2011 JSPE - Saft

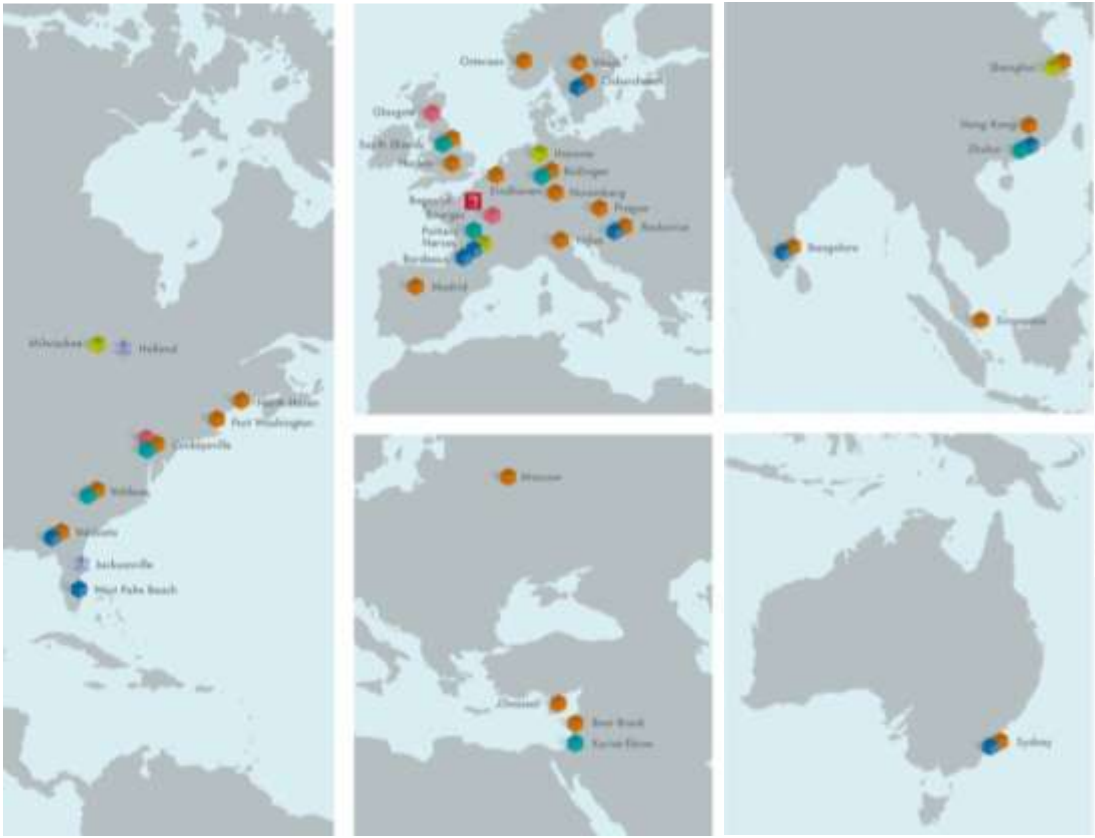
Advanced Lithium Power Sources – Squad Power

4 May 2011

Squad Power – Key Topics

- Saft Background
- Improved Target Acquisition System - Lithium Battery Box
- Battery Life
  - > Expectations vs. Experience
- Fielded Lessons
  - > Expecting the Unexpected
- Energy Storage on the Grid
- Squad Portable Storage
  - > Central hub for energy
- Platform Mounted Storage
  - > Integrating at a higher level

An International manufacturing network close to its customers



Specialty Battery Group production site
High-performance, primary and rechargeable lithium and silver batteries for the electronics, defence and space industries.

Industrial Battery Group production site
Rechargeable nickel and lithium-based batteries for demanding industrial applications.

Saft sales network

ASB
(50% Saft, 50% EADS)

Johnson Controls-Saft
(Saft 49%, Johnson Controls Inc. 51%)

Sites under construction

Jacksonville project update

- Contract signed with Department of Energy
- Factory construction contract signed
- Official ground-breaking ceremony held March 15th, 2011
- Over 350 MWh plant capacity by 2015 with room for further expansion
- Start of production H2 2011

Jacksonville Building Progress (as of January)

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 3000 batteries have been fielded for combat use. Systems in Iraq and Afghanistan (TRL-9).
- Raytheon has recognized Saft with the Supplier Excellence Award five years in a row due to our performance on this program.

