

The Navy's Lithium Battery Safety Program



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Lithium Battery Safety Program

Outline of Presentation

- **Introduction and Background on Lithium Batteries**
- **History of the Lithium Battery Safety Program (LBSP)**
- **Process for Lithium Battery Safety Approval**
- **LBSP and WSESRB Relationship**
- **Conclusion and Questions**



Lithium Battery Safety Program

Lithium Facts:

- Element with Atomic Number 3
- Lightest Alkali Metal ($\rho = 0.53 \text{ g/cm}^3$)
- Silvery, Metallic Solid at Room Temp
- Very High Thermal and Electrical Conductivity
- Highest Specific Heat of any Solid Element
- Source – Salts & Hydrates
- Melts at 180.5 C (357.0 F)
- Reacts with Water
- Burns in Air
- Very High Electrochemical Potential
- Extremely Mobile +1 Ions

ALKALI METALS

Lithium

Sodium

Potassium

Rubidium

Cesium

Francium

es

H

Li

Na

K

Rb

Cs

Fr

Be

Mg

Ca

Sr

Ba

Ra

Sc

Y

La

Ce

Pr

Nd

Ti

Zr

Hf

Nb

Ta

Db

V

Cr

Mn

Fe

Co

Ni

Cr

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Xe

Rn

He

Ne

Ar

Kr

Xe

Rn

La

Ac

Ce

Th

Pr

Pa

Nd

U

Pm

Np

Sm

Pu

Eu

Am

Gd

Cm

Tb

Bk

Dy

Cf

Ho

Es

Er

Fm

Tm

Md

Yb

No

Lu

Lr

6.94
Atomic
Weight



Lithium Battery Safety Program

Lithium Uses and Applications



NON-ENERGETIC:

- Lithium Citrate Used in the Original 7-Up Soda (Original Name, ~1929, was "Bib-Label Lithiated Lemon-Lime Soda")
- Lithium Carbonate Used As Anti-Depressant Drug
- Lithium Compounds Used in the Production of Aluminum from Oxides (Enhances conductivity for electrolysis of Al_2O_3)
- Li-Al Alloys Used in Lightweight Structural Applications (Aircraft)
- Lithium Oxides and Fluorides Used in Glasses and Ceramics (Mt. Palomar Telescope)
- Lithium Stearate Used in All-Purpose and High-Temperature Lubricant



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Lithium Uses and Applications (cont.)

ENERGETIC:

- **Lithium Metal Used As a Heat-transfer Medium**
- **Lithium Metal Used Directly As a Fuel (Mk 50 Propulsion)**
- **Lithium Metal (and Alloys) Used As Battery Anode Material**
- **Other Emerging Technologies - Lithium Perchlorate Oxygen Storage, Lithium Semi-cell Fuel Cells, etc.**



Lithium Battery Safety Program

Q. What is a lithium battery?

A. One or more electrochemical cells (containing lithium as a metal, alloy or compound) electrically connected in an appropriate series/parallel arrangement to provide the required operating voltage and current levels including, if any, monitors controls and other ancillary components (fuses, diodes), case terminals and markings

Linden & Reddy, Handbook of Batteries, Third Edition

A. A self-contained chemical reactor (containing lithium as a metal, alloy or compound) that is capable of transforming chemical energy into electrical energy on demand

Levy & Bro, Battery Hazards and Accident Prevention



Lithium Battery Safety Program

Lithium Cell Types Used by the Navy

- **Primary (Non-rechargeable)**
 - Active
 - Reserve
 - **Liquid electrolyte**
 - **Thermal**
- **Secondary (Rechargeable)**



