

## Prior NATO Scientific and Technical Activities in Munitions Health Management

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### ***ABSTRACT***

*Over the past 20 years, the community of technical practitioners in munitions safety, quality assurance, life cycle assessment, and life extension throughout NATO have worked to accumulate and disseminate the Alliance's knowledge on these topics, to facilitate exchange, growth, and interoperability. NATO member nations are constantly balancing the need to keep munition items in their inventories longer, against the cost of surveillance programs to assure long-term stability and safety. Some nations are installing simple data loggers and sensors (costing between \$100-500) on individual munition items, in conjunction with comprehensive basic and applied technology development initiatives to understand the aging and degradation mechanisms. The technology, known as Integrated Munition Health Management (IMHM), may be used to extend the safe service life of munition items like rocket motors, large warheads, and complex electronic guidance and control packages. The Alliance's science and technology organization has worked with practitioners throughout the member nations to foster collaboration and exchange, and there are a number of activities which have facilitated this. This paper presents an overview of the topic, and highlights the major NATO science and technology activities in this technical area.*

### **1.0 INTRODUCTION**

Munitions may refer to the complete range of items from inexpensive commodities like bullets, to the largest possible conventional missiles. When looking at this range, two broad categories of munitions may be distinguished that are separated by the following characteristics:

- Non-serialized items (bullets, grenades, general-purpose bombs) with no- or very simple interaction with weapon/launch platform. These have long-running production lines (years or decades), generally made in very large quantities with many items stockpiled for ready use, and may have multiple suppliers.

## Prior NATO Scientific and Technical Activities in Munitions Health Management

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- Serialized items (smart munitions, missiles) which have complex interactions with the launch platform. Production is done in batches for a somewhat limited timeframe (3-10 years), and there is rapid evolution of technological integration (meaning that individual systems are often upgraded during their life, or become obsolete and are replaced with new systems. The stockpile is usually managed with enough on hand to last until the next upgraded weapon system is procured. There is usually only one supplier.

The information contained herein could be used as a general guideline for munitions life modelling and condition verification on many different types of systems, but the prime example used in the community is often a rocket motor and missile. Some of the more general statements (e.g. about need for external sensors) may also be applicable to other items that may also be of interest for life modelling and condition verification (e.g. warheads, pyrotechnics, boosters, fuses, etc.).

## 2.0 BACKGROUND

From a NATO perspective, the Conference of National Armaments Directors (CNAD) Ammunition Safety Group (CASG) publication AOP-46 “The Scientific Basis for the Whole Life Assessment of Munitions” provides a good reference for munitions quality evaluation programs. However, this document and other current practices in energetics surveillance methodologies, residual life prediction, and condition modelling, have shortcomings, when it comes to inputs, outputs, and validated and/or verified results. Current approaches focus mainly on regular destructive testing of an extremely limited number of assets with limited modelling. Furthermore, while it would be best to select assets for this testing, which had seen the most severe service history (widest temperature excursions, worst storage conditions, etc.); this is virtually impossible with the current inventory tracking methods.

Over the course of almost three decades of Alliance standardization of life assessment processes, a number of observations are paramount:

- There is a common approach to munitions surveillance throughout the NATO nations.
- The common approach consists of a combination of detailed destructive tests of munitions and component functional tests.
- Some modelling is done, but collecting experimental data from aged components forms the main component of most surveillance programs.
- The number of munitions sacrificed to destructive evaluation is very small. (Often one item is examined out of a batch of hundreds or more.)
- The items which are destructively evaluated are usually chosen at random.
- The results of the destructive evaluation are applied to entire groups/batches of “like” items.

The NATO Science and Technology Office (STO) has facilitated a number of meetings and working groups who have helped provide a technical basis for what munitions health management means, and how it fits in the context of the existing safety, life cycle, and life extension communities.

These experts agree on a number of topics, but the two most pressing are probably:

- That because of a lack of major incidents, there is currently no strong incentive to dramatically change the current surveillance approach. Some of the most recent examples, which highlighted the need of well-founded surveillance programme, were the rocket motor incidents with the Sparrow MK58 motor in the late 1990s. The users' community saw the importance of MHM, but these lessons were easily forgotten after two or three job rotations.
- The surveillance community has a strong desire for more data to support a greater confidence in the munitions quality statements that they are asked to make. These are the people who have to make decisions and proclamations with regard to the safety or life extension of munitions in the inventory. It is incredibly difficult for example to know if the random samples pulled for inspection are the "best" or "worst" items of the lot.

### **3.0 PAST NATO TECHNICAL EXCHANGE ACTIVITIES**

The following section highlights the combined activities that have focused on various technical and policy aspects of what has become known as Integrated Munitions Health Management. The output (documents, presentations and reports) of all of these activities is available to citizens of NATO member nations, and in many cases to citizens of NATO Partners for Peace and Partners Across the Globe nations. Visit the NATO Science and Technology Organization at [www.sto.nato.int](http://www.sto.nato.int) for more information and to request access. Additionally, many of the documents are available through the NATO Munitions Safety Information Analysis Center (MSIAC) which also houses a number of more detailed reports and surveys addressing specific munition safety and policy-related topics. Visit MSIAC at [www.msiac.nato.int](http://www.msiac.nato.int) for more information.

