices to improve the manufacturing processes

Technology Approach

- IBIF investment will co-fund these press control and measurement improvements at EaglePicher
- Modern controllers and press measurement devices will be adapted to the specialized presses and validated for all pellet types (anode, cathode, separator/electrolyte and heat)
- Will improve ALL thermal batteries made by EP for Air Force, Army, Marine Corps and Navy weapons, and increases surge production capacity

Status

- Project time line to completion is six months
- Estimated start date is May 2009
- Contracted via Picatinny Arsenal

COTR: Sam Stuart (812) 854-5958

FY08 IBIF - Development of Industrial Process for High Yield, High Quality Automated Thermal Battery Stacking & Inspection (Advanced Thermal Batteries Inc).

Advanced Cruise Missile

PROBLEM

High cost of hand built thermal batteries

OBJECTIVE

Reduce cost of battery production

APPROACH

Research design and cost of the automated pellet stacking part of the battery assembly

BUSINESS STRATEGY

- Of interest by several services
- Executed by Air Force for DLA
- Performed by Advanced Thermal Batteries, Inc.
- Started 1 Oct 08 for 14 months

Funding	FY-08	FY-09
IBIF	$652K	TBD

LEVERAGED EFFORTS

- This technology is of interest to primarily the military.
- The automation of battery assembly can reduce costs.

BENEFITS / WARFIGHTER RELEVANCE

- Cost of batteries to targeted systems reduced by 7.5%.
- Potentially higher reliability due to less human touch.

IMPLEMENTATION

- Present battery in Advanced Cruise Missile
- Present battery in MK-54 Torpedo

COTR: Robert Drerup (937) 904-4373

FY08 IBIF - Advanced Process Engineering for Cost Effective Battery Mfg. (Firefly Energy)

Conventional lead grid (left).
Firefly carbon-graphite foam grid (right)

Challenge

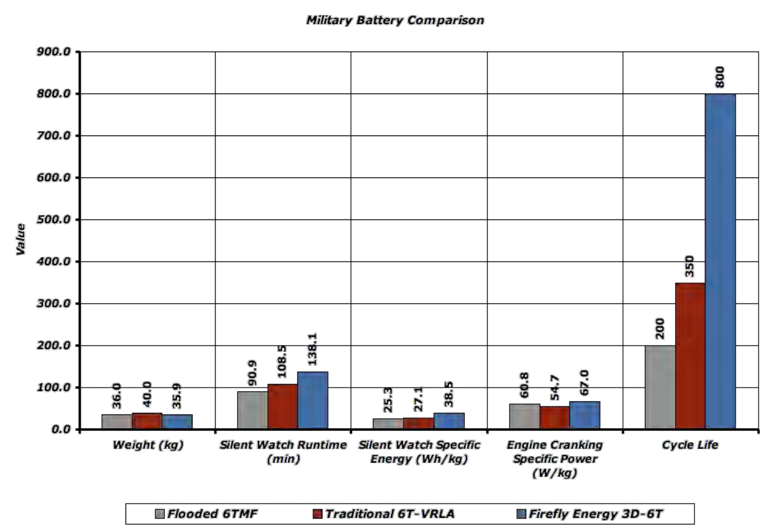
Current lead acid batteries have limitations when used in hot climates, relatively short shelf lives and are not able to meet future needs such as "Silent Watch

•Project Goals:

- •To replace traditional lead acid batteries with advanced lead acid technologies
- • Improved process engineering to reduce scrap and improve component performance
- • Develop automated production techniques to produce these batteries in a cost effective manner
- • Reduce the unit price of the new battery

Benefits

- Performance
  - Up to 50% increase in battery runtime
  - 4 fold increase in cycle life
  - 20% reduction in battery weight
- Logistical
  - Reduced battery demands
  - Reduced maintenance costs
  - Less batteries to store and transport
- Projected (contractor) annual savings
  - $1M+ over 100,000 batteries (Assumes only a 20% conversion to Firefly 6T)
  - Life cycle costs could be between $36 - $63M per year depending on actual demand



COTR: Marc Gietter (732-532-6764)

Industrial Base Innovation Fund (IBIF)

- FY 09 - $19 million add
- BAA amount: $10 million
- 8 Dec: JDMTP submits topics to DLA
- 9 Jan: BAA advertised in FED BIZ OPS
- Early Feb: Pre-proposal Conference
- 6 Mar: BAA closes
- April 2009: Proposal review
- June 2009: Selectees announced

ARRA Projects

- $5M Ceramic Matrix Composites
- $19M Fuel Cell Manufacturing Technology Initiative
  - Leverages DDRE Grand Challenge
  - 2 Fuel Cell Systems
  - 25 Watt Soldier Portable (follow-on to success of 2008 DOD Wearable Power Challenge)
  - 300 Watt Squad Level Charger to support GSE (endorsed by PEO-Soldier)

FY09 ARRA Project
Soldier Portable and Squad Level Fuel Cells

DESCRIPTION

- Develop soldier portable (25 watt) and squad level (300 watt) fuel cells
- Leverage existing technologies to mitigate risk
- Conduct field testing of systems to assure user acceptance
- Automate production lines to increase reliability and decrease unit cost
- Initiate LRIP
- Transition products to PM SWAR and DLA.

BENEFITS/METRICS

- Establish domestic production base
- Economic stimulus to U.S. industry through job creation and retention.
- Provides power for battery recharging.
- Reduces battlefield logistics of fuel and batteries.

FUNDING ($M)

FY08	FY09	FY10	FY11
0.0	19.0	0.0	0.0

Look for the opportunity to bid in FED BIZ OPS by end of May 2009

Thank You!

USMC Organizations involved in Research and Acquisition