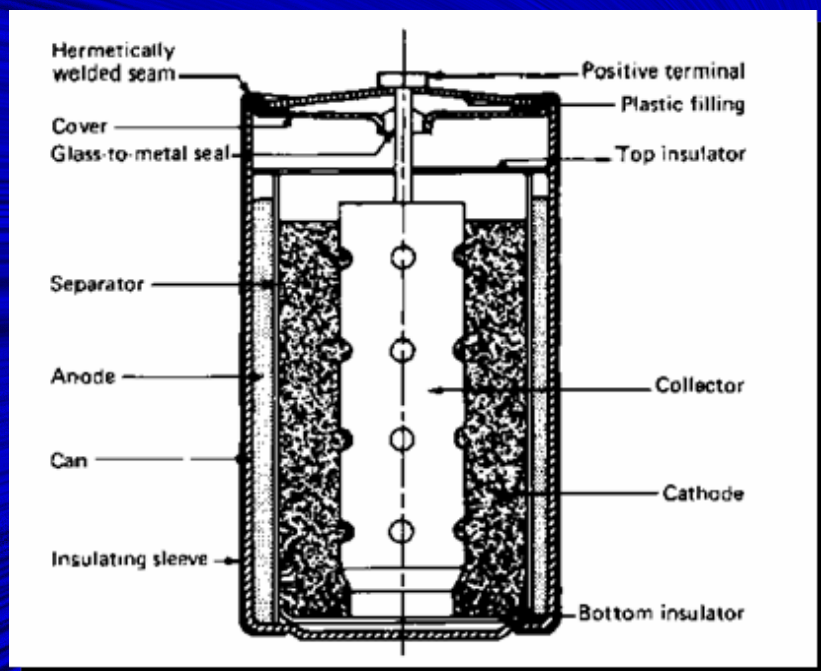
Lithium Battery Safety Program

Lithium Cell Chemistries Used by the Navy

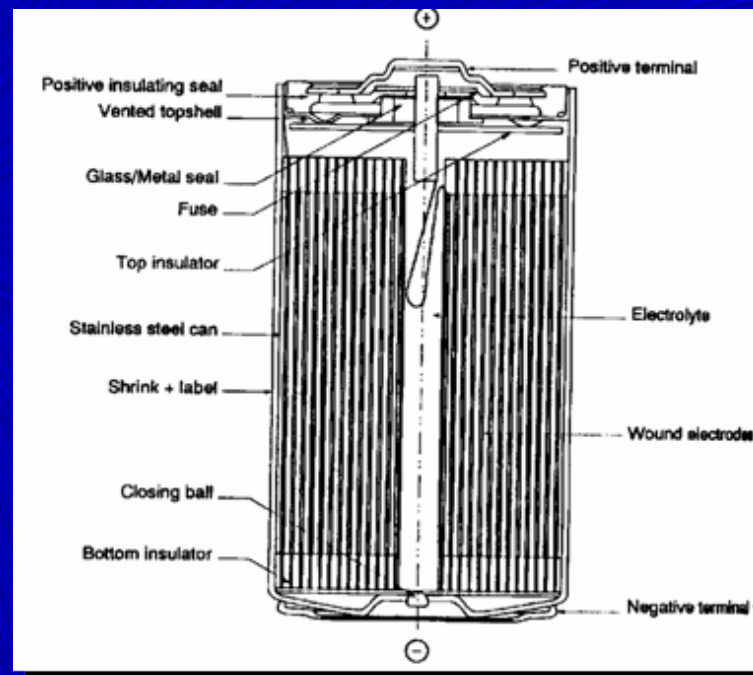
- **Solid Cathode -- Li/MnO₂, Li/CF_x, Li/FeS₂, Li/V₂O₅**
- **Liquid Cathode -- Li/SOCl₂, Li/SO₂, Li/SO₂Cl₂**
- **Lithium metal anode**
- **Lithium alloy anode**
- **Lithium ion anode**

Lithium Battery Safety Program

Lithium Cell Designs Used by the Navy



Bobbin

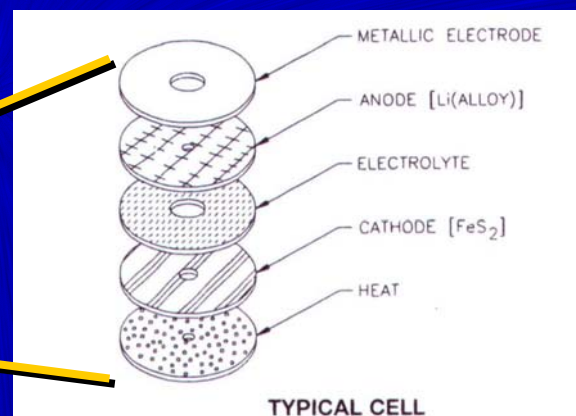
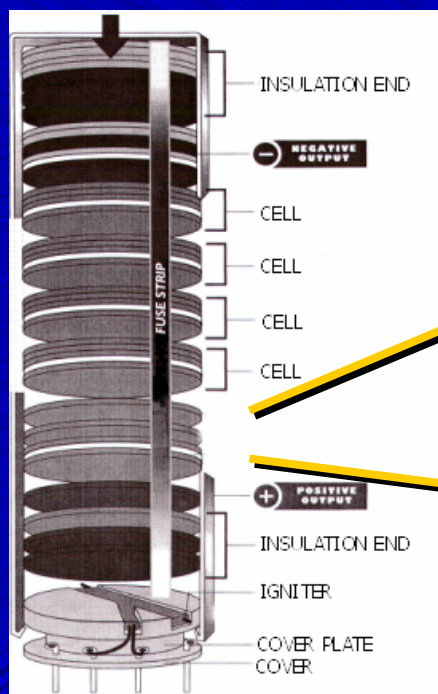