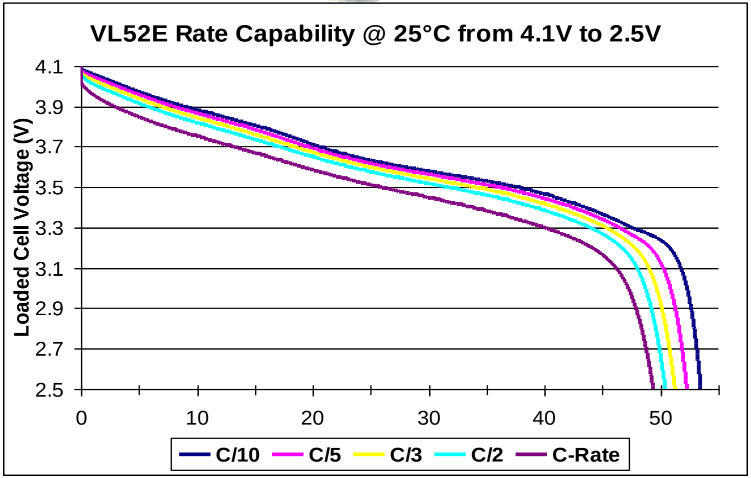
Raytheon

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 > 5 years
  - Reduced service cost
- Only required field maintenance is periodic charging
- Battery specs:
  - 28 V, > 100 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

