

When Batteries Go Bad

“9310”

Serious Testing for Serious Batteries

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Joint Power Expo, New Orleans LA,
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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 NAVSEA 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!

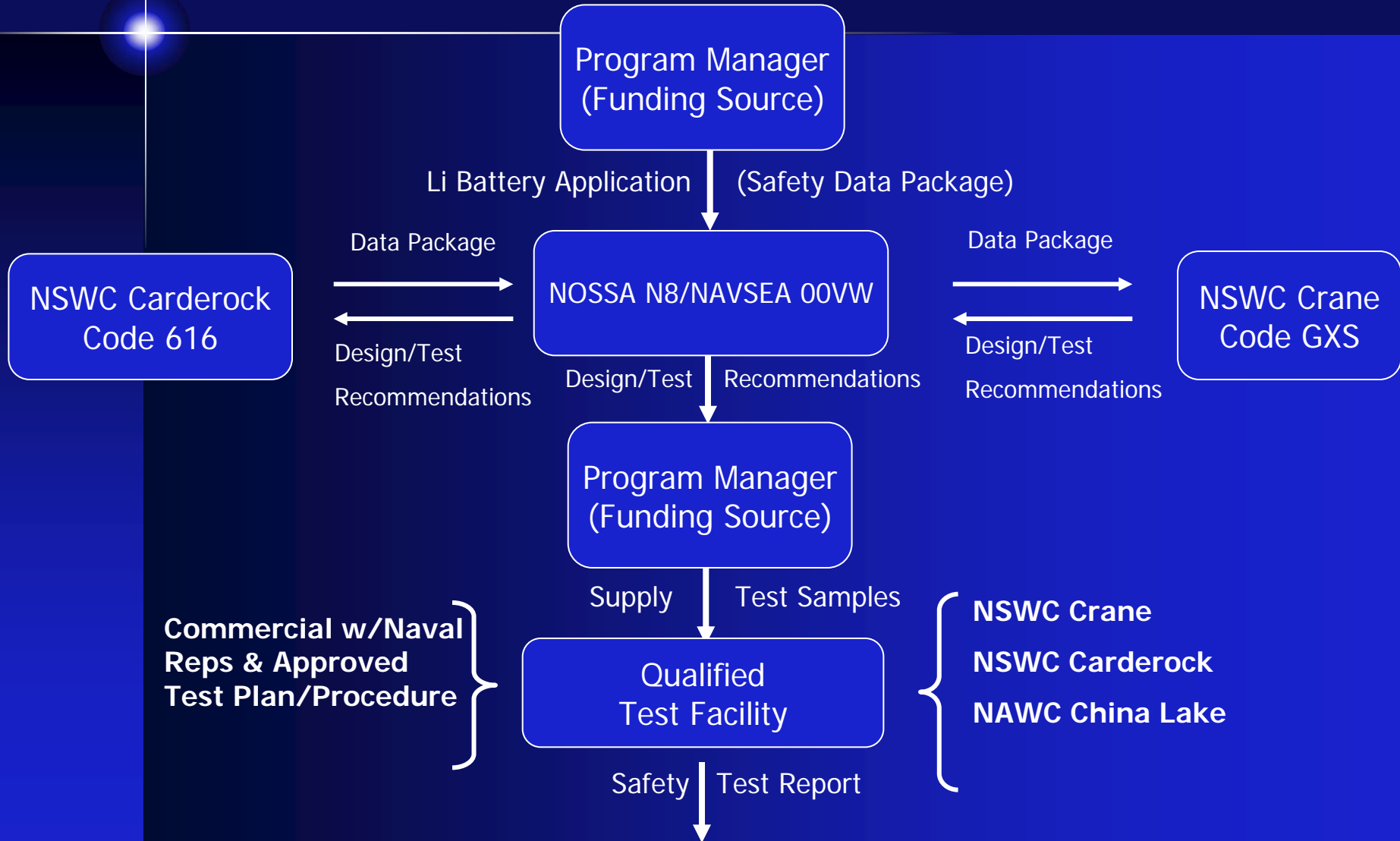
“Just Gimme the Certified Battery List...”

