Naval Undersea Warfare Center

Division Keyport

March 10th, 2005

Avionics Gyro COTS Replacement Program – Accelerated Life Testing

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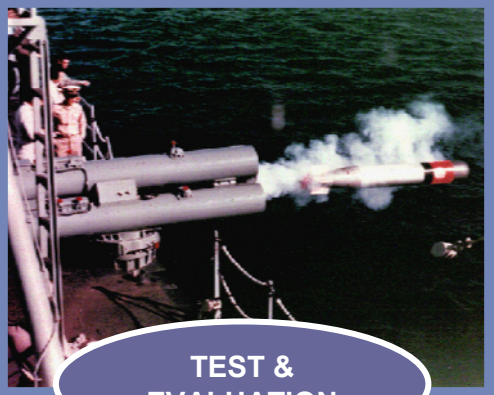
NAVSEA
KEYPORT
Undersea Warfare Center Division

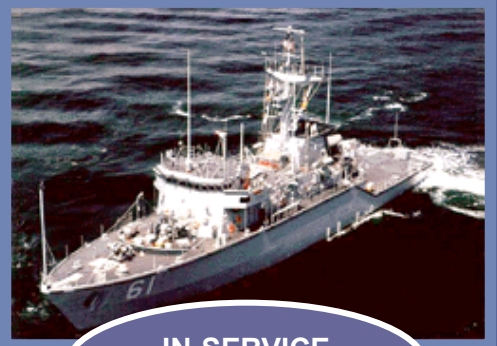
OUR MISSION

"Support the mission of the Naval Undersea Warfare Center by providing test and evaluation, in-service engineering, maintenance and repair, fleet support, and industrial base support for undersea warfare systems, undersea weapon systems, countermeasures and sonar systems. Execute other responsibilities as assigned by the Commander, Naval Undersea Warfare Center."



TEST & EVALUATION

SYSTEMS DEPENDABILITY FOR THE WARFIGHTER



IN-SERVICE ENGINEERING

FLEET SUPPORT

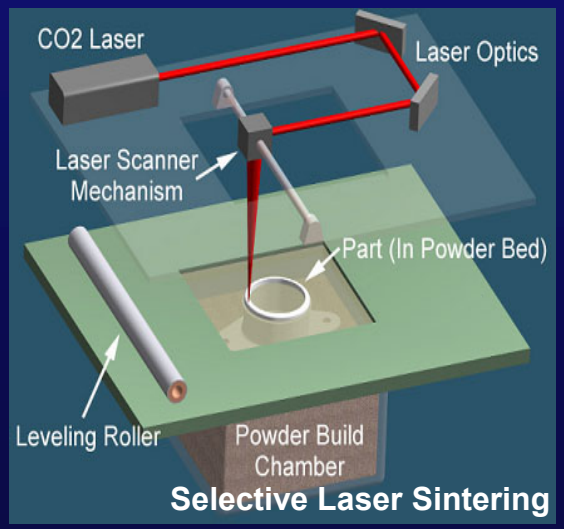
MAINTENANCE & REPAIR

INDUSTRIAL BASE SUPPORT

CENTER FOR INDUSTRIAL AND TECHNICAL EXCELLENCE

NUWC Division, Keyport was designated as a Center for Industrial and Technical Excellence (CITE) by Secretary of the Navy in July 2002:

- **Encourages partnerships with private industry or other entities to perform work or utilize facilities / equipment**
- **Allows participating activities to retain funds from lease or sale of material**
- **Designed to lower the cost of infrastructure at organic depot facilities and provide better product at lower cost**



Selective Laser Sintering

Current CITE Partnerships	Goals
Depot Apprentice Partnership	Partnership with Bremerton Naval Shipyard and Olympic College to support the restart of our trades apprentice program
Pearl Harbor Heavyweight Torpedo IMA	Partnership with SUB PAC, Raytheon and PMS 404 for operation of the IMA at Pearl Harbor Hawaii.
Torpedo Upgrade Facility Partnership	Partnership with Raytheon for the lease of an operating building at Keyport for the manufacture of torpedo upgrade kits.
Undersea Vehicles Partnership	Partnership with ARL Penn State to support development test and analysis of prototype undersea vehicles.