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

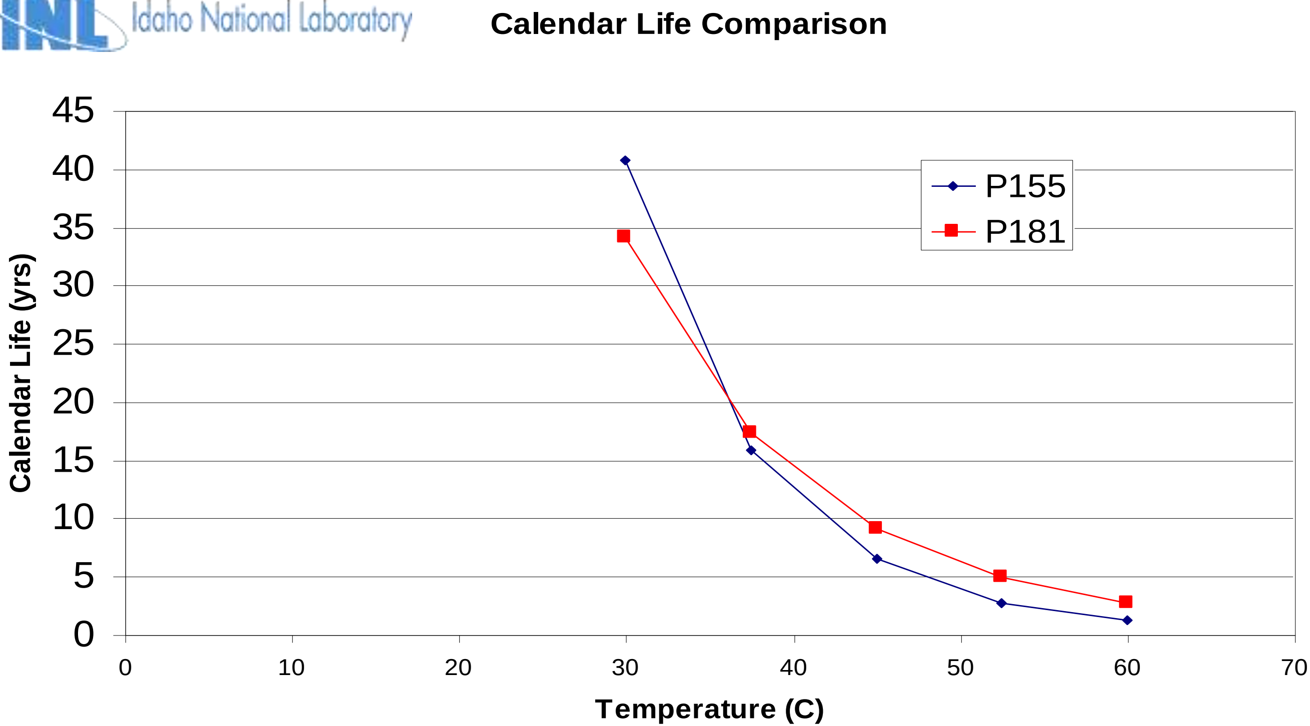
Battery Life

- 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

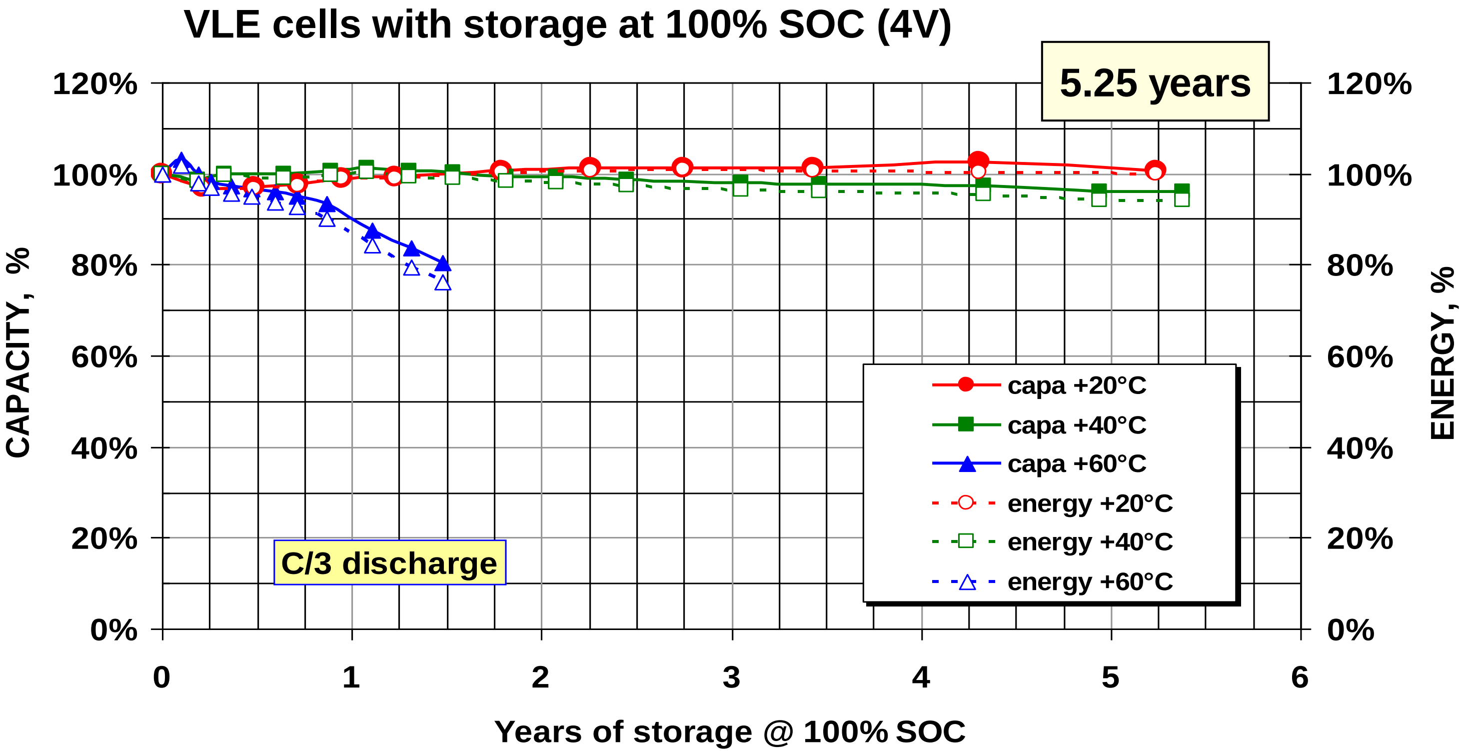
Battery Life - Definitions

- 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)