Spiral Wind

Linden & Reddy, Handbook of Batteries, Third Edition

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Lithium Cell Designs Used by the Navy

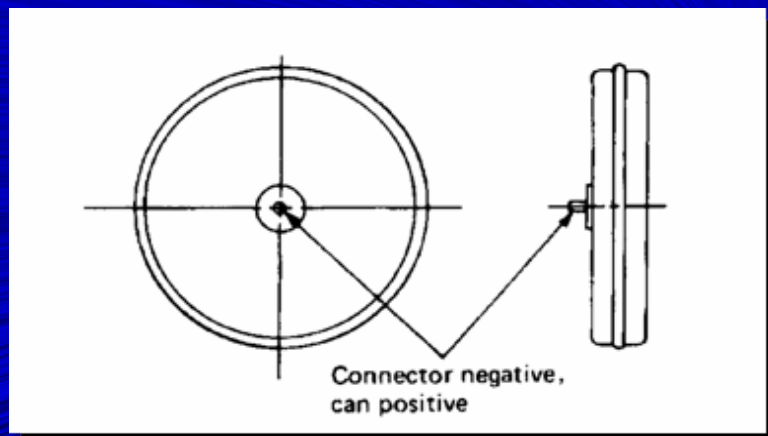


Bipolar Stacked Plates

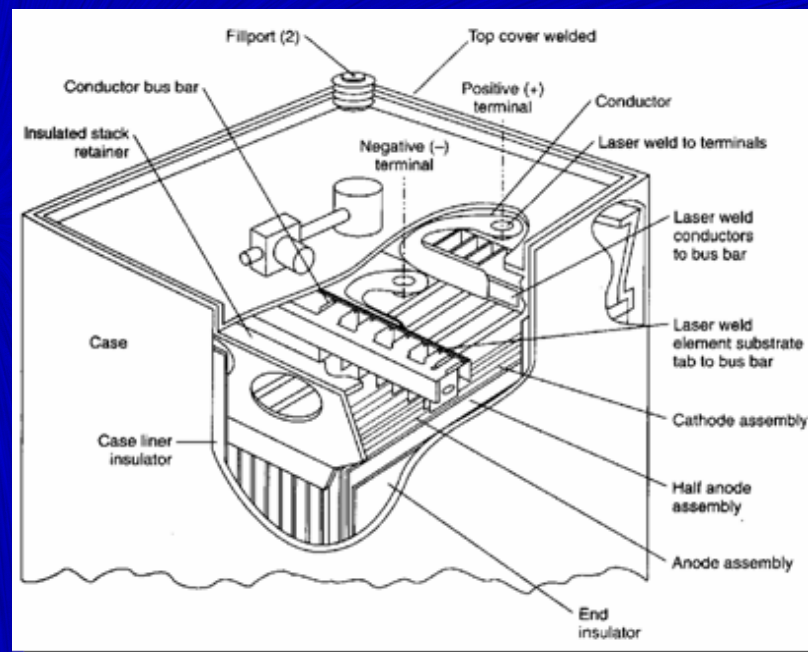
ASB-MSB Thermal Batteries Guide/EPT Technical Guide

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Lithium Cell Designs Used by the Navy