H-60 and H-53 Aircraft Gyro Replacements

- Existing electromechanical Gyros replaced with solid state technology
- Existing MTBF 600 hours
- Calculated new MTBF 44,000 hours

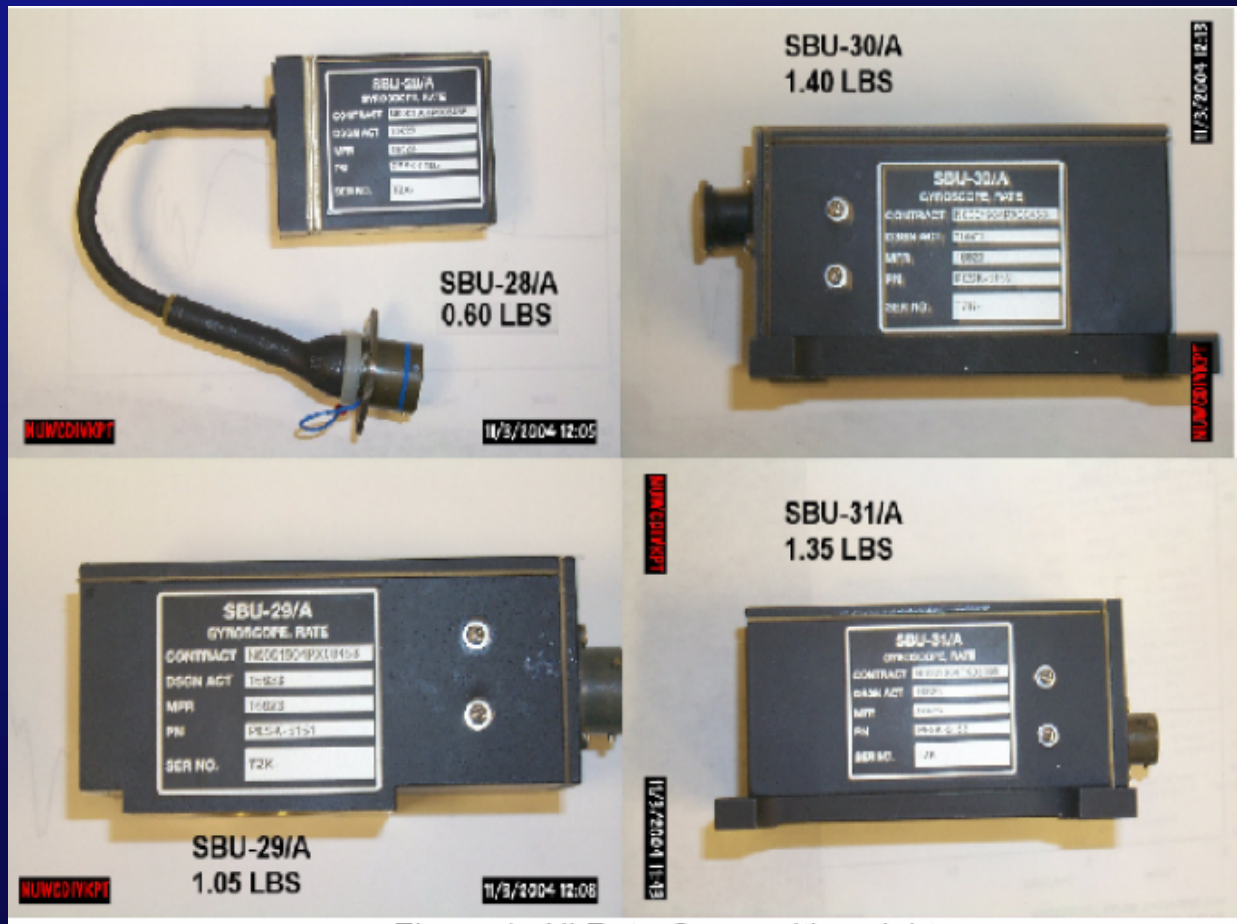


Figure 1. All Rate Gyros with weights

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Rate Gyro Test Program

- Environmental Stress Screen (ESS) – Remove latent defects
  - Nondestructive temp and vibration
  - 100% sample rate for test samples and production
- Qualification Testing – Requirements Based
  - Temp & Humidity
  - Thermal Shock
  - Vibration
  - EMI
  - ESD
  - Altitude
  - Mechanical Shock
- Qualification by Analysis
  - Rainfall
  - Salt Spray
  - Sand and Dust
  - Fungus
  - Explosive Vapors
- HALT – Design Support
  - Exploratory Temperature
  - Exploratory Vibration
  - Test to Failure with combined Temperature & Vibration
- STRIFE – Durability Assessment
  - Combined Temperature and Vibration
  - Low Voltage and High Voltage Simulations

Qualification Testing

Vibration