Battery Life - Calendar Stability at Temperatures

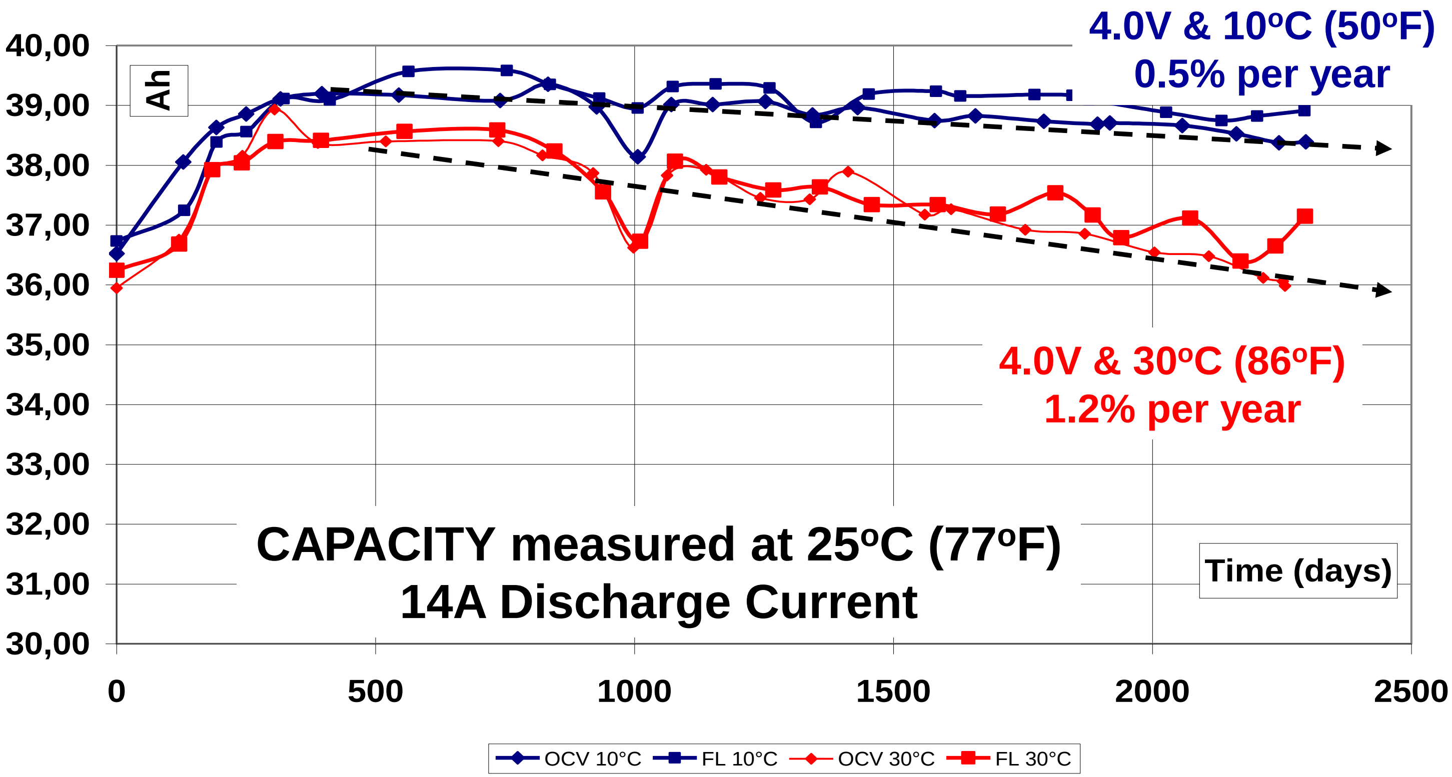


Battery Life - VES140 Cell for Space

- 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 7 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?

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 – Battle Damage

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

Renewable Energy - Commercial

	Grid level	Demand side
Centralized	■ High power Energy Storage ▪ Smoothing / Ramping support ▪ Grid stabilization/Power Quality ▪ Ancillary services ■ Bulk energy storage ▪ Energy dispatching ▪ Avoid disturbances ▪ Defer grid upgrades ABB Solar Farms	■ Commercial Storage ▪ Peak Shaving to avoid demand charges
Distributed	■ Smart Grids ▪ Controlled energy flows between decentralized generation and grid Guadeloupe	■ Smart Consumption ▪ Self-consumption ▪ Zero-energy houses ▪ Safe against outages ▪ High efficiency Sol-ion Apollo