Coin



Prismatic

Linden & Reddy, Handbook of Batteries, Third Edition



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Lithium Cell Sizes

- **Button cell (0.01 Ah)**
- **2/3 AA (0.60 Ah)**
- **1/2 AA (0.95 Ah)**
- **2/3 A (1.20 Ah)**
- **AA (1.90 Ah)**
- **A (2.8 Ah)**
- **9V (1.20 Ah)**
- **1/3 C (0.86 Ah)**
- **2/5 C (2.50 Ah)**
- **C (5.4 Ah)**
- **D (7.2 Ah)**
- **DD (16.5 Ah)**
- **Specialty design cell
(2,200 Ah)**
- **10,000 Ah prismatic cell**



Lithium Battery Safety Program

Where Lithium Batteries Are Used in the Navy

- **Communication Radios**
- **Mine Countermeasures**
- **Locator Beacons**
- **Memory Back-Up**
- **Emergency Signal Devices**
- **Missile Guidance & Control**
- **Laser Detection Devices**
- **Night Vision Goggles**
- **Expendable Training Devices**
- **Mines**
- **Electronic & Acoustic Decoys**
- **Sonobuoys**
- **Deep Ocean Sensors**
- **Transponders**
- **Telemetry Systems**
- **Small UUV Propulsion**
- **Laptop Computers**



Lithium Battery Safety Program

Common Safety Devices for Lithium Batteries Include:

- **Electrical fuses**
- **Thermal fuses**
- **Diodes (charging and bypass)**
- **Voltage monitors**
- **FETs**
- **Vent structures**
- **Fuseable separators**



Lithium Battery Safety Program

Lithium Battery = Stored Chemical Energy

- **Controlled release of this energy provides electrical power in the form of current and voltage**
- **Uncontrolled release of this energy can result in fire, exposure of toxic materials, shrapnel, high pressure events, and any combination thereof**



Lithium Battery Safety Program

Origin of the Navy's Lithium Battery Safety Program

- **First marketed in early 1970, primarily for military applications**
- **Featured substantial increases in both gravimetric and volumetric energy density**
- **Commercial and military facilities explored safety characteristics in the lab in conjunction with fielding systems**
- **Seven personal injuries were reported during the period 1976 through 1983, including one death**



Lithium Battery Safety Program

- **NAVSEAINST 9310.1A of 11 March 1982**
- **NAVSEANOTE 9310 of 11 June 1985**
- **NAVSEAINST 9310.1B of 13 June 1991**
- **Technical Manual for Batteries, Navy Lithium Safety Program And Procedures S9310-AQ-SAF-010 of 20 July 1988**



Lithium Battery Safety Program

S9310-AQ-SAF-010

- **Introduction**
- **Selection and review**
- **Design**
- **Use**
- **Packaging**
- **Storage**
- **Transportation**
- **Disposal**
- **Emergency response procedures**
- **Safety and performance tests for certification**
- **Pass fail criteria**
- **Safety**



