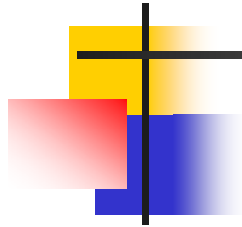


Guided Weapon In-service Surveillance – Science or Engineering?

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Topics

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Overview

- In-service surveillance of guided weapons is a safety-critical activity of defence: failures could have catastrophic consequences
- Different approaches to surveillance have different levels of rigour and accuracy:
 - 'engineering' approach
 - 'scientific' approach



Overview

- Crucial need for DMO to know service life of ordnance, to plan and manage weapons
- Need to know the effects of Australian & overseas environment on weapons:
 - Temperature
 - Vibration
 - Shock (incl. thermal shock)
- Impact on operational reliability & safety
- Supplied data usually for US environment – not for Australia



Background (1)

- Guided Weapons and Explosive Ordnance Branch (GWEO DMO) provides in-service support to the military (RAAF, Army & RAN):
 - Surveillance of guided weapons
 - Maintenance of guided weapons
 - Logistics support
- Stakeholders:
 - Military as customers
 - Defence/DMO as service providers (logistics/in-service surveillance) to military (tri-service)
 - DSTO as service providers to DMO (advice, test firing)
 - JPEU as service providers to DMO (radiography, test firing)



Background (2)

- Systems engineering:
 - In-service surveillance:
 - Safety & reliability of guided weapons
 - Surveillance Plan + Risk management + Technical Regulation
 - How to determine status of weapons?
 - 'Scientific' & 'Engineering' approaches to surveillance
 - 'Scientific': measurement of physical properties (destructive testing) + life estimation based on deterioration
 - 'Engineering': radiography & visual inspection + life increment



Background (3)

- In-service surveillance:
 - Surveillance plan with mandated test program undertaken at GWEO
 - Re-certification of weapon periodically (DEOP 105)
- Risk management
 - Identification of hazards
 - Assessment of hazard severity & probability
 - Risk assessment & mitigation



The Story (1)

- Case studies:
 - Harpoon: guided weapon available in surface, subsurface and air launched forms (for RAN & RAAF resp.)
 - NULKA: a missile decoy (Australian design; in service with RAN & USN)
- GWEO DMO experience of surveillance
 - Harpoon
 - Test failures in US & at GWEO; reported defects
 - US surveillance found problems affecting fuse & engine
 - US reports -> failure modes; tests; estimated shelf life



The Story (2)

- GWEO DMO experience of surveillance
 - NULKA:
 - Managed by NULKA Program Office
 - Defects & test failures found at GWEO
 - DSTO reports & US reports
- Problems encountered:
 - Generating & baselining data (OEM help needed)
 - Piggybacking on the overseas plans
 - Difficulty of getting data from US (& timeliness thereof)
 - Applicability of US data to AUS conditions
 - Cost of Harpoon data



Analysis (1)

■ Achieving success in surveillance is due to knowledge encapsulated in Defence Regulatory system. Risk assessment and management is part of the regulatory system.

■ Leading questions:

- How are we doing our surveillance?
- How can we improve what we are doing?

■ The Harpoon story: Surveillance approach

- The 'engineering' approach
- Visual inspection, radiography & other simple tests
- Periodic assessment & increase of shelf life in line with assessment
- US estimates of shelf life of components do not cover AUS conditions (neither storage nor transport)



Analysis (2)

The Harpoon story: Issues

- Age of current inventory
- US failures in flight and during testing
- Faults identified during US surveillance
- Conditions of Australian environment

The NULKA story: Rigorous testing and measurement of critical parts of the system, particularly the rocket motor:

- 'Scientific' approach: Measurements of physical properties of propellant under laboratory conditions
- Accelerated ageing tests -> shelf life
- Measurement of shelf life of propellant from test results
- Static firing of rocket motor
- Temperature data logging
- Plus the usual: visual, Xray.....



Analysis (3)

Propellant ageing in NULKA:

- Accelerated ageing tests
- Propellant Modulus data from US NSWC NULKA report
- Data analysis: ageing rate, m at ambient, 40°C, 50°C, 60°C (see table)
- Normalised ageing rate, m/m_A where $m_A = 0.0369$ (see table)

Conclusions:

- Ageing is slightly elevated at 50°C
- Ageing significantly raised at 60°C (six fold rate increase)
- Accelerated ageing at 60°C gives data for 6 years service in 1 year of testing

Propellant modulus, E

$$E = m t + b,$$

where t = time (months)

m = slope

Temperature (°C)	m	m/m_A
Ambient	0.0369	1.00
40	0.0392	1.06
50	0.0439	1.196
60	0.2183	5.92

Propellant Modulus with time



Analysis (4)

■ Comparison with literature

- Significantly raised ageing effect in Harpoon warhead at 60°C (Zinn, 2006)
- Significantly raised ageing effect in particular high explosive at 70°C (Sharp, 2003)
- Consistent shelf life in Harpoon and NULKA programs; also consistent with literature
- Other reports from NATO and DSTO

■ Australian storage & transport conditions different from US

- Instrumented missiles & motors (Doolan, 2004)



Analysis (5)

■ How to estimate shelf life :

- Life time models (DSTO reports: e.g. Ho, 2000; Doolan, 2004b).
- Extrapolation of measurements - inaccurate compared to interpolation
- Time series analysis
- Reliability models
- Accelerated ageing



Analysis (6)

- Issues: Non-energetics-caused failures in SM1 and Harpoon
- How to deal with non-energetics ?
 - Flight testing & other data
 - Accelerated ageing
 - Traditional engineering checks, including visual, Xray & MTS testing
 - Pro-active component replacement



Lessons Learned

- Advantages of 'scientific' approach:
 - Better estimate of shelf life – *not* ad-hoc – life estimate vs. life increment
 - Coverage of AUS storage & transport conditions
- Effects of environment & transport on ageing
 - Temperatures above 50 deg C cause accelerated ageing
 - Thermal shock & vibration are significant
- Issues remaining:
 - Shock & vibration during transport
 - Effects of thermal shock & high temperature
 - Apply 'science' to other guided weapons
 - Lack of US & AUS data
 - Non-energetics



Conclusion

- The 'scientific' approach is preferred:
 - Laboratory measurements of physical properties
 - Temperature & shock data logging
 - Miniaturised sensors embedded in missiles
 - Shelf life estimation: method an issue
- Improvements:
 - Lab testing to be pursued & lack of resources
 - Shock data logging
- Non-energetics still an issue



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- Other NATO reports
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Glossary/Acronyms

- DMO Defence Material Organisation
- DSTO Defence Science & Technology Organisation
- GWEO Guided Weapons and Explosive Ordnance Branch
- JPEU Joint Proof & Experimental Unit
- MTS Missile Test Set
- NATO Northern Atlantic Treaty Organisation
- NSWC Naval Surface Warfare Center, USA
- RAAF Royal Australian Air Force
- RAN Royal Australian Navy
- SM1 Standard Missile-1



Questions and discussion