Renewable Energy - Military

	Grid level	Demand side
Centralized	■ High power Energy Storage ▪ Smoothing / Ramping support ▪ Grid stabilization/Power Quality ▪ Ancillary services ■ Bulk energy storage ▪ Energy dispatching ▪ Avoid disturbances ▪ Defer grid upgrades ABB Solar Farms Installation	■ Commercial Storage ▪ Peak Shaving to avoid demand charges
Distributed	■ Smart Grids ▪ Controlled energy flows between decentralized generation and grid Guadeloupe FOB	■ Smart Consumption ▪ Self-consumption ▪ Zero-energy houses ▪ Safe against outages ▪ High efficiency Sol-ion Apollo Squad / FOB

Renewable Energy – Military / Squad Power

	Grid level	Demand side
Centralized	■ High power Energy Storage ▪ Smoothing / Ramping support ▪ Grid stabilization/Power Quality ▪ Ancillary services ■ Bulk energy storage ▪ Energy dispatching ▪ Avoid disturbances ▪ Defer grid upgrades **Installation**	■ Commercial Storage ▪ Peak Shaving to avoid demand charges (avoid inefficient use of costly fuel) **FOB**
Distributed	■ Smart Grids ▪ Controlled energy flows between decentralized generation and grid (size generation to load) **FOB**	■ Smart Consumption ▪ Self-consumption (renewable) ▪ Zero-energy (reduced fuel need) ▪ Safe against outages (mission) ▪ High efficiency **Squad / FOB**

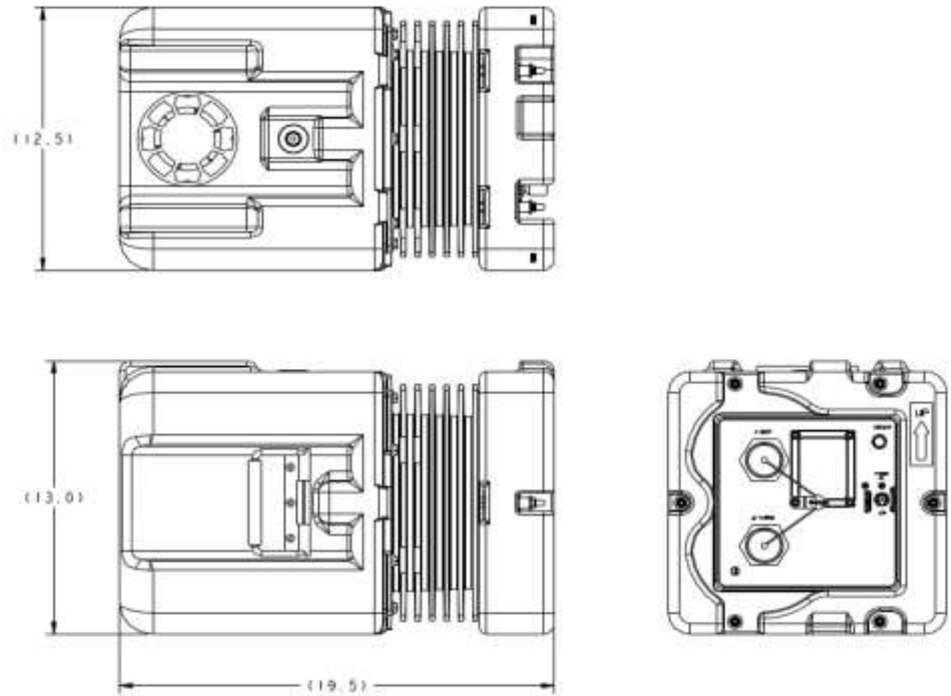
Advanced Lithium Power Source

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

- Available Now!