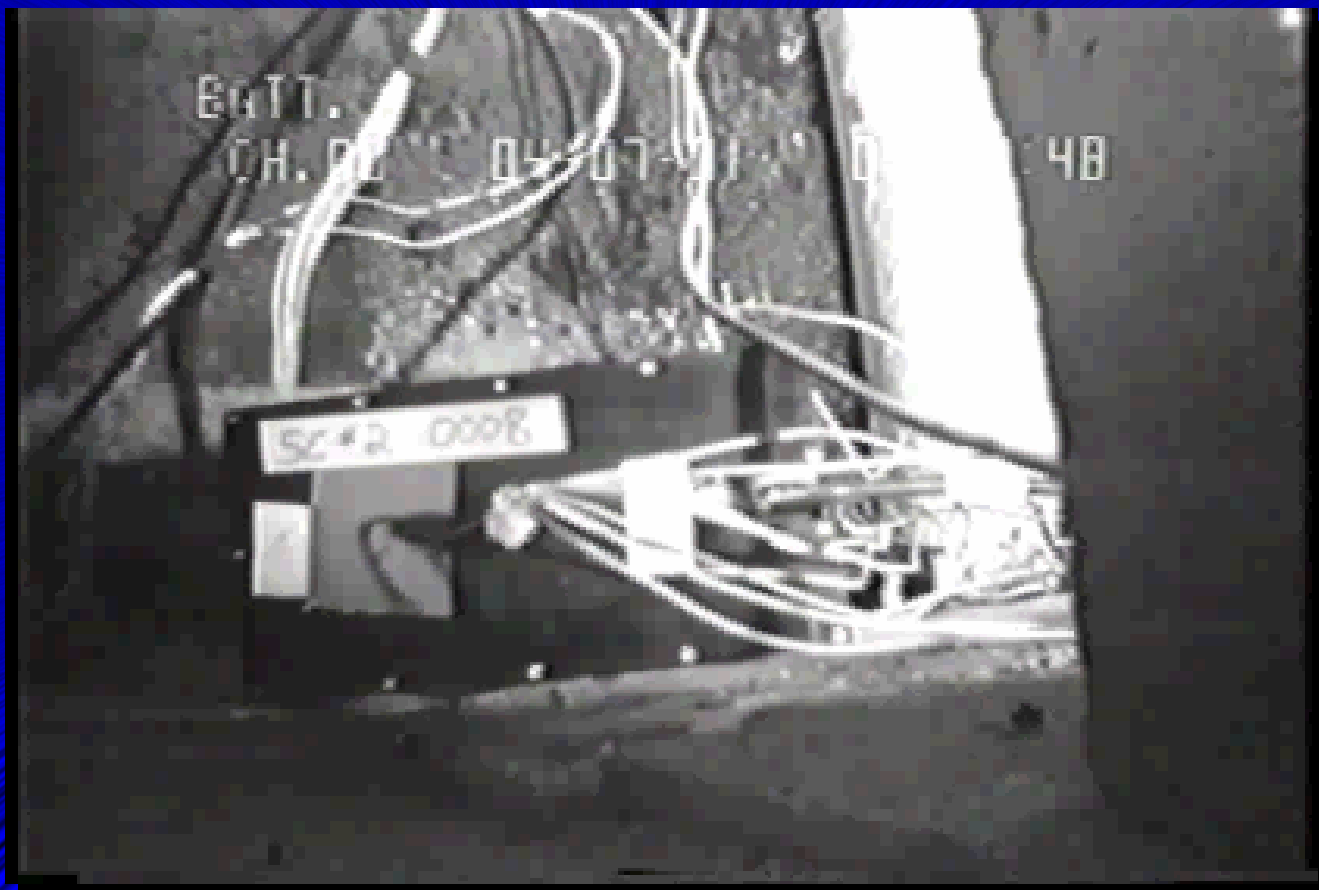
Lithium Battery Safety Program

SAFETY TESTING (Primary Batteries)

- **Constant current discharge & reversal**
- **Short circuit**
- **High temperature**
- **Charging**
- **Electrical safety device**



Lithium Battery Safety Program





Lithium Battery Safety Program

SAFETY TESTING (Thermal Batteries)

- **Unactivated: Environmental**
- **Activated**
 - **High Rate Discharge**
 - **Thermal Abuse**
 - **Open Circuit**
 - **Charging**



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Lithium Battery Safety Program





Lithium Battery Safety Program

SAFETY TESTING (Reserve Batteries)

- **Unactivated**
 - Environmental
 - High Temperature
- **Activated**
 - Constant Current Discharge and Reversal
 - Short Circuit
 - Open Circuit
 - High Temperature Activation



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SAFETY TESTING (Rechargeable Batteries)

- **Short Circuit**
- **Overcharge/Discharge**
- **Overdischarge/Charge**
- **High Temperature**
- **Electrical Safety Device**



Lithium Battery Safety Program





Lithium Battery Safety Program

REQUIREMENTS FOR APPROVAL

- Request letter
- Safety data package
- Test report
- Safety evaluation letter
- Draft approval letter



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REQUEST LETTER

- **Defines**
 - **System**
 - **Platform**
 - **Action desired**
- **Submitted on letter head**
- **Signed**



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SAFETY DATA PACKAGE

- **Battery/Cell Description**
 - **Battery manufacturer**
 - **Model Number and/or Part Number**
 - **Electrical description**
 - **Operating life**
 - **Physical dimensions and description**
 - **Marking indicating battery chemistry**
 - **Cell and/or battery yield pressure**
 - **Material Safety Data Sheets**
 - **Cell failure mode**



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SAFETY DATA PACKAGE (CONT.)

