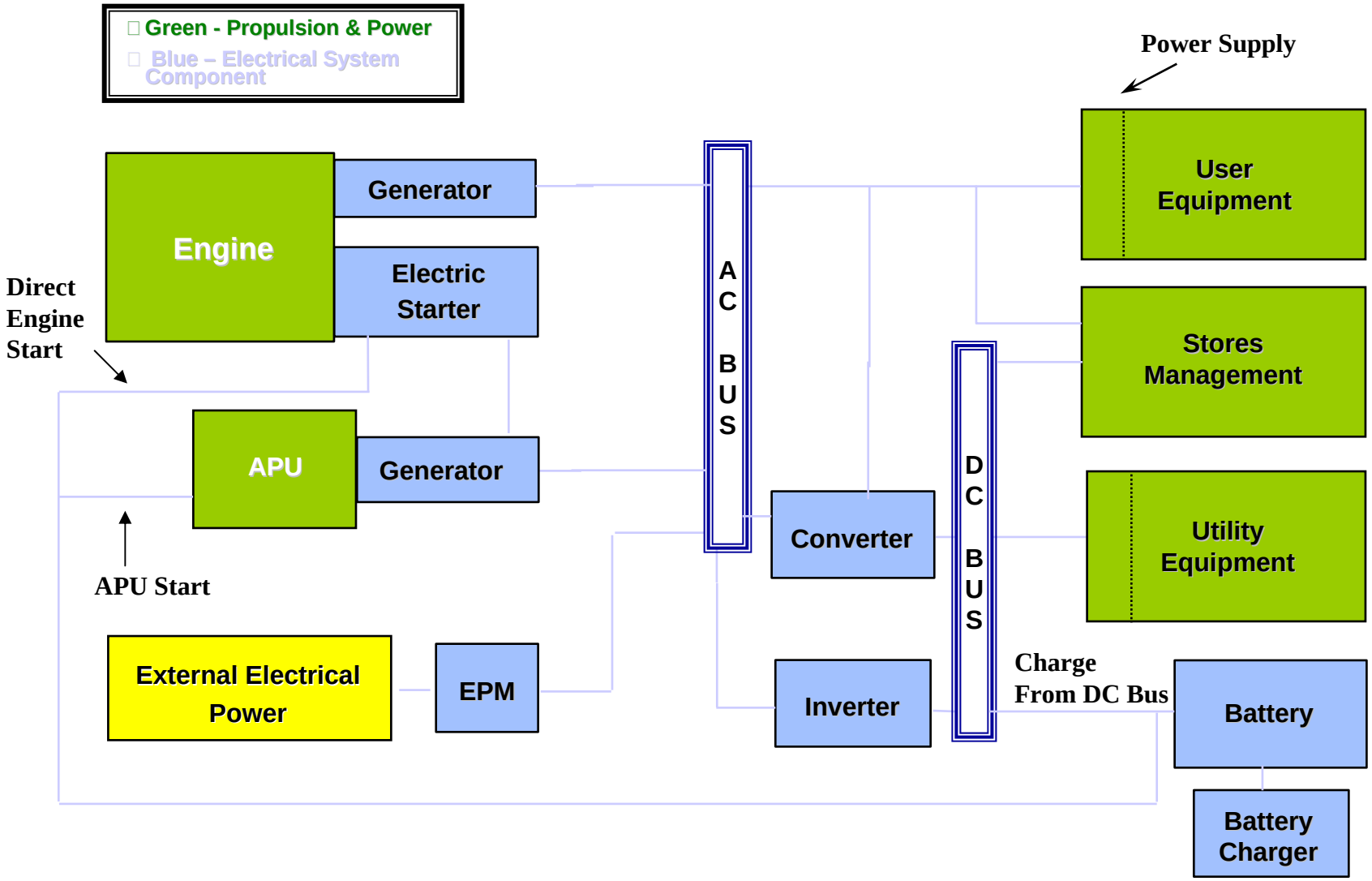
Battery Requirements for Application of Lithium Ion and Lithium Polymer To Achieve Standardization and Improved Reliability

Bill Johnson
Manager AIR-4.4.5.2 Electrical Power
E-mail: william.r.johnson@navy.mil
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



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)