Physical Configuration

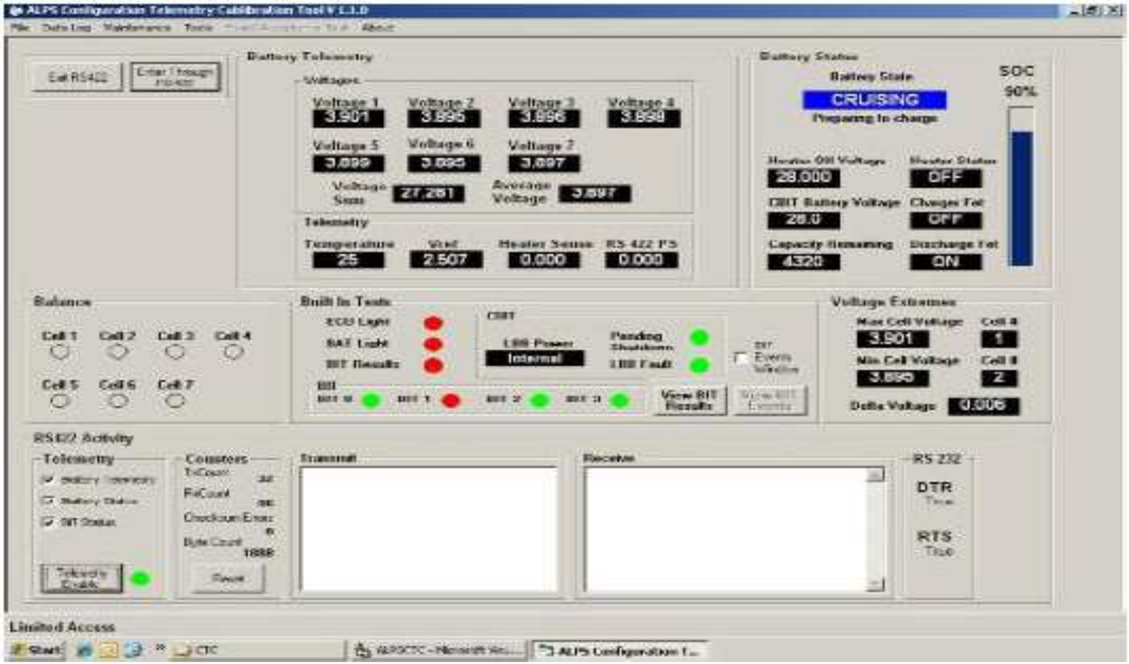
- Dimensions:
  (inches)



Discharge / Charging Options

- DC Output
  - > 30 Amp circuit breaker protected
- AC Input
  - > AC input can vary – 110/220V
  - > Less than 10 Amp draw at 110V
- DC Input
  - > Connects to 28V Nominal MIL ground vehicle bus
  - > Uses bus voltage to determine when to charge
    - only when engine operational
  - > Accepts up to ~10 Amp charging energy

Data / System Graphical Interface Tool



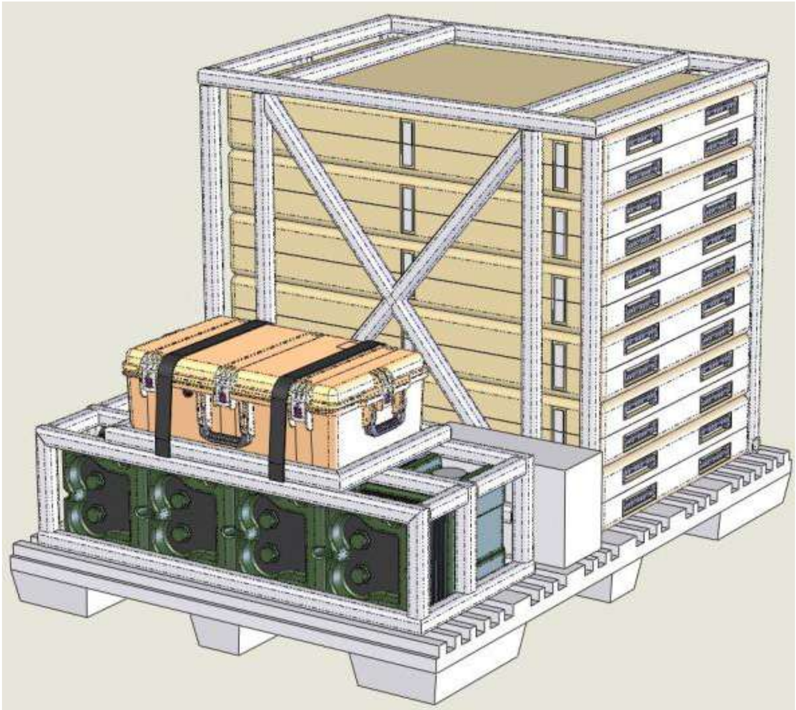
- Tool allows detailed view of battery status
- Data available over RS-422 bus – Integrates with higher level platform

ALPS Key Attributes

- Life Cycle Cost
  - > Proven technology outlasts BB2590 by factor of 10
  - > Proven calendar life 7 years and counting …
- System Simplification
  - > AC / DC Charging all in one box – No complicated cabling
- Rugged for Field Use
  - > Uses proven housing / durable design
  - > Proven simple state of charge gauge and interface
- Enhanced operational profile
  - > 2.6 kWHr
  - > Longer mission run time