- 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

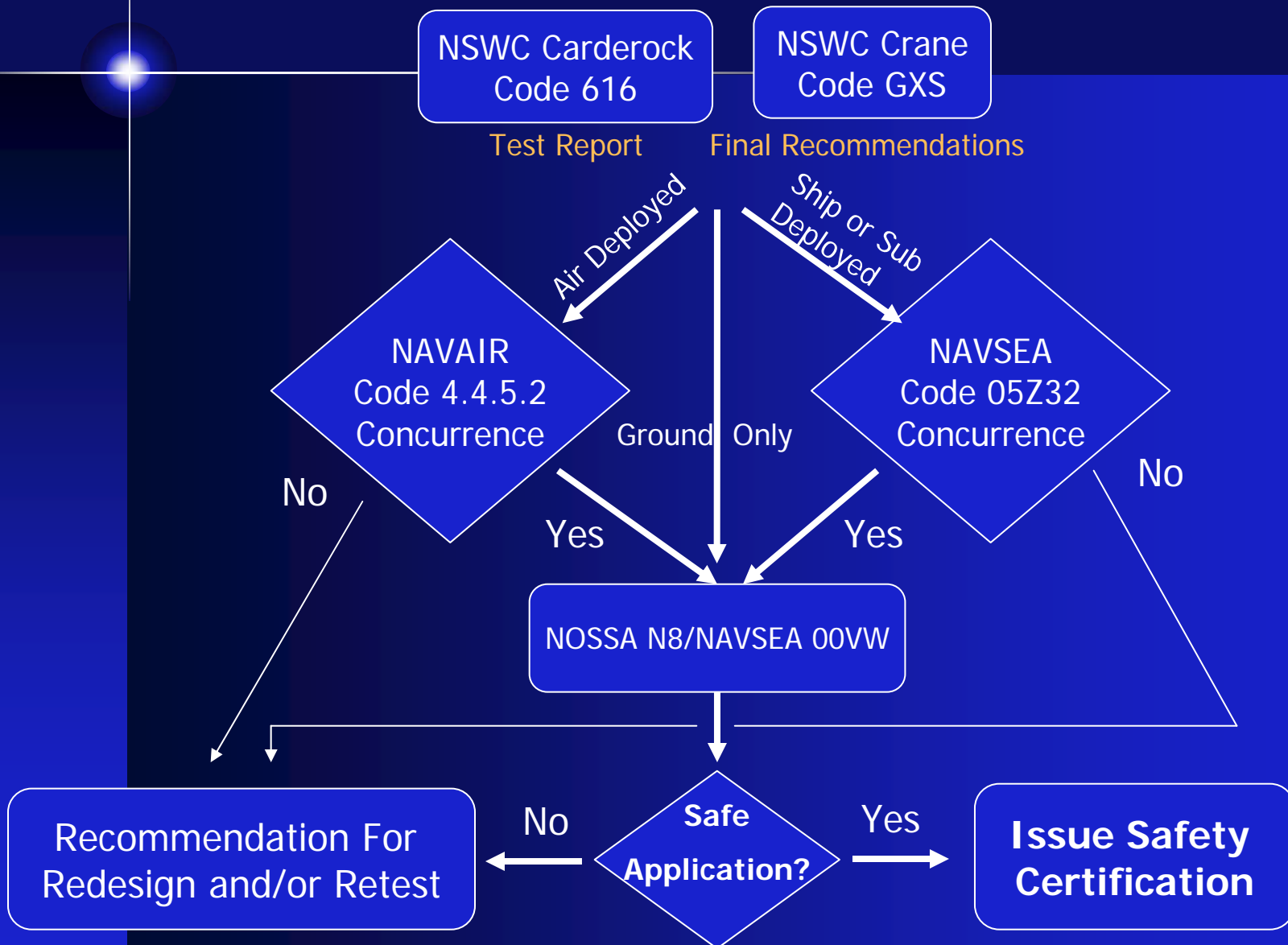
NOSSA/NAVSEA00V Interim 9310 Guidance

- 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/SO₂, Li/SO₂Cl₂, Li/SOCl₂, Li/MnO₂, Li/CF_x, Li/FeS₂, 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°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



DEPARTMENT OF THE NAVY
NAVAL ORDNANCE SAFETY AND SECURITY ACTIVITY
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3817 STRAUSS AVENUE, SUITE 108
INDIAN HEAD, MD 20640-5151

8020
Ser N84/265
18 Feb 09

From: Commanding Officer, Naval Ordnance Safety and Security Activity
To: Program Executive Officer, Littoral and Mine Warfare (PEO-LMW (EOD-2))
Subj: EXTENSION OF LIMITED SAFETY CERTIFICATION OF LITHIUM ION POLYMER BATTERY PROPOSED FOR USE DURING TEST AND EVALUATION OF THE UNMANNED UNDERWATER VEHICLE AND THE HYDROGRAPHIC MAPPING

Ref: (a) PEO LMW ltr 8027
(b) NOSSA ltr 8020 S
(c) Email NAVSEA (SE

Encl: (1) NAVSURFWARCN CR of 10 Dec 08



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8020
Ser N84/266
18 Feb 09

From: Commanding Officer, Naval Ordnance Safety and Security Activity
To: Program Executive Officer, Submarines (PMS-415/ F. Wineman)

Subj: EXTENSION OF LIMITED SAFETY APPROVAL OF LITHIUM ION BATTERIES USED IN TEST AND EVALUATION OF THE ELECTRIC COMMON VERY LIGHTWEIGHT TORPEDO

State ARL ltr of 12 Nov 08
A ltr 8020 Ser N841/1056 of 7 Jul 08

JRFWARCN CARDEROCKDIV ltr 13280 Ser 61/09-046 of 09

to the request of reference (a), the Naval



1
NAVA

From: Commanding Off. Activity
To: Commander, Spa (Code 2774/B.)
Subj: LIMITED SAFETY LITHIUM ION BATTERY TEST FIXTURE
Ref: (a) SPAWAR ltr (b) Email NAVSI
Encl: (1) NAVSURFWARCN of 11 Dec 08