NAVAIR

- 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

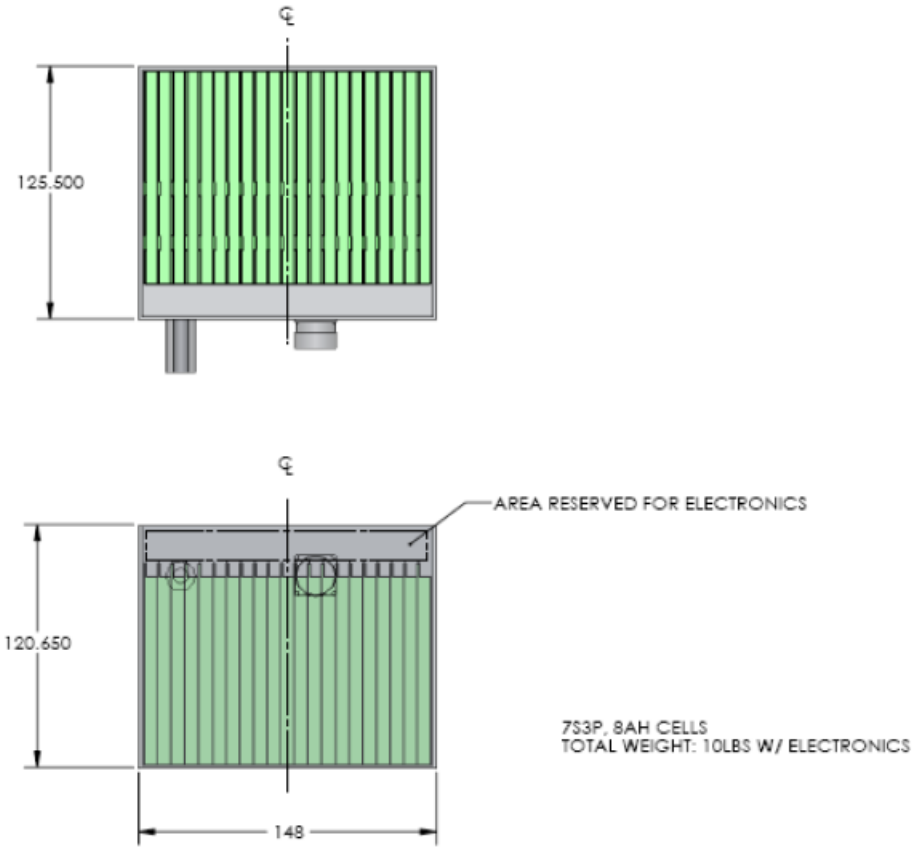
Technology Development (cont)

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

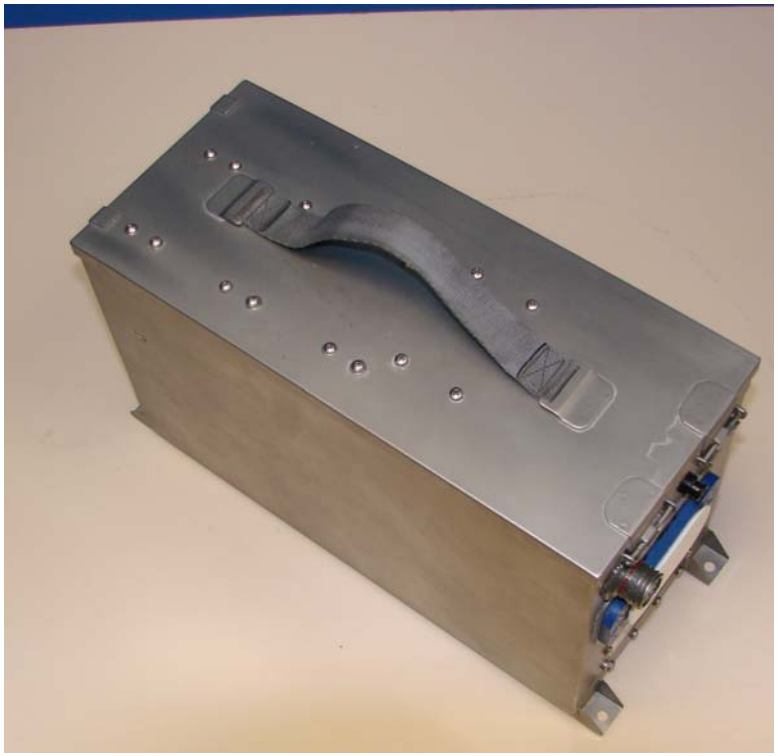
Test	Sample	1	2	3	4
1. Dimensions	All	The batteries mounting holes were not in complains. See note 1.			
2. Strength of Vent Tubes	All	OK	OK	OK	OK
3. Color & Marking	All	No marking labels were on the batteries. See note 2.			
4. Weight	All	16.65 lbs	15.85 lbs	15.7 lbs	lbs
5. Initial Capacity Discharge	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

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)

NAVAIR

- 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

Lithium Battery 2

Kokam Battery Development 1

Lithium Battery 3

Li Battery 5
SAFT NUCAS

Lithium Battery 4 – High Rate
Kokam Battery Development 2

New Opportunities for Safety

- 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?