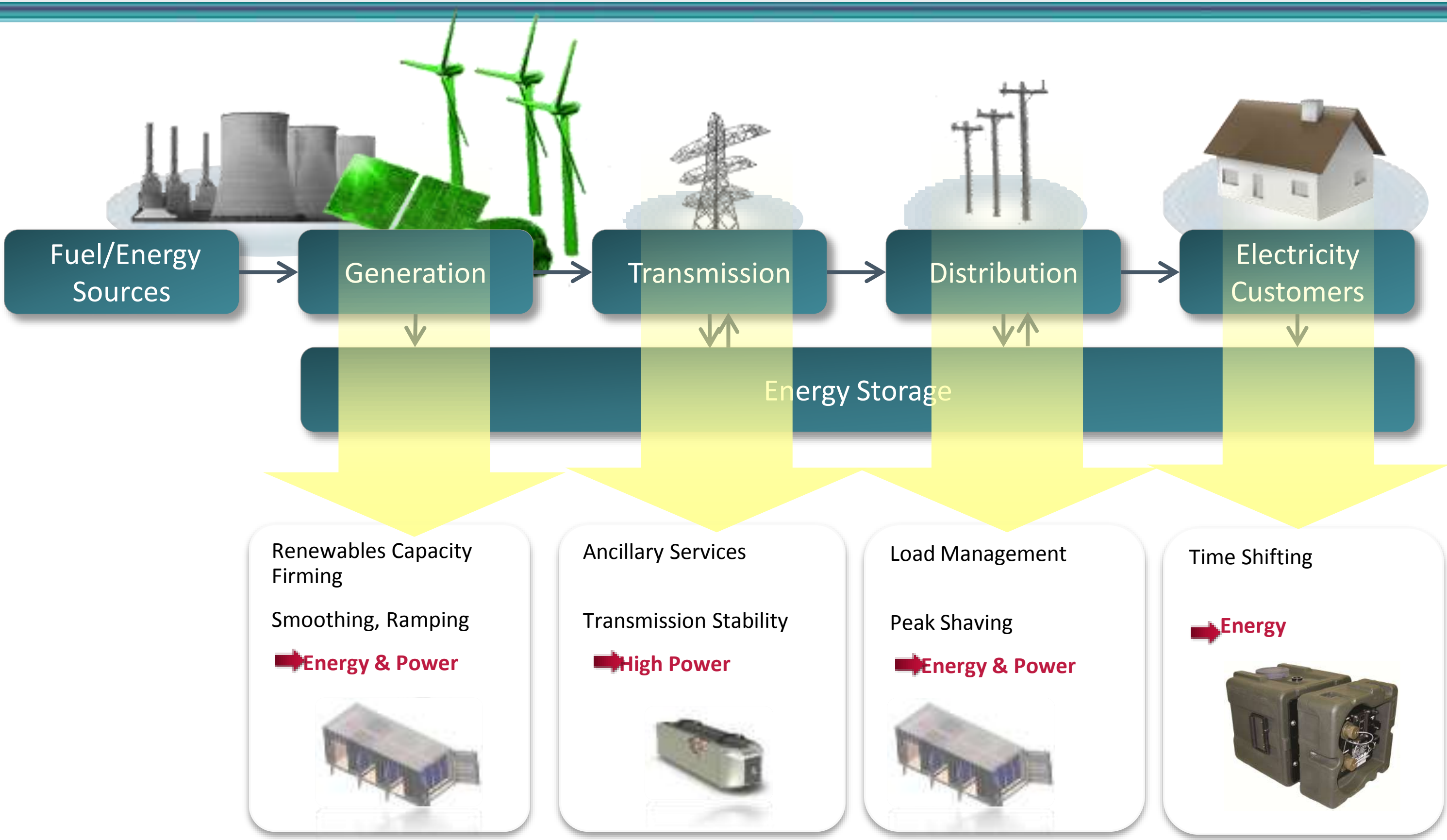
ALPS – System Component

- ALPS – Part of System
  - > Integrates to renewables
  - > Man-portable
  - > Communicates with large system
    - • Control of energy flow
    - • Interface with user



  - > Image courtesy of Iris Technology Corporation

Energy Storage Value Chain



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?

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