- **Lithium battery-powered equipment description**
 - **Manufacturer**
 - **Model number and/or Part Number and device name**
 - **Diagram of the system's overall mechanical interfaces**
 - **Battery housing/container, strength, and free volume**
 - **Battery installation**
 - **Safety features or venting mechanisms**
 - **Current drain**
 - **Block diagram of system**
 - **Electrical schematic**



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SAFETY DATA PACKAGE (CONT.)

- **Logistics**
 - **Logistics and operational use**
 - **Packaging**
 - **Storage facilities**
 - **Transportation methods**
 - **Disposal information**
 - **Battery changeout replacement plan**
- **Functional, environmental and safety tests performed to date**
- **Proposed safety testing program plan**



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PASS-FAIL CRITERIA

- **An inability of the lithium batteries or lithium battery-powered equipment to meet the *"passing"* criteria does not necessarily result in an automatic rejection of the equipment for service use.**



Lithium Battery Safety Program

UNIT CRITERIA

- ***Land:*** Unit has a fail safe vent system to keep pressure below 50 percent of the yield pressure of the unit.
- ***Surface Ship:*** Same as above, except no external fire or flame.
- ***Aircraft:*** Same as above, except the use of liquid cathode lithium cells and batteries is strongly discouraged.
- ***Submarine:*** Total containment. Internal pressure shall stay below 50 percent of the yield pressure of the battery compartment.



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UNIT CRITERIA (Cont.)

- **Relief Mechanism Criteria**
 - If pressure relief mechanisms are provided in the unit, they must prevent the pressure from reaching a peak value of 50% of the yield pressure of the unit.
 - If pressure relief mechanisms are not provided, the recorded peak pressure in any test must not exceed 50% of the yield pressure of the unit to be considered safe.



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UNIT CRITERIA (Cont.)

- **Batteries must not vent in response to the Electrical Safety Device Test**
- **Reaction from the battery shall not adversely affect the safety of the unit**



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SAFETY EVALUATION LETTER

- **Contains the results of the review of the data submitted**
 - Request letter
 - Safety data package
 - Test report
 - Any other related information
- **Provides justification for recommendation for approval based on technical evaluation of all test and design data**
- **Restrictions and limitations**