#### **3.1 AGARD Symposium "Service Life of Solid Propellant Systems"**

May 1996

Output: The Propulsion and Energetics Panel of the Advisory Group for Aerospace Research and Development (AGARD) held a symposium covering all aspects of service life determination for solid rocket and gun propellant systems. There were 43 papers presented over the week-long symposium, representing eight nations and covering topics including chemical and physical aging mechanisms in energetic materials, test methods, and embedded stress gages to measure bond stresses in motors.

#### **3.2 Task Group AVT-119 "Health Monitoring of Munitions"**

2004 to 2007

Output: Two demonstrations of technology. A trial or "limited" demonstration was held at an AVT meeting, and the full demo was held at a NATO Research and Technology Board (RTB) meeting. The overall goals of the task group were to review the available systems and analyze the principal possibilities that microelectromechanical systems (MEMS devices) and similar evolving technologies with much lower power requirements and greater sensing capabilities could offer for monitoring individual munition items. Additionally, the group sought to demonstrate available technology and show how NATO could benefit from these advancements.

## **Prior NATO Scientific and Technical Activities in Munitions Health Management**

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### **3.3 Task Group AVT-160 “Health Management of Munitions”**

December 2007 to October 2010

Output: The task group held three smaller workshop-style events to collect focused information in sub areas of sensors, integration, and safety/security. This information was merged with policy input gathered from meetings with NATO Allied Command Transformation, the NATO ammunition safety group, and multiple other organizations, to create the overarching final report. This final report contains a treatise on the available technology, how to implement that technology in various types of munition systems, examples of how to integrate the data and information collected into life cycle assessment practices for munition systems of various complexity, and guidance on the safety, security, and assurance practices needed to address future policy statements.

### **3.4 Symposium AVT-176 “Advances in Service Life Determination and Health Monitoring of Munitions (HMOM)”**

April 2010

Output: This three-day symposium with more than 100 attendees provided a forum for NATO experts in munitions design, life assessment, monitoring, sensor systems and safety to provide information on the current state-of-the-art techniques. It was a unique opportunity for specialists from nine Nations to discuss MHM issues in this tri-service context in NATO, since the last relevant RTO meeting on this topic was held fourteen years earlier.

### **3.5 Lecture Series AVT-228 “Munitions Health Management”**

June to September 2013

Output: A two-day lecture was hosted in the UK and the US, formally presenting primarily the output from the final report of AVT-160, but also including pertinent examples of lessons learned, implementation, and results from various nations. The lecturers were able to delve into more detail and provide many examples from various nations’ efforts across the Alliance.

### **3.6 Cooperative Demonstration of Technology AVT-212 “Integrated Munition Health Management”**

October 2014

Output: A Cooperative Demonstration of Technology (CDT) organized by the AVT-212 technical committee of NATO’s Science and Technology Organisation (STO), the Applied Vehicle Technology (AVT) Panel, and the Munitions Safety Information Analysis Centre (MSIAC), in cooperation with industry partners. This was the first CDT of this type organized in the NATO Headquarters by the STO, with the aim of illustrating the benefits of technologies to decision-makers and end-users. There were presentations, posters, and hardware articles representing efforts of seven nations. More than 150 people attended over its two-day-run at NATO HQ.

### **3.7 NATO Smart Defence Initiative “Integrated Munition Health Management”**

2017 to 2020

Output: The SDI will seek to consolidate the needs of the contributory / involved nations along the structure of a NATO STANAG, and produce a guide to IMHM that will assist all nations in the development and

deployment of these technologies in existing and future munition systems. Nations' representatives participating in the SDI are developing a scope for the guide that will ensure that the standard is aligned with technology development, fits with acquisition requirements, facilitates logistics, and increases the availability of the Alliance's capabilities in the long term.

### **3.8 Symposium AVT-268 “Advances in Munition Health Management Technologies and Implementation”**

October 2017

Output: The Research Specialist Meeting provides a forum for NATO experts to provide detailed information on technology developments over the last decade, current best practices and impediments to implementation. Representatives from the Smart Defence Initiative are asked to contribute by outlining future needs/requirements which will serve as guidance for further technology developments.

#### **4.0 Summary**

There is a general trend, as identified by the practitioners participating in these activities, away from specific technical aspects of condition assessment and science, toward more practical issues of data collection and system integration. This could be due to an improved understanding of the technical issues associated with condition assessment over the past two decades. Many of the practitioners presenting work have identified the critical needs associated with being able to detect failure, understand its ramifications, and to make predictions of future condition, and in many cases they have also identified tools that can be used to gather this information. The stumbling block in most cases is the final “leg,” or integration of those tools throughout the population of weapons.

#### **Presenter Bio**

Wade Babcock joined the NATO Munitions Safety Information Analysis Centre in 2015 as the Technical Specialist Officer for munition materials sciences. Prior to that, he led the Weapon Effects and Analysis Branch at the US Naval Surface Warfare Center at Indian Head, Maryland. He has worked in the area of munition materials, sensor integration, and modelling & simulation for more than 20 years. Wade completed a bachelor of science degree (1993) and master of science (1995) at NC State University in Materials Science and Engineering, and holds a green

**Prior NATO Scientific and Technical  
Activities in Munitions Health Management**

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belt in Lean Six Sigma. Current areas of specific interest are understanding and modelling the long term material degradation in munition systems, application of novel sensor technologies to capturing environmental exposure and explosive effects, and health management of “perishable” munitions inventory items (items whose life or performance is affected by exposure to heat, cold, humidity, chemicals, etc.)