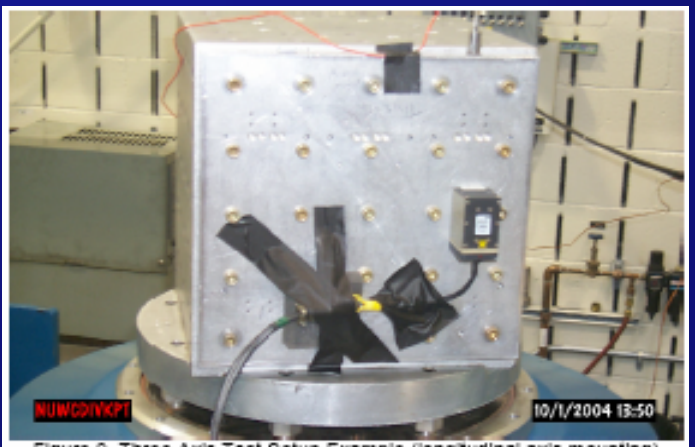

Figure 9. Three Axis Test Setup Example (longitudinal axis mounting)

Figure 3. Rate Functional Test Setup Example

Rate Table

Drop Shock

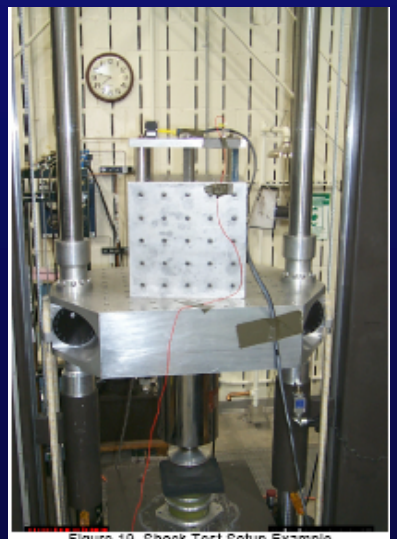
Figure 19. Shock Test Setup Example

Figure 16. Temperature-Rate Functional Test Setup Example

Rate Table with Temperature Box

HALT

- HALT is a test to failure approach to find potential design weaknesses
  - Should be performed during design phase
- Used existing equipment
- Results
  - Exploratory Thermal
    - Low Temp: -100 deg F (Still functioning)
    - High Temp: 250 deg F (Still functioning)
  - Random Vibration: 33g's (Still functioning)
  - Thermal Cycling: -80 to 170 100 cycles (still functioning)

STRIFE Testing

- STRIFE (stressful life) is an approach to determine durability
- Goal was to simulate 44,000 hours of operation
- For Vibration:
  - MIL-STD-810F Fatigue Relationship
    - Inverse Power Equation

$$\left(\frac{W_0}{W_1}\right) = \left(\frac{T_1}{T_0}\right)^{\left(1/M\right)}$$