Lithium Battery Safety Program

APPROVAL LETTER

- **Issued from NOSSA**
- **States conditions and limitations for use**



Lithium Battery Safety Program

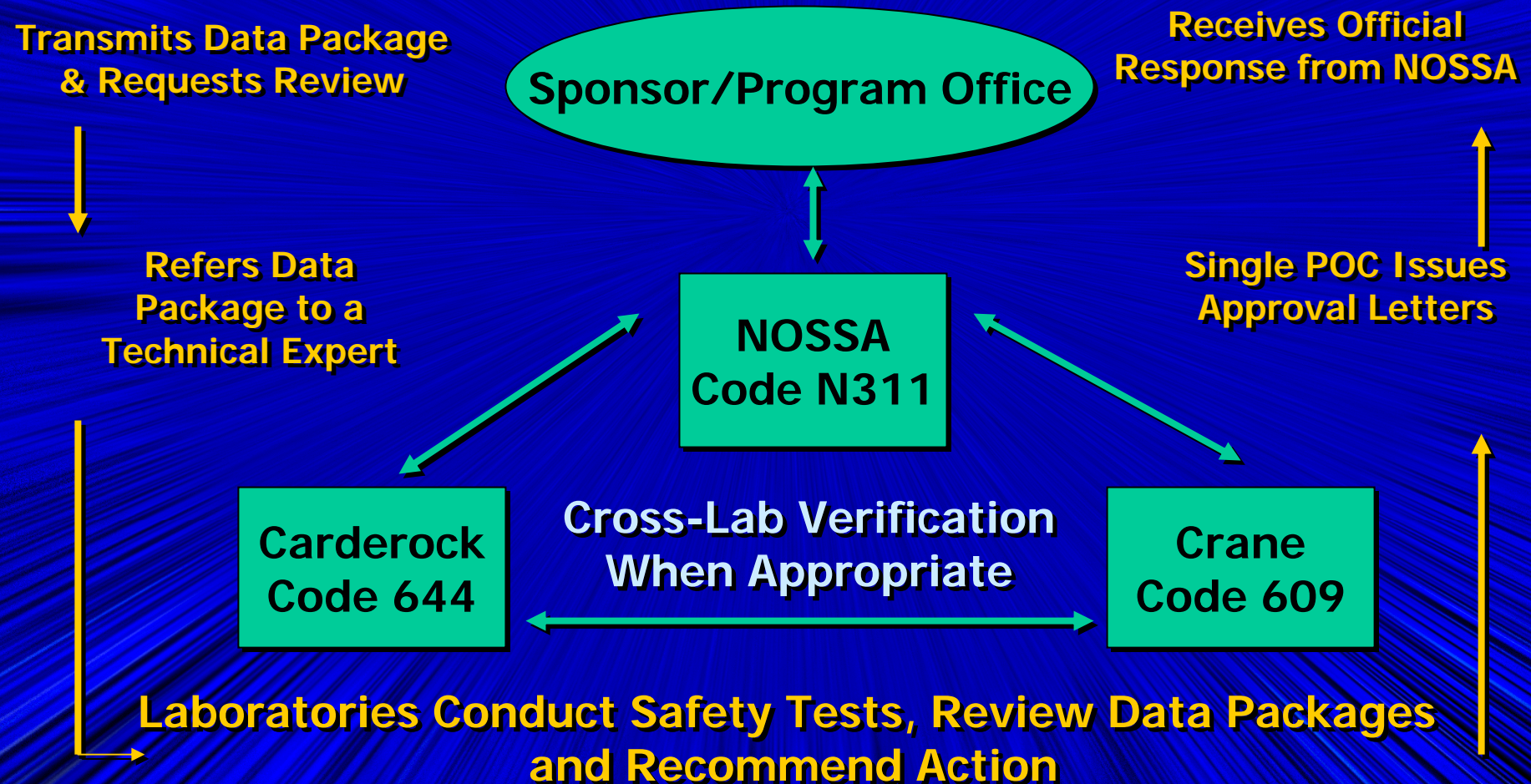
TIME TABLE

- **Three weeks to two months after receipt of all information**



Lithium Battery Safety Program

Lithium Battery Safety Program Tasking





Lithium Battery Safety Program

Impacts of Lithium Battery Safety Program

- **Lithium battery database**
- **Single POC for battery-related inquiries**
- **Design changes**
 - **Alternate non-lithium power sources**
 - **Added safety devices**
 - **Revised battery designs**



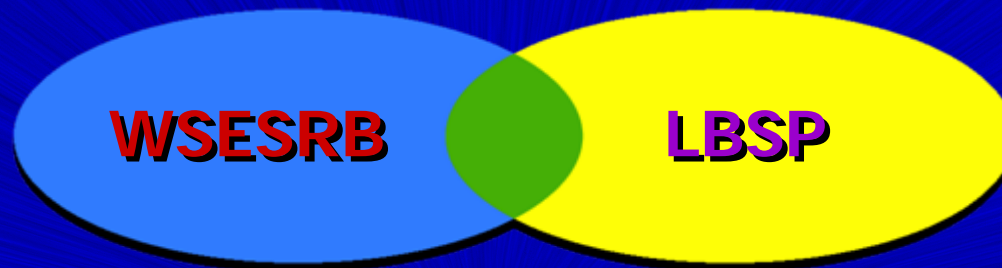
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Relationship to WSESRB

- **LBSP supports WSESRB charter by providing a source of data for hazard assessments on systems that include lithium batteries**
- **LBSP is independent of WSESRB because many applications that include lithium batteries are not subject to WSESRB review**
- **LBSP is similar in function to the SSSTRP and FISTRP**



Lithium Battery Safety Program



WSESRB Only	Both	LBSP Only
Aegis	AFD	Reconnaissance UUVs
Nimitz	Artillery Fuzes w/batteries	CSEL Radio
JSHIP	Missile Systems	Integrated Navigation Sonar Sensor
2.75 Rocket System	LMRS	Army/USMC Comm Devices
BFTT	Torpedoes	Expendable Mobile ASW Training Target
Anti Tank Weapon	Countermeasure UUVs	Versatile Exercise Mine



Lithium Battery Safety Program

Conclusion

The concept of a lithium battery encompasses a wide variety of specific characteristics

The Navy has an excellent safety record with lithium battery use, and this is the process by which we have met and will continue to maintain this record

LBSPs primary function is to minimize risk to personnel and platforms while allowing the use of lithium batteries to advance our military capabilities



Lithium Battery Safety Program

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