1. In response to the Ordnance Safety and Security Activity (NOSSA) limited safety certification (P/N) NL2024HD22 lithium ion battery test fixture, this 11 years of at-sea and in Pacific facilities, at Battery charging operations shall only be conducted in sea based laboratory facilities; no charging operations for SSC Pacific Test Fixture lithium ion battery shall be conducted on surface platforms. This safety certification is based on the safety evaluation contained in enclosure (1), and expires 31 December 2010. Naval Sea Systems Command (SEA05232) has reviewed the documentation and concurs with the recommendation for extended limited certification as indicated in reference (c).

2. The NOSSA point of contact is Mr. Christopher A. Batchelor (N84) on DSN 354-6038, commercial (301) 744-6038, or email: chris.batchelor@navy.mil.

R. M. SWANSON
By direction

Copy to: (Electronic)
NAVSURFWARCN CARDEROCKDIV (Code 616/Ms. J. Banner)
NAVSURFWARCN DIV Crane (GXS/Mr. M. Tisher)
COMNAVSSEASYSOM (SEA0523/Mr. Moniri, SEA05232/Mr. D. Cherry)

From: Commanding Officer, Naval Ordnance Safety and Security Activity
To: Program Executive Officer, Littoral and Mine Warfare (PMS-EOD 26)

Subj: LIMITED SAFETY CERTIFICATION OF LITHIUM BATTERY PROPOSED FOR USE IN TEST AND EVALUATION OF THE FOSTER-MILLER HULL UNMANNED UNDERWATER VEHICLE LOCALIZATION SYSTEM

Ref: (a) PEO LMW ltr 8027 Ser EOD-26/203 of 13 Nov 08
(b) Email NAVSEA (SEA05232)/NOSSA (N84) of 4

Encl: (1) NAVSURFWARCN CARDEROCKDIV ltr 13280 Ser of 14 Nov 08

1. In response to the request of reference (a), the Ordnance Safety and Security Activity (NOSSA) grant safety certification for use of the three lithium batteries listed in Table 1 for use in the Explosive Ordnance (EOD) Hull Unmanned Underwater Vehicle Localization (HULLS). This certification is based on the safety evaluation contained in enclosure (1) and is limited to use of Foster-Miller EOD HULLS involving deployment and recovery on Navy surface platforms and shore-based facilities a 30 September 2009. Naval Sea Systems Command (SEA05232) has reviewed the documentation and concurs with the recommendation for limited certification as indicated in reference (c).

Table 1

LITHIUM BATTERIES USED IN THE FOSTER-MILLER EOD HULLS

Battery Manufacturer	Battery Part Number	Sys/Local
Foster-Miller/AGM	D0800110202	SCV vehicle
Tadiran	TL-5186	SCV vehicle
Bren-Tronics	BB-2590/U	OCU



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8020
Ser N841/271
18 Feb 09

From: Commanding Officer, Naval Ordnance Safety and Security Activity
To: Program Executive Officer, Littoral and Mine Warfare (PMS-EOD 26)

Subj: EXTENSION OF LIMITED SAFETY CERTIFICATION OF LITHIUM ION RECHARGEABLE BATTERY PROPOSED FOR LIMITED USE IN THE BLUEFIN HOVERING AUTONOMOUS UNDERWATER VEHICLE

Ref: (a) PEO LMW ltr 8027 Ser EOD-26/215 of 3 Dec 08
(b) NOSSA ltr 8020 Ser N841/876 of 23 May 07
(c) Email NAVSEA (SEA05232)/NOSSA (N84) of 9 Feb 09

Encl: (1) NAVSURFWARCN CARDEROCKDIV ltr 13280 Ser 61/08-372 of 16 Dec 08

1. In response to the request of reference (a), the Naval Ordnance Safety and Security Activity (NOSSA) extends the limited safety certification of reference (b) for use of the lithium battery, Bluefin Part Number (P/N) BFB15-30-000, for continued use in Bluefin Hovering Autonomous Underwater Vehicle (HAUV) at Navy facilities.

2. This extension is based on the safety evaluation contained in enclosure (1). This extended certification is limited to use of the HAUV system involving deployment from Navy surface platforms and shore-based facilities, is contingent upon all HAUV battery charging occurring only at shore-based facilities and under monitoring by trained personnel, and expires 31 December 2009. Naval Sea Systems Command (SEA05232) has reviewed the documentation and concurs with the recommendation for extended limited certification as indicated in reference (c).

3. The NOSSA point of contact is Mr. Christopher A. Batchelor (N841) on DSN 354-6038, commercial (301) 744-6038, or email: chris.batchelor@navy.mil.

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COMNAVSSEASYSOM (SEA0523/Mr. K. Moniri, SEA05232/Mr. D. Cherry)

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

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