W_0: Baseline Vibration Level
W_1: Test Vibration Level
T_0 : Baseline Time
T_1 : Test Time
M : Material Constant = 4 (connectors)

Material Constant Ranges from:
Kipp Company Paper M=2 (random Vib)
MIL-S-810 M=4-6
D.S. Steinburg M=6.4

For this example:
W_0= 4.2 g's RMS
T_0 = 44,000 hours
T_1 = 250 hours

W_1 = 15.2 g's RMS

STRIFE Testing

- For Thermal:
  - Min and Max temps based on HALT
    - -75F and 175F
  - Ramping and dwell times based on equipment capability and functional test requirements
  - MIL-H-344 used for acceleration factor

$$D = N * S^{B}$$

D is Damage Index
N is Cycles
S is delta Temperature
B is Fatigue exponent (2.5 for solder)

For this example:
N = 750 test cycles
S = 250 delta F
D= 7.41e8

If actual environment is S=80 delta F:
D= 7.41e6 (same effective damage index)

N=12944 cycles for actual environment

STRIFE Testing

Combined Vibration and Thermal Testing with Liquid Nitrogen Assist

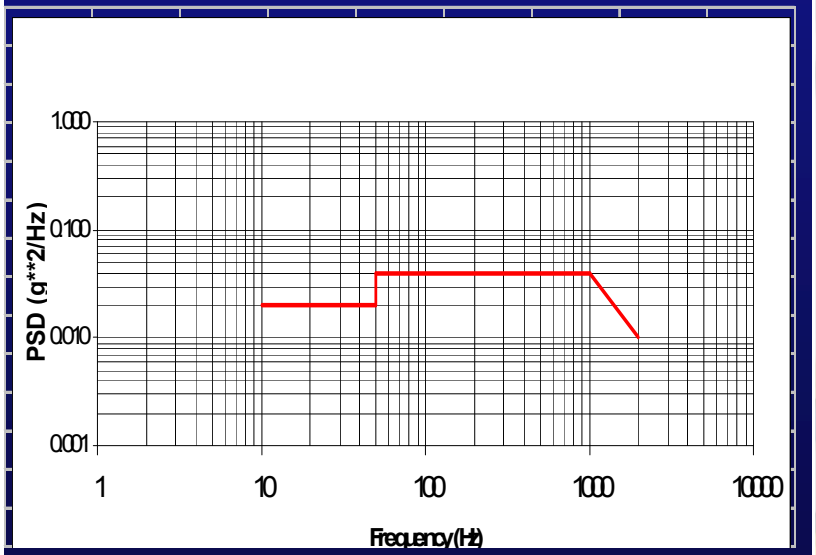

Figure 13. STRIFE Test Setup Example

STRIFE Testing

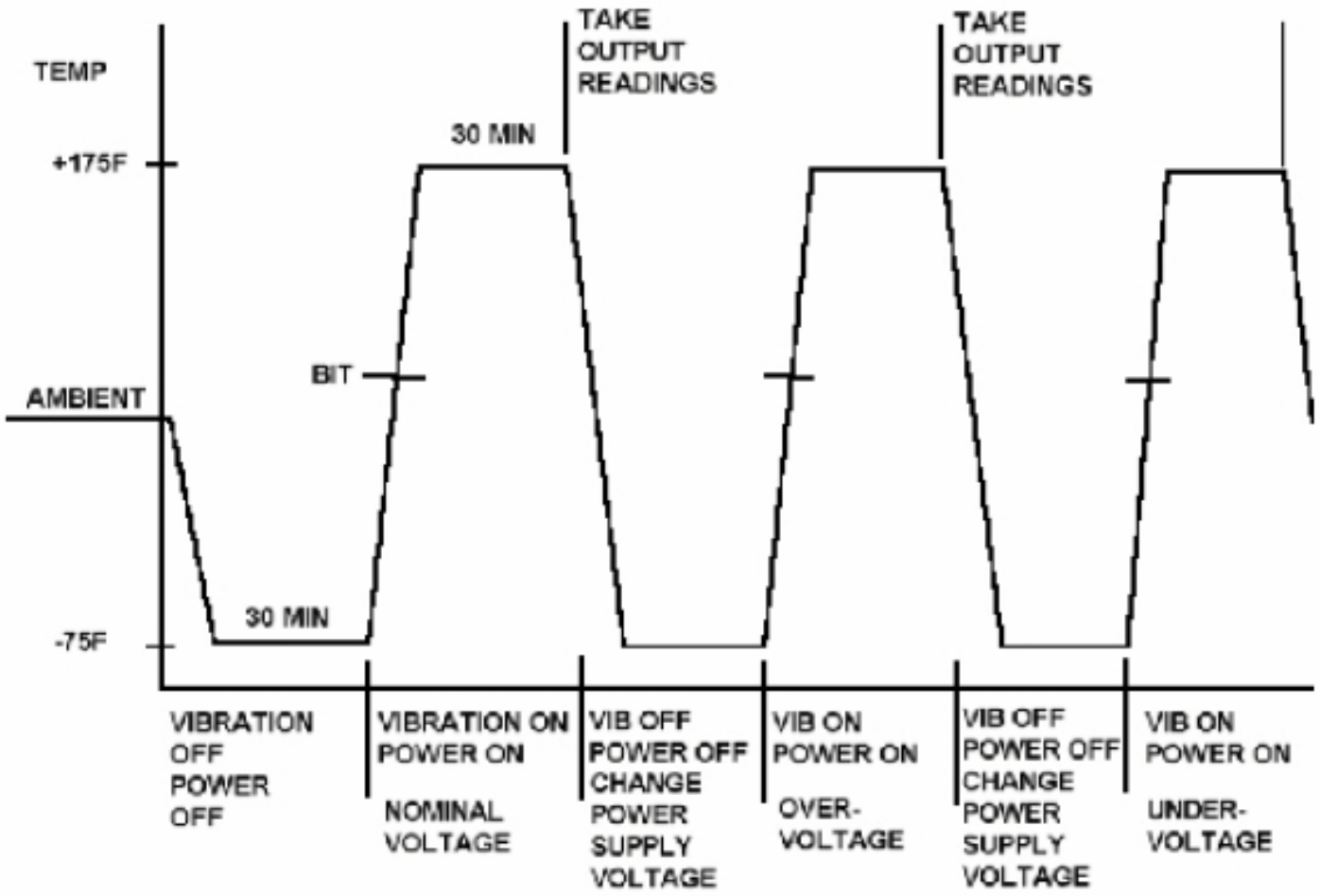

Figure 14. STRIFE profile (one complete cycle)

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STRIFE Analysis

- Using Assurance Tables from "Statistical Design and Analysis of Engineering Experiments", *Lipson and Sheth*, 1973, McGraw-Hill

For a sample of two with no failures:

Vibration: 86.5% *Assurance* population will survive 44,000 hours at 4.2 g's
or 99.8% *Assurance* population will survive 14,667 hours at 4.2 g's

Thermal: 86.5% *Assurance* population will survive 12944 cycles at 80 delta F
or 99.8% *Assurance* population will survive 4315 cycles at 80 delta F

For comparison, one sample with no failures would give 63.2% assurance at 44,000 and 95.0% assurance at 14,667 for vibration

Assumption is that test samples adequately represent population

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Closing Thoughts

- Navy (DoD?) Environmental Test labs designed around 1960's technology and equipment
  - Steady state environments
  - Single axis vibration
  - Requirements based test design
- My Approach:
  - Upgrade equipment
    - Multi-axis vibration
    - High performance thermal systems (LN2)
  - Educate Programs about value of accelerated life testing (HALT/HASS/STRIFE/ESS)

NAVSEA Keyport's 3-Axis Electro-dynamic Vibration Test System

Accelerated Life Testing is part of an Effective T&E approach

Failure Distribution Model

Failure